MEDICAL DEPARTMENT
UNITED STATES ARMY
IN WORLD WAR II

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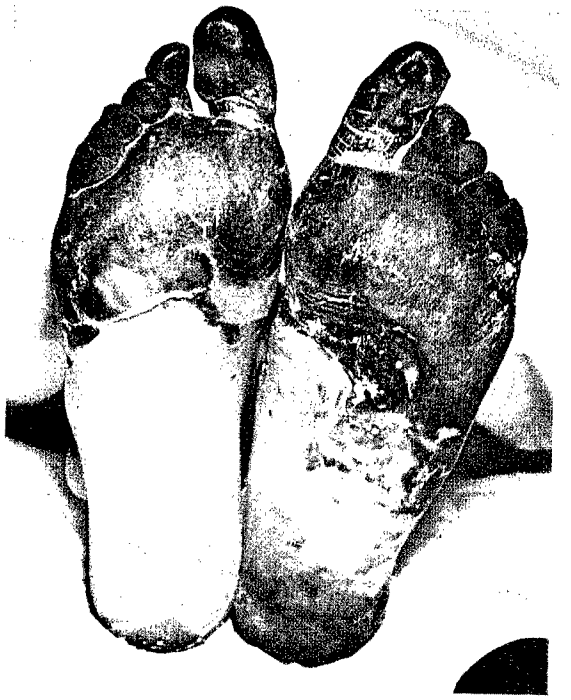

Trenchfoot, ground type.

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MEDICAL DEPARTMENT, UNITED STATES ARMY

COLD INJURY, GROUND TYPE

Prepared under the direction of

Major General S. B. HAYS

The Surgeon General, United States Army

Editor in Chief

Colonel JOHN BOYD COATES, JR., MC

Associate Editor

ELIZABETH M. MCFETRIDGE, M. A.

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COLD INJURY, GROUND TYPE, IN WORLD WAR II

The Historical Unit, United States Army Medical Service

Colonel JOHN BOYD COATES, JR., MC, *Director*
Colonel O. F. GORIUP, MSC, *Executive Officer*
Lieutenant Colonel C. A. PENDLYSHOK, *Chief, Special Projects Branch*
DONALD O. WAGNER, Ph. D., *Chief, Historians Branch*
WILLA B. DIAL, *Chief, Editorial Branch*
WILBOUR C. LOWN, *Chief, Promotion Branch*
JOSEPHINE R. KYLE, *Chief, Research and Archives Branch*
HAZEL G. HINE, *Chief, Administrative Branch*

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COLD INJURY, GROUND TYPE

by

Colonel Tom F. Whayne, *MC, USA (Ret.)*
Professor of Preventive Medicine, School of Medicine, University of Pennsylvania, Philadelphia, Pa.

and

Michael E. DeBakey, M. D.
Professor of Surgery and Chairman of the Department, Baylor University College of Medicine, Houston, Tex.
Formerly Colonel, MC, AUS

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MEDICAL DEPARTMENT, UNITED STATES ARMY

The volumes comprising the official history of the Medical Department of the United States Army in World War II are prepared by The Historical Unit, United States Army Medical Service, and published under the direction of The Surgeon General, United States Army. These volumes are divided into two series: (1) The administrative or operational series; and (2) the professional, or clinical and technical, series. This is one of the volumes published in the latter series.

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Foreword

It is a lamentable but nonetheless incontrovertible fact that most of the serious losses which occurred from cold injury among United States Army troops in World War II should not have occurred. It would be less than candid not to acknowledge this painful truth.

These losses occurred, as is repeatedly pointed out in this volume on cold injury, because the lessons of the past were not learned. The British experience in World War I was not recollected by the United States Army in World War II. The experience of the Aleutians, where the losses from cold injury were numerically small but proportionately large, was not transferred to the Mediterranean theater, in which the losses were both numerically and proportionately significant. The lessons of the Mediterranean theater were not transferred to the European theater, in which the preliminary figure of approximately 46,000 cases reported as cause of admission in the fall and winter of 1944–45 accounted for about 5 percent of all admissions to medical treatment. The more complete figures now available, which include cases of cold injuries associated with wounds and other conditions, bring the total number of cold injuries for the European theater to approximately 71,000, most of which occurred in the 1944–45 winter. The total number of cold injury cases in all theaters for the entire war period was 91,000.

The bitter experiences of the Aleutians campaign and the Mediterranean and European theaters were finally appreciated, and there seems little doubt, had invasion of Japan been necessary, that casualties from cold injury would have been reduced to the irreducible minimum because the planning had been so careful and so farsighted. In both the Mediterranean and the European theaters, it is true, efficient plans of prevention and control of cold trauma were eventually set up. They produced excellent results in the Mediterranean theater in the second winter of fighting, but they were set up in the European theater almost too late to prove their efficiency. The individual ingenuity of the American soldier was a factor in preventing a worse disaster than actually occurred.

There are no absolute excuses for the epidemics of cold injury which occurred on the Continent of Europe during World War II. There are, however, a number of explanations for them. The first, as just pointed out, was failure to learn the lessons of the past. For that matter, the European theater failed to profit from its own early experience. It was not realized that the high-altitude cold injuries which had originally beset the Eighth Air Force in Europe in 1942 and 1943 were of the same general etiology as the ground type of cold injury which was to occur later and that they were susceptible to the same general principles of prevention and control.

Cold, wet, or cold and wet in combination are, of course, the basic causes of cold injury, but this statement does not tell the whole story. Predisposing factors are also of great importance. In World II, these factors included (1) the intensity of combat; (2) the inadequacy of clothing and footgear; (3) the pressure of events which required that new troops be taught so much in such a limited period of time that they were not taught the essential facts of cold injury; and (4), as General Bradley himself has acknowledged, the taking of a calculated risk, for which a price had to be paid, when, in the summer and early fall of 1944, it was decided that gasoline and ammunition should take precedence in transportation over supplies of winter clothing.

No single person and no single branch of service can be blamed for what happened. The prevention of cold injury is primarily a function of command from the highest to the lowest echelon. It requires the assumption of responsibility by all personnel, including the Medical Corps, which, though its role is purely advisory, must nonetheless assume the responsibility for making its advice forceful as well as correct.

Cold injury is a condition for which no satisfactory treatment existed in World War I or World War II and for which no fully satisfactory method of treatment has yet been found. Its prevention is therefore doubly imperative. Although, in the circumstances of warfare, the necessities of combat take precedence of every other consideration, it is still perfectly possible to prevent most cases.

The historical chapters of this volume set forth the important details of what happened concerning cold injury in all recorded wars of history as well as in World War I and World War II. Its possible causes and predisposing factors are set forth from every angle in the very complete chapter on epidemiology, in which the presentation is based on the concept that the same epidemiologic principles can be applied to trauma due to cold as are applied to infectious diseases and that the same general principles of control are operative. The clinical chapters clearly indicate the inadequacy of our basic knowledge of cold injury and the unsatisfactory results of present methods of treatment; they also point up the necessity for continued studies in these fields. The urgent necessity for preventing a repetition of past experiences is apparent in the chapter on costs.

I think it no exaggeration to say that this is the most comprehensive volume on the ground type of cold injury that has ever been published. I think it equally fair to say that, if it is carefully studied and if the lessons of the experience of the United States Army in World War II are properly read, marked, learned, and inwardly digested, there should be no similar experience in any future war.

S. B. HAYS,
Major General,
The Surgeon General.

Preface

Cold injury as it affects large numbers of men is primarily a form of wartime trauma. The history of all military campaigns conducted in winter, both in temperate and in cold climates, reveals crippling losses from this cause. Between wars, the staggering cost of cold trauma in time of war is almost entirely forgotten.

The British losses in World War I and the costly experiences of United States forces in Europe in World War II (as well as, more recently, in Korea) make it imperative that the knowledge so painfully gained shall not again be forgotten. It is imperative that all of this knowledge be preserved. It is particularly imperative that the principles of prevention of cold injury become a part of peacetime military training and planning.

This volume has three purposes:

1. To record the history of cold injury, ground type, in World War II.

2. To summarize what has been learned of the nature of this form of trauma, including its pathologic physiology, its epidemiology, its military cost, and its management, including the rehabilitation of casualties from this cause.

3. To formulate, from the materials of the past history of cold injury, the principles of a sound program for its prevention and control in future military operations in cold regions and in temperate regions during cold weather.

It is hoped that by concentration on the broad scope of the problem and on its multiple phases, including its epidemiology, research may be stimulated which will result in more positive and more effective methods and practices for preventing, controlling, and treating this important variety of environmental injury.

This history of cold injury in World War II began as two independent projects. One volume was intended as a part of the surgical series and the other as a part of the preventive medicine series of the history of the Medical Department of the United States Army in World War II. It soon became apparent that the interests of a comprehensive, concise, and useful history would best be served by a joint effort. Happily, the data already assembled independently could be readily amalgamated, and the combination suggested fruitful avenues for further study of the historical files and the medical materials of World War II.

Statistics used in the tables and text of this volume were personally collected by the authors or their collaborators or were based on preliminary summary unit reports. The Medical Statistics Division, Office of the Surgeon General, has reviewed and, where possible, has verified all statistical data and furnished more complete data based on sample tabulations of individual medical records.

For statistical purposes, trenchfoot and frostbite are not always separated in Army reports. Clinically, they are often indistinguishable. Practically, it would have been better if no attempt had been made to differentiate them. Generally speaking, whatever is said about one in the following pages may be regarded as equally applicable to the other unless specific exception is made. Similarly, whatever is said about cold injuries of the feet may be regarded as equally applicable to cold injuries of the hands, which, as a practical consideration, are affected in only a very small proportion of the injuries of this type.

TOM F. WHAYNE,
Colonel, MC, USA (Ret.).

MICHAEL E. DEBAKEY, M. D.

Acknowledgments

The preparation of a comprehensive volume such as this requires the labor, cooperation, and assistance of many persons other than the authors. We are happy to acknowledge our debt to them.

The epidemiologic studies on cold trauma in the European Theater of Operations during World War II were made by Col. John E. Gordon, MC, formerly Chief, Preventive Medicine Division, Office of the Chief Surgeon, European Theater of Operations, and now Professor of Preventive Medicine and Epidemiology, School of Public Health, Harvard University. Colonel Gordon also gave indispensable advice and assistance in the final epidemiologic evaluations.

The chapter on cold injury in the Mediterranean Theater of Operations is based almost entirely on the special reports made during the war by Col. Fiorindo A. Simeone, MC, now Professor of Surgery, Western Reserve University School of Medicine. The discussions of therapy in the Mediterranean theater are derived from the same reports.

Similarly, the clinical discussions of trenchfoot in the Zone of Interior, including therapy, were derived from special reports prepared by Lt. Col. Harris B. Shumacker, MC, formerly Chief of Surgery, Mayo General Hospital, now Professor of Surgery, Indiana University Medical Center.

Much of the information concerning the activities of the Medical Department in the Pacific theaters of operations was provided by Col. I. Ridgeway Trimble, MC, formerly Consultant in Surgery, Southwest Pacific Area, now Professor of Surgery, Johns Hopkins University School of Medicine.

Dr. Simeone, Dr. Shumacker, and Dr. Trimble have contributed materially to this volume and have also checked and rechecked the chapters dealing with their wartime fields of activity. Their assistance and cooperation are gratefully acknowledged.

Mrs. Josephine P. Kyle and her staff in the Historical Unit, United States Army Medical Service, provided material from the historical file and checked and corroborated data obtained from other sources.

Miss Zelma E. McIlvain, Historian, the Historical Unit, United States Army Medical Service, collected and abstracted most of the material for the chapter on cold injury in the European Theater of Operations. She also collected and abstracted some of the material used in the chapters on cold injury in the Aleutian Islands, the Mediterranean Theater of Operations, and the Pacific theaters.

Mr. E. L. Hamilton and his staff, Medical Statistics Division, Office of the Surgeon General, furnished valuable statistical data, checked and revised tables and graphs, and advised on methods of statistical analysis and presentation.

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Mr. McDonald Smith, under the direction of Mr. Herman Van Cott, Chief, Medical Illustration Service, Armed Forces Institute of Pathology, prepared the very excellent layouts for the illustrations in this volume and supervised the artwork and the preparation of the illustrations for printing.

We are also appreciative of the help and cooperation we have had from Col. John Boyd Coates, Jr., MC, USA, Director of the Historical Unit, United States Army Medical Service. He has read the entire volume critically several times and, from his personal experience with cold injury in the European theater, has corrected errors and supplied many details of interest and value which had not come to our attention. His contribution to this volume has gone considerably beyond the ordinary editorial function.

Finally, grateful and lasting appreciation is expressed to Miss Elizabeth M. McFetridge, who, as associate editor of this volume, not only put together, with uncommon skill, the manuscripts, notes, and thoughts of the authors but also at times served as adviser, arbiter, and peacemaker, and always as a treasured and trusted friend.

TOM F. WHAYNE,
Colonel, MC, USA (Ret.).

MICHAEL E. DEBAKEY, M. D.

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CHAPTER I

General Considerations of Battle Trauma

The inevitable consequence of war is physical injury to large numbers of men. The injury may be caused directly by the weapons and engines of combat (battle injuries) or may arise from the environment in which soldiers must operate (nonbattle injuries, disease). Thermal injuries, because they are the result of environmental heat or cold, are classified as nonbattle injuries, though they are usually incurred in the line and in some respects might more reasonably be classified as combat injuries. The sum total of all these injuries, no matter what form they may assume, is designated as war trauma.

Military strategy and tactics have been greatly influenced by injury and disease in many recorded campaigns. Medicomilitary history is the continuing record of the effect of trauma and of the planning and research instituted to improve methods of (1) treatment and repair of the injuries which result from it, and (2) rehabilitation of battle casualties.

Disease formerly exacted a much heavier toll in war than did combat injuries.[1] It is only in quite modern times, in fact, that battle deaths have exceeded deaths from disease. This reversal was first observed in the Danish War of 1864 in the German forces. A similar excess of battle deaths over disease deaths prevailed for German troops in the Franco-Prussian War of 1870–71, in the campaign in South-West Africa in 1904–7, and in World War I. Records for the Russo-Japanese War show a ratio of deaths from disease to battle deaths of less than 1 for both Russian and Japanese troops.

Improvement in this respect was considerably longer in coming in the United States Army (table 1). The ratio of deaths from disease to battle deaths (killed in action or died of wounds) in the Union Army in the Civil War (1861–65) was 1.81:1. In the Spanish-American War, the ratio for the year 1898 was 12.65:1 if deaths from typhoid in the United States are included. The ratio for the whole United States Army for a period coinciding almost exactly with the duration of the war (1 May 1898 to 31 August 1898) was 5.25:1. For the calendar year 1898, the ratio in the overseas area was 2.82:1.

In World War I, the tide finally turned; the ratio of deaths from disease to battle deaths (killed in action plus died of wounds) became 0.34:1 in the American Expeditionary Forces in Europe and 1.02:1 for the whole Army. In World War II, the ratio for United States forces in the European Theater of Operations was 0.01:1; for the total United States Army, if killed in action are included, the ratio is 0.07:1.

[1] Gordon, J. E.: The Strategic and Tactical Influence of Disease in World War II. Am. J. M. Sc. 215: 311–326, March 1948.

TABLE 1.—*Morbidity and mortality data for the United States Army in four major wars, 1861–1945* [1]

[Death rate and admission rate expressed as number per annum per 1,000 average strength]

Wars	Deaths from—		Ratio of deaths from disease to deaths from battle injuries and wounds [2]	Death rate from disease	Admission rate from disease	Case fatality rate from—			Daily noneffectiveness per 1,000 from—	
	Disease	Battle injuries and wounds				Disease	Battle injuries and wounds	Nonbattle injuries	Disease	Nonbattle injuries
	Number	*Number*				*Percent*	*Percent*	*Percent*		
Civil War (North)	199,720	110,238	1.81:1	62.0	2,339.1	2.6	13.3	[3]	[3]	[3]
Spanish-American War	1,939	369	5.25:1	25.6	2,005.8	1.6	6.1	1.6	17.5	[3]
World War I	51,447	50,510	1.02:1	16.5	851.5	1.7	6.1	1.9	41.6	4.5
World War II	15,779	219,560	.07:1	.6	587.5	.1	4.5	3.1	30.3	6.4

[1] Data on deaths are fairly well restricted to periods of actual hostilities, but the admission rates, case fatality rates, and noneffective rates shown in almost all instances are for somewhat longer periods, including the periods of hostilities. This is due to the basis on which the data were compiled in that only data for calendar or fiscal years could be obtained.

[2] Includes killed in action.

[3] Data are not available.

The Army-wide death rate for disease in World War II was reduced to less than one-twentieth of its World War I level. Case fatality rates for disease were reduced to about one-fifteenth of this level. Morbidity rates for disease were generally reduced by about a third, although the experience in special theaters, particularly the tropical theaters at the beginning of the war, was not uniformly favorable. The average daily rate for noneffectiveness per 1,000 average strength from all causes in the total Army was 58 in World War I (April 1917–December 1919) and 44 for World War II (1942–45). Comparable rates for noneffectiveness for all disease in the whole Army were 42 for World War I and 30 for World War II per 1,000 average strength.

The case fatality rate for battle casualties in World War II was approximately half of the rate for World War I (exclusive of gas casualties), the decrease reflecting the better medical care provided in World War II. The case fatality rate for nonbattle injuries, on the other hand, increased by about one-half in World War II as compared to World War I. In terms of total Army strength, the death rate from battle causes decreased by about one-half between World War I and World War II, but the non-battle-injury death rate in World War II was almost double the rate for World War I.

As these data demonstrate, disease has become progressively less costly in war, while battle trauma and nonbattle injuries have become relatively more costly.

THE EPIDEMIOLOGY OF TRAUMA

In the past, a great deal of effort has been expended in collecting the records of battle casualties and in classifying, analyzing, and interpreting them. Serious endeavors have been made to assess the influence on casualty

rates of such factors as equipment, training, nutrition, fatigue, seasoning, leadership, psychologic preparation for war, and motivation in general. The emphasis, however, has been almost entirely on battle casualties and the important communicable diseases. Up to the present time, the role of total mass injury has received little attention. Almost no attempt has been made to study noncombat injuries and to assess their importance in terms of the mass problem or to determine whether military trauma can be approached epidemiologically. On the contrary, it has been the general practice to look upon nonbattle injuries and accidents as losses that are inevitable and that must be accepted when many men operate many machines under stress. Even less attention has been paid to the trauma that comes about directly as the result of environment. Thermal injuries, as already noted, are included in the latter category.

The advances which have been made in medical science have provided a better understanding of the causation of communicable disease, and a better knowledge of the behavior of disease has therefore also become predictable, at least to some degree. It was this predictability, together with the development of the tools, procedures, and methods for the control of disease, that brought about the reversal, already commented upon, in the relative positions of disease and injury in the two World Wars. Historically, however, the change from the conviction that loss from disease is an inevitable part of military operations to the concept of concerted programs of prevention for its control or eradication has been slow to evolve. Military history provides dramatic episodes in this evolution. Against the conquest of typhoid fever in World War I, for instance, must be set the disastrous effect of the dysenteries on the British forces on the Gallipoli Peninsula in 1915–16. Furthermore, the evolution of the new concept has been incomplete as well as slow, as is demonstrated by the casualties suffered from malaria by the Allied forces in the Pacific in World War II.

As disease has become increasingly less costly in war, both battle casualties and nonbattle casualties have become relatively more costly, and the question has naturally arisen: What can be done to make trauma less of a liability? There seems no real reason why mass injury should be less amenable to epidemiologic evaluation and interpretation than mass disease. Much progress has been made in the experimental and clinical study of trauma. Treatment by surgical measures has made great strides, and knowledge of the clinical management of the individual traumatized soldier is now far advanced. The study and understanding of injuries likely to be sustained in given types of operations have become scientific enough to make preliminary estimates accurate within reasonable limits.

If, however, trauma is to be viewed as an entity, these advances are not enough. Trauma must be studied through the whole range of cause and effect and in terms of time, place, and person. It must be analyzed from the standpoint of the primary role of agent, host, and environment. All of the factors, in short, which arise from, or which influence, these various circumstances and

which produce the final effect of trauma, or which prevent its occurrence, must be evaluated and considered.

Such an epidemiologic concept of trauma is not entirely new. Pirogov,[2] toward the close of the last century, declared that war is the epidemiology of trauma. This is an extremely perceptive observation, though somewhat oversimplified, since military trauma, as already pointed out, is not a single entity. An investigation of the epidemiology of trauma as a group composed of special types of injuries would be as nonproductive as a study of the epidemiology of the exanthematous diseases as a group. In the same manner that the epidemiology of measles, scarlet fever, and smallpox, for instance, must be studied disease by disease, so must the general field of military trauma be broken down into its component parts. Thus, the epidemiology of accidents might be subdivided into industrial, vehicular, and other special types. The epidemiology of thermal injuries would be subdivided into those caused by heat and those caused by cold. Only by such an approach to single components that are relatively clear-cut entities and are amenable to study can the broad principles applicable to trauma as a whole be ascertained.

Although this approach has never yet been properly or fully utilized, one component of nonbattle trauma—cold injuries of the ground type—assumed such tactical and strategic importance during World War II that it was necessarily studied on a mass basis. This was not a necessity which had been anticipated. The history of most past wars, including World War I, shows that during cold weather military activities were always either considerably lessened or came to a practically complete halt. It seems reasonable to assume, furthermore, that environmental factors will exert the same influence during the winter on each of the two opposing military forces. In World War II, however, the decision, in the autumn of 1944, to go forward with an intensive winter campaign in the European theater, in an effort to hasten the end of the war, reversed the usual circumstances, and the reversal introduced an unusual opportunity to study the mass effects of injuries caused by cold during large-scale military operations.

Before World War I, trauma caused by cold had never been subjected to thorough scrutiny as a military problem. That conflict, with its static trench warfare, saw trenchfoot develop into a significant medical and surgical problem among British and French troops, as well as among German troops. The studies on cold injury which were undertaken then, as soon as the problem became apparent, were directed toward defining the clinical nature of this type of trauma, establishing the pathologic process, and determining effective forms of therapy. Prevention was emphasized in practice, but chiefly as it could be applied to the individual soldier, to rotation of units, and to supplies. It is true that all of these considerations are fundamental, but their applicability under

[2] Pirogov, N. I.: Das Kriegs-Sanitäts-Wesen und die Privat-Hülfe auf dem Kriegsschauplatze in Bulgarien und im Rücken der Operirenden Armee 1877–1878. Aus dem Russischen von Dr. Wilhelm Roth und Dr. Anton Schmidt. Leipzig: Verlag von F. C. W. Vogel, 1882, p. 299.

the static trench warfare of World War I could not have been expected to meet the exigencies of the active mobile warfare characteristic of World War II.

The over-all problem of mass injury caused by cold was not approached epidemiologically in World War I. In fact, trenchfoot was not even conceived of as subject to epidemiologic principles and laws. At that time, epidemiology was chiefly construed to mean the detailed study of outbreaks of infectious diseases. Its scope did not include chronic disease or injury nor did it encompass the study of disease or injury as a whole. Its application to chronic noninfectious disease, however, was not long in coming after the war ended. Emerson's [3] discussion of heart disease as a public health problem was first published in 1921. His similar discussion of mental health was published in 1922. Since that time, the development of the broad concept of epidemiology in the field of noncommunicable diseases, injuries, and accidents has been chiefly the work of Gordon.[4]

This same observer, with his associates in ETOUSA (European Theater of Operations, United States Army), showed in World War II that mass injury is quite as susceptible to epidemiologic analysis as is mass communicable disease.

A similar epidemiologic analysis of cold injury, ground type, was not made for the Army as a whole in World War II. Its feasibility, however, is clearly evident in the field surveys and investigations carried out in the European theater (p. 176) and by analyses of the data collected in the Office of the Chief Surgeon of that theater and in the Office of the Surgeon, MATOUSA (Mediterranean Theater of Operations, United States Army). These records, supplemented by records of individual units and divisions, all proved, as will be shown in detail in the course of this presentation, that, as a crippling malady, cold trauma behaves in accordance with the same biologic laws and principles that govern diseases of large populations.

The most significant and most distressing fact about cold injuries in World War II is that the experiences in one theater were not transmitted to the other theaters. The experiences in the Aleutians in 1943 were lost on the Mediterranean theater. The European theater did not profit from the lessons learned in the Mediterranean theater, though the experience in Italy clearly demonstrated that trenchfoot is a condition which is almost entirely preventable if an epidemiologic analysis of its causation is made and if there is aggressive command support. The cold injury experience in that theater occurred in the winter of 1943–44. The prevention and control program established the following winter was extremely effective. The losses from cold injury were materially less than those sustained the previous winter. Yet it was not until the late months of 1944, after an even more devastating cold injury experience, that a similarly effective program was instituted in the European theater.

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[3] Emerson, Haven: Selected Papers. Battle Creek: W. K. Kellogg Foundation, 1949.

[4] (1) Gordon, J. E., and Augustine, D. L.: Tropical Environment and Communicable Disease. Am. J. M. Sc. 216: 343–357, September 1948. (2) Gordon, J. E.: The Epidemiology of Accidents. Am. J. Pub. Health 39: 504–515, April 1949. (3) Gordon, J. E.: Epidemiology—Old and New. J. Michigan M. Soc. 49: 194–199, February 1950. (4) Robert, H. L., and Gordon, J. E.: Home Accidents in Massachusetts. A Study in the Epidemiology of Trauma. New England J. Med. 241: 435–441, 22 Sept. 1949.

In the planning of the assault on Japan, the exorbitant military cost of losses from cold injury in Italy and in western Europe was fully recognized by the War Department and the Commander in Chief, AFPAC (United States Army Forces in the Pacific). The result was a well-coordinated wet-cold indoctrination program which made use of the principles and practices tested in those theaters and which, if its implementation had proved necessary, would undoubtedly have reduced to negligible proportions losses from this cause in the Pacific.

CHAPTER II

General Considerations of Cold Injury

TYPES OF COLD INJURY

In addition to total freezing of the deep tissues, cold injuries include chilblains, trenchfoot, frostbite, and immersion foot. All of these injuries, irrespective of environmental and other modifying circumstances, are related by the common factor of cold. They are differentiated and can be classified chiefly according to the degree of cold which has given rise to the injury, the duration of exposure, and the environmental factors, chiefly wet, which intensify the effect of low temperatures.

The temperature level at which cold injury will occur is not absolute. The level is dependent upon the various factors which have just been listed. It is modified by such other factors as fatigue, malnutrition, and, perhaps, individual variations in resistance. The upper limit of temperature at which cold injury may occur has also not been established. During World War II, men shipwrecked in the Gulf Stream, in which the temperature was 60°–70° F. (15.6°–21.1° C.), presented immersion foot, with sensory changes and gangrene, after 8 days.[1] Webster, Woolhouse, and Johnston,[2] who reported some of these cases, were unwilling to accept cold as a causative agent, but their interpretation seems open to question in view of Lewis' demonstration (p. 235) that the skin begins to lose heat at 61° F. (16.1° C.) and that immersion in water hastens the loss. A variety of cold injury was observed in United States troops after the landing at Leyte in the Philippine Islands (p. 211), and another variety, so-called shelterleg (p. 9), was reported in persons who had spent the nights in damp, but not necessarily very cold, London subways during the bombings early in the winter.

Cold is the agent which causes tissue damage. This is true whether it is the mild, continuous type of cold which causes chilblains; the severe, dry cold which causes frostbite; or the combination of cold and wet which causes trenchfoot and immersion foot. Different degrees of cold may give rise to what appear to be significant pathologic differences,[3] and the resulting clinical manifestations may also vary in severity, but basically the pathologic process

[1] (1) White, J. C.: Vascular and Neurologic Lesions in Survivors of Shipwreck. I. Immersion Foot Syndrome Following Exposure to Cold. New England J. Med. 228:211–222, 18 Feb. 1943. (2) White, J. C., and Scoville, W. B.: Trench Foot and Immersion Foot. New England J. Med. 232:415–422, 12 Apr. 1954. (3) Webster, D. R., Woolhouse, F. M., and Johnston, J. L.: Immersion Foot. J. Bone & Joint Surg. 24:785–794, October 1942.

[2] See footnote 1 (3).

[3] Ariev, T. V.: Fundamental Outlines of Present Day Knowledge of Frostbite. Medgiz: Moscow, 1943. This is one of a series of 16 papers originally published in Russian from 1939 to 1944 and translated into English and published by Earl R. Hope, in Ottawa, Canada, in 1950 under the title "Frostbite."

is essentially the same in all cold injuries. This observation, while it holds particularly for frostbite, trenchfoot, and immersion foot, which constitute the ground-type injuries of military importance, does not exclude the occurrence of immersion foot in tropical waters when the period of exposure is sufficiently long.[4]

The interrelationships of the various cold injuries can best be understood by defining them as entities and noting the etiologic factors which, in conjunction with cold, are responsible for their production.

Chilblains

Chilblain has been described as trenchfoot of the hand, though it may also occur on the lower extremity. The lesions are most frequently located on the dorsal surface of the phalanges, between, rather than over, the joints. Although any portion of the dorsal surface may be affected, the thumbs are relatively exempt. Any portion of the lower extremity may also be affected, though the anterior tibial surface of the leg, especially in women, is probably the most common location.[5]

Chilblains may disappear within a few days or may assume a chronic form and last for weeks and months. In the chronic form, the condition is also known as erythrocyanosis, Bazin's disease, lupus, pernio, and dermatitis hiemalis.

The disease is provoked by cold above freezing which is experienced intermittently over long periods of time. It is observed chiefly in climates characterized by moderate cold and a high degree of humidity. The subjects are usually young persons, whose hands are likely to be colder than normal, and sometimes deeply colored, all the year round. The majority give a history of daily exposure in a cold, moist atmosphere. As a result, the injury of the preceding day has not been compensated for before there is the insult of added exposure on the succeeding day, and one lesion thus tends to develop over another.

Skin which has previously been damaged in any way is peculiarly susceptible to chilblains. Lewis [6] has also demonstrated that the condition is prone to appear in persons whose skin is hypersusceptible to the stimulation of cold. If the histamine test is carried out under standard conditions, with the skin at its ordinary temperature, the reaction is abnormal. His explanation is that the predisposing cause of chilblains is a chronically defective circulation: "It is to the high vascular tone of the limb vessels, to the readiness with which the temperature of fingers or other parts falls to that of its surroundings, and to the long delay in the release of this spastic condition of the vessels after

[4] Ungley, C. C., and Blackwood, W.: Peripheral Vasoneuropathy After Chilling. "Immersion Foot and Immersion Hand." Lancet 2: 447-451, 17 Oct. 1942.

[5] (1) Lewis, T.: Observations on Some Normal and Injurious Effects of Cold Upon the Skin and Underlying Tissues. II. Chilblains and Allied Conditions. Brit. M. J. 2: 837-839, 13 Dec. 1941. (2) Schaefer, C. L., and Sanders, C. E.: Pernio (Chilblains). J. Missouri M. A. 38: 159-160, May 1941.

[6] See footnote 5 (1).

general vasodilatation sets in, that the chilblain subject seems to owe his predisposition to these lesions."

The typical chilblain first appears as a red, swollen, tender lesion, which is usually warm or hot to the touch and which is characterized by obvious vasodilatation and subcutaneous edema. The only symptom at this time is itching. When the lesion becomes chronic, the original state of vasodilatation is no longer apparent, but the swelling may increase and the tissues may become tenser. The color becomes a deep purple or reddish purple. Blister formation and ulceration may develop. In the chronic form, itching is replaced by tenderness and actual pain. Regardless of whether the condition is acute or chronic, indolence and slow healing are prominent and are to be explained by the defective circulation which underlies its development.

Shelterleg

Shelterleg is the term applied to the swollen lower extremities which physicians began to see in numbers soon after the initiation of the blitz of London in 1940.[7] Knight,[8] who first described the condition, referred to it as trenchfoot in civilians. Although all ages and both sexes were affected, shelterleg was most frequently observed in elderly, obese women. Contrary to expectations, however, neither varicose veins nor cardiac lesions were present in affected subjects any more frequently than they would be found in an average population of the same age.

Inquiry of these patients practically always revealed that they had been spending their nights in a sitting position, sometimes at home, more often in the subways. The platforms were crowded, no bunks had then been installed,[9] and people brought their own chairs, usually of the deck type, and slept upright in them. The subways were cold and damp, but the chief etiologic factor seemed to be dependency of the parts, plus pressure on the popliteal space from the crossbars of the chairs. In an occasional instance in which the condition was unilateral, it was found that the patient had spent the night with one leg crossed over the other. In other words, the responsible causes—cold, dampness, dependency, and interference with the circulation—were precisely the causes which were later responsible for the cold injuries observed in ground troops in Italy and western Europe. The lack of specific predisposing causes in most of the affected persons suggests that the capillary walls, even when the extremities are entirely sound, are incapable of maintaining their tone for an indefinite period against the influence of gravity without intervals of recumbency or of active movement.

When the nocturnal habits were changed, rapid relief occurred in all uncomplicated cases of shelterleg except for a small group of patients whose

[7] (1) Knight, B. W.: "Trench Foot" in Civilians (correspondence). Brit. M. J. 2: 610–611, 2 Nov. 1940. (2) Shelter Legs (editorial). Lancet 2: 722, 7 Dec. 1940. (3) The Shelter Problem (reports of societies). Brit. M. J. 2: 801–802, 7 Dec. 1940.

[8] See footnote 7 (1).

[9] See footnote 7 (2).

deaths could be traced directly to these habits. Soon after Knight had described the condition, Simpson [10] called attention to a significant increase in the occurrence of fatal pulmonary emboli in London; there were 4 fatal cases in September and October 1939 and 24 for the same period in 1940. Twenty-one of these twenty-four fatalities had occurred in persons who were in the shelters or, more usually, who were just leaving them after a night, or a succession of nights, spent in them. The subjects were usually elderly, 18 of the 24 being over 60 years of age. Most of the patients were somewhat obese, and several had varicosities of the veins of the legs. In every instance, however, the precipitating circumstance seemed to be the long period spent in a deck chair or some similar chair, the front edge of which compressed the popliteal space and caused obstruction, with subsequent stasis, edema, and thrombosis, presumably in that order. Deaths from this cause, Simpson noted, were already decreasing at the time of his report, as the provision of bunks was increasing, and he put the figures on record merely to emphasize the need for haste in providing the necessary equipment in the shelters. He also called attention to the mechanical factor, which is not ordinarily so clear cut, in the development of thrombosis and to the fact that the thrombi originated in the tibial veins and not in the large pelvic veins.

Shelterleg was no part of the war picture in the United States, since the circumstances which gave rise to the condition in England were never duplicated in this country. Dependency for long periods, however, without change of position, is responsible for the so-called traveler's legs sometimes observed in civilian practice after long trips in trains, automobiles, or airplanes. As a rule, the discomfort and edema are promptly relieved when movement is resumed, though it may be a matter of days before the edema disappears completely.

Immersion Foot

Immersion foot [11] is a form of tissue trauma which follows prolonged immersion of the feet in water not sufficiently cold to cause frostbite. It has been observed, as already mentioned, after exposure in subtropical waters. Ungley [12] described it as "peripheral vasoneuropathy after chilling." Clinically and pathologically, it is indistinguishable from trenchfoot, which would be expected, since it originates from essentially the same causes.

Immersion foot typically appears in shipwrecked persons who have been exposed to cold and wet for long periods of time. It is usually associated with

[10] Simpson, K.: Shelter Deaths From Pulmonary Embolism. Lancet 2: 744, 14 Dec. 1940.

[11] (1) See footnote 4, p. 8. (2) Brownrigg, G. M.: Frostbite in Shipwrecked Mariners. Am. J. Surg. 59:232-247, February 1943. (3) Ungley, C. C.: Immersion Foot and Immersion Hand (Peripheral Vasoneuropathy After Chilling). Bull. War Med. 4:61-65, October 1943. (4) Ungley, C. C.: Treatment of Immersion Foot by Dry Cooling. Lancet 1:681-682, 29 May 1943. (5) Immersion Foot. Bull. U. S. Army M. Dept. No. 70, pp. 26-33, November 1943. (6) White, J. C., and Warren, S.: Causes of Pain in Feet After Prolonged Immersion in Cold Water. War Med. 5:6-13, January 1944. (7) Blackwood, W.: Studies in the Pathology of Human "Immersion Foot." Brit. J. Surg. 31:329-350, April 1944. (8) Goldstone, B., and Corbett, H.: Aetiology of "Immersion Foot." Brit. M. Bull. 2:148-149, 1944. (9) Fausel, E. G., and Hemphill, J. A.: Study of the Late Symptoms of Cases of Immersion Foot. Surg., Gynec. & Obst. 81:500-503, November 1945. (10) Wayburn, E.: Immersion Hypothermia. Arch. Int. Med. 79:77-91, Jaunary 1947.

[12] See footnote 11 (3).

dependency and immobility of the lower extremities and with constriction of the limbs by clothing and shoes. Other factors which play more or less important roles are (1) body cooling, as the result of wind; (2) total immersion; (3) repeated immersion; and (4) inadequate clothing, seasickness, and starvation. In the reported cases, younger and older persons seemed to suffer more severely from immersion foot than persons between 17 and 40 years of age. It was also the experience of shipwrecked survivors during World War II that those who lost heart and gave up hope suffered more severely, and sometimes died more quickly, than their companions who were of better spirit. The incidence and severity of immersion foot, however, are more directly influenced by the duration of exposure and the temperature of the water than by any of the other factors listed, though Ungley [13] expressed the opinion that the only specific effect of immersion is to keep the parts cold.

Three stages of immersion foot are recognized:

1. A prehyperemic stage, lasting from a few hours to a few days. In this stage, the extremities are cold, numb, swollen, and discolored, and peripheral arteries may be transiently or persistently pulseless. If pulsations continue absent, gangrene will ensue.

2. A hyperemic stage, lasting from 6 to 10 weeks. In this stage, the symptoms and signs include tingling or pain, motor disturbances, temperature differentials of the skin, increased swelling, blister formation, ulceration, and sometimes gangrene.

3. A posthyperemic stage, lasting for weeks or months. In this stage, symptoms and signs are absent if the environment is reasonably warm, but there is often sensitivity to cold suggestive of the similar sensitivity observed in Raynaud's disease.

The immediate symptoms of immersion foot are numbness, moderate pain, tingling or itching, sometimes cramps in the calves of the legs, and a sensation, on walking, as if the feet were being pressed into cotton wool. Edema, which is the most prominent physical finding, may appear within a few hours or after several days. The skin, which is initially reddened, becomes successively pale, mottled, and finally blue or black.

Trenchfoot

Trenchfoot is a thermal injury sustained as the result of exposure to cold short of freezing in a damp or wet environment. Arbitrarily, it is said to occur in the temperature range between 32° and 50° F. (0° and 10° C.). Actually, as already noted (p. 7), the maximum temperature has not been established. Recognized predisposing causes include immobility and dependency of the limbs, insufficient clothing, and constriction of the parts by shoes, socks, and other garments. Trenchfoot commonly occurs under combat conditions, when immobility is forced by enemy action and when circumstances make adequate foot care difficult or entirely impractical. The prevalence is

[13] See footnote 11 (4), p. 10.

influenced by the weather, the type of combat action, the type of terrain, the supply of food and clothing, and individual and organizational training policies and procedures for the care of the feet.

Trenchfoot is characterized pathologically by circulatory, neurologic, and sudomotor changes, which are manifested by signs of local tissue damage and sterile inflammation. As some observers have pointed out, this type of cold injury is almost identical with gradual frostbite, which might be expected, since the primary etiologic factors are the same except for differences in the degree of cold.[14]

The term "trenchfoot" came into use in World War I for the obvious reason that the injury was prevalent when static trench warfare was the rule. Although this type of warfare was the exception during World War II, this type of cold injury was unfortunately very frequent at certain periods in certain theaters of operations, and the term was retained (p. 187), partly for lack of a better one and partly because the implications of the nomenclature were so generally understood.

Frostbite

Frostbite is a tissue injury [15] which evolves actual freezing of the skin and subcutaneous tissues. It results from (1) prolonged exposure to freezing and subfreezing temperatures, as distinguished from trenchfoot, which is diagnosed (arbitrarily) when the temperature is above freezing, or (2) brief exposure to extremely low temperatures. The latter type of injury was observed in World War II chiefly in fliers, in the form of high-altitude frostbite.

Exposed portions of the body, such as the fingers, ears, nose, chin, cheeks, forehead, and feet, are most frequently frostbitten. Frostbite of the penis, from exposure during urination, is not infrequent in cold climates. Both the incidence and the severity of the condition depend upon the degree of cold, the duration of exposure, and the wind velocity. Contributory factors include circulatory stagnation caused by inactivity, constriction of the parts, general vasoconstriction, trauma, and nutritional deficiencies.

Frostbite may appear suddenly, as the result of direct exposure of unprotected parts during extremely cold or windy weather or as the result of contact of unprotected skin with cold metal during such weather. It may also develop gradually, and even insidiously, as the result of prolonged exposure of even protected parts. A local burning or stinging sensation or a twinge of pain followed by numbness usually supplies ample warning of what is occurring. The skin assumes a grayish or whitish, waxy appearance. Sometimes all the

[14] Greene, R.: Frostbite and Kindred Ills. Lancet 2:689-693, December 1941.

[15] (1) See footnotes 3, p. 7, and 14. (2) Lewis, T.: Observations on Some Normal and Injurious Effects of Cold Upon the Skin and Underlying Tissues. III. Frost-Bite. Brit. M. J. 2:869-871, 20 Dec. 1941. (3) Frostbite. Bull. U. S. Army M. Dept. No. 71, pp. 24-27, December 1943. (4) Stucke, K.: Kälteschäden and Erfrierungen im Felde [Cold Injuries and Frostbite on Active Service]. Bruns' Beitr. z. klin. Chir. 174:1-10, November 1942. Abstract Bull. War Med. 4:507, May 1944. (5) Richards, R. L.: Injury From Exposure to Low Temperature: Clinical Features, Prevention, Treatment. Brit. M. Bull. 2:141-142, 1944.

PLATE 1.—Various types and stages of high-altitude frostbite.

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involved tissues are extremely hard and fixed. In other instances, the affected part is indicated by the presence of a small, superficial, plaquelike lesion.

The first pathologic response to frostbite is an acute inflammatory reaction, quite similar to that observed in burns. Thawing is invariably followed by a state of reactive hyperemia, the intensity of which depends upon (1) the degree and duration of the exposure and (2) the rate at which the temperature of the part is raised. As in burns, the triple response characteristically present in the affected area, which is explained by the release of histaminelike substances from injured tissue cells, consists of (1) local reddening, (2) the appearance of a blister or of a blister and a wheal, and (3) a flare.

The eventual tissue damage depends upon the degree and extent of the actual freezing which has occurred and to an equal or even greater degree upon the transudation of fluid, and sometimes of blood cells, into the tissue spaces during the period of reactive hyperemia. The transudation is the direct result of increased permeability of the damaged capillary endothelium, which leads to swelling of the tissues, edema, and gross blister formation. In severe cases, secondary thrombosis of arterioles and capillaries may produce regional anoxia and cyanosis, which may go on to gangrene. Whatever the pathologic manifestation, the basis of the process is the prolonged peripheral vasoconstriction induced by cold.

High-Altitude Frostbite

High-altitude frostbite (plate 1) is a type of cold injury sustained by aviators and other flying personnel when they are flying in altitudes in which extreme degrees of cold (−40° to −52° C.) are encountered and in which wind velocities may be in excess of 200 miles per hour. Among the contributing causes are freezing of the oxygen mask, insufficient clothing, inefficiency of electrically heated clothing, and inadequate supervision and discipline of flying personnel, which result in unnecessary exposure of the hands by removal of the gloves (p. 131) and other failures to prevent exposure. This type of frostbite is most often observed on the hands, but it may occur on any exposed part of the body and after only a few seconds of exposure.

High-altitude frostbite was first described by Col. Loyal Davis, MC, Senior Consultant in Neurosurgery, Office of the Chief Surgeon, ETOUSA, and his associates,[16] in 1943. Since then, there has been rather general acceptance of their thesis that this type of frostbite is essentially the same as other types of cold injury but that it differs from the ground type in clinical severity and in the rapidity with which pathologic changes occur. Cold, just as in the ground type, is the primary agent which produces the pathologic changes, but the extreme low temperatures introduce two secondary mechanisms; namely, (1) generalized anoxemia and (2) local anoxemia of the affected parts. The local anoxemia is caused by the reduction of the local blood flow as a result of acute

[16] Davis, L., Scarff, J. E., Rogers, N., and Dickinson, M.: High Altitude Frostbite. Preliminary Report. Surg., Gynec. & Obst. 77: 561–575, December 1943.

vascular spasm. The basic morphologic change, according to these observers, is damage by cold to the endothelium of the terminal capillary loops. In mild injuries, the change is limited to a pathologic permeability of the capillary walls. In more serious injuries,thrombus formation occurs at the arteriolar-capillary junction. In the few pathologic specimens available for study, both arteries and arterioles showed a remarkable thickening of the intima (fig. 1), the vessels resembling those seen in endarteritis obliterans. The veins were not involved.

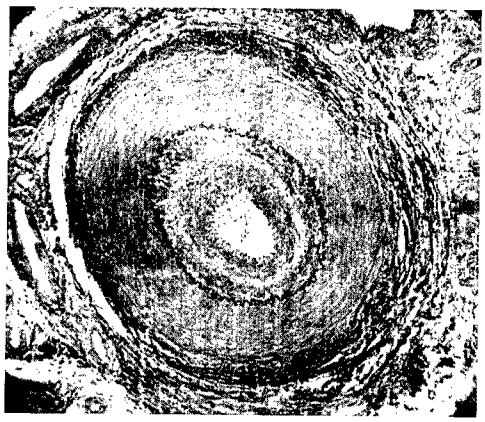

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FIGURE 1.—Photomicrograph of cross section of small artery 2 cm. proximal to line of demarcation of gangrene in finger amputated because of severe high-altitude frostbite, dry type. Note marked thickening of intima and absence of central thrombus and of evidences of recanalization. The endothelium is intact.

In the mild type of high-altitude frostbite, the fingers, after a brief period of exposure, become painfully cold, numb, stiff, waxy white, hard, brittle, and completely insensitive to touch. They cannot be flexed or extended voluntarily, and often they cannot be moved passively. Surface temperatures of the affected fingers may be 7.2° to 10.8° F. (4° to 6° C.) lower than those of the corresponding fingers on the unaffected hand. Even early in the injury, capillary microscopy shows no blood at all in the terminal capillaries on the dorsum of the fingers about the nail beds (fig. 2). This phenomenon, according to Davis and his associates, can be explained in two ways. It may be the result of an initial intense vasomotor spasm of the terminal portions of the arterioles, or, in some instances, it may be the result of a secondary thrombus at the point at which the arteriole, with its muscular wall, joins the thin-walled capillary.

Recovery from even mild high-altitude frostbite may be quite slow (fig. 3). Several hours are likely to elapse before the tips of the fingers begin to soften. If, however, the extremities and body can be brought back to normal body temperature there will be no blister formation, gangrene, or evident residuals, though the fingers may ache and throb for several hours and paresthesia may persist for days or weeks.

If the exposure to cold has been prolonged, tissue damage is severe and often permanent, and clinical manifestations are also severe. Two types of lesions, a wet type and a dry type, have been observed.

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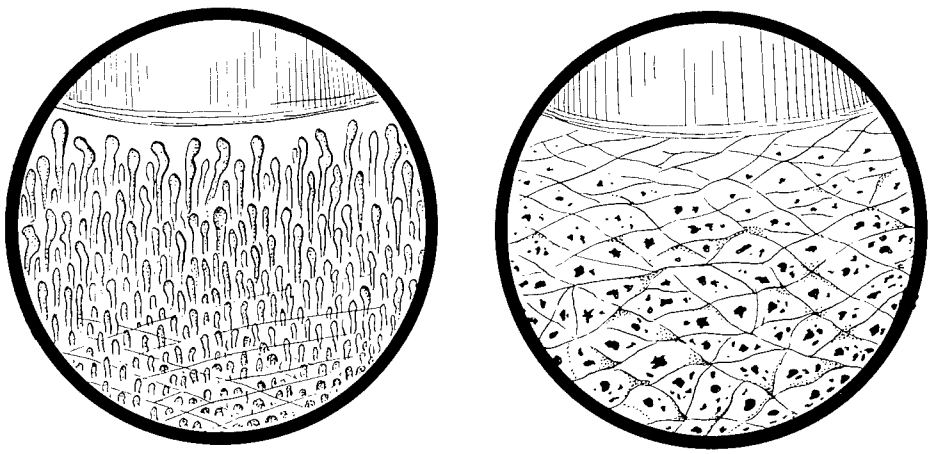

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FIGURE 2. Drawing of microscopic appearance of capillary bed at base of nail in normal finger and in frostbitten finger. Note hairpin appearance of parallel capillary loops in normal finger and their absence in affected finger. The thrombosed stumps of the arterioles are characteristic of the frostbitten finger.

FIGURE 3.—Persistent blanching of fingers due to vasoconstriction 7 hours after exposure to high-altitude temperature of −40° C. (−40° F.).

The wet lesion (figs. 4, 5, 6, 7, 8, 9) takes the form of multiple small cutaneous blisters, which appear almost at the same time upon many areas of the skin of the affected part. They increase rapidly in size and eventually coalesce to form one or more huge blisters, which may involve the entire dorsum of a finger or even the whole hand. Though these blisters sometimes resemble the simple vesicles of second-degree burns, more often the pathologically excessive fluid is held fast within the tissues composing the superficial layers of the skin.

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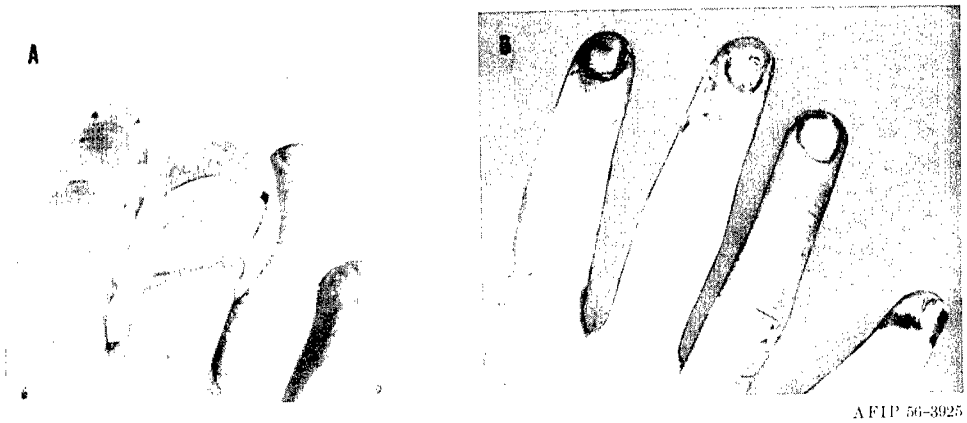

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FIGURE 4. Wet type of moderately severe high-altitude frostbite. A. Typical blister formation. The index finger shows a single vesicle which has completely collapsed after incision. The middle finger shows a blister which has failed to collapse after liberal incision, because of the excess fluid held within the tissues. Neither blister is hemorrhagic. B. Fingers shown in view A 1 month later. Blisters have dried, and desquamation has occurred. Note loss of nail and absence of normal skin markings, as well as the delicate, tight, shiny, new epithelium. These fingers remained sensitive to cold for many months.

On aspiration, a small amount of fluid is obtained, if any at all, but fluid which is sometimes clear and sometimes contains red blood cells will ooze slowly for several hours from the puncture hole. Hemorrhage most often takes place beneath the nails, which are likely to be lost. Superficial layers of skin are eventually dissected away from the deeper layers by extravasated fluid and are cast off, frequently in the form of a complete cast of the part (fig. 8). Most of the germinal layer comes away with the cast (fig. 9), and epithelial regeneration is therefore possible only from the remnants of germinal epithelium left in the ducts of the sweat glands. The newly regenerated skin varies in color from dusky pink to dusky blue. It is thin, smooth, shiny, and tightly drawn. Cold tolerance is greatly reduced (chart 1), and anesthesia or hypesthesia to pain and touch, with loss of sweating, may continue for months (fig. 10).

The dry type of high-altitude frostbite (figs. 11, 12, 13, 14, 15, 16), which usually follows more severe exposure to cold, at first resembles the wet type. Thawing is a slow process, however, and instead of blister formation the affected parts become extremely tense, the skin has the appearance of dull ground glass and becomes progressively drier, and the deeper tissues assume a progressively darker shade of dusky gray. All the tissues eventually shrivel and mummify, the changes being most marked at the distal portions of the extremities. After 2 or 3 weeks, a line of demarcation is clearly evident, and spontaneous natural amputation will take place unless surgical intervention terminates the process.

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FIGURE 5.—Wet type of severe high-altitude frostbite. A. Severe blister formation 24 hours after injury. B. Hands shown in view A 2 months later, showing regeneration of lost nails. The skin in the blistered areas is beginning to recover its normal surface markings. Sensory disturbances and loss of sweating persisted for many months.

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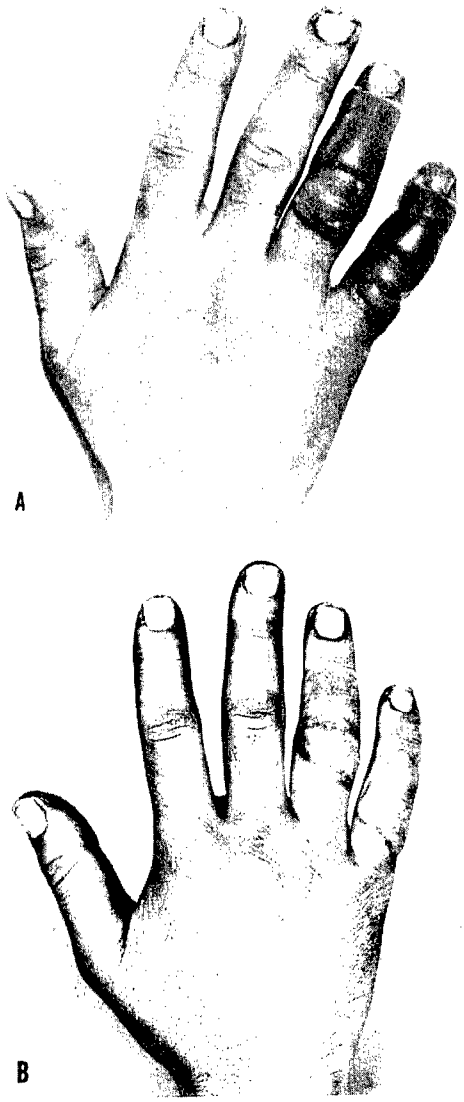

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FIGURE 6.—Wet type of moderately severe high-altitude frostbite. A. Hemorrhagic blisters. Note discoloration of nails. B. Hand shown in view A 10 days later. The blisters have dried up, and the skin has an ecchymotic appearance. Desquamation occurred later.

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FIGURE 7.—Wet type of severe high-altitude frostbite, with hemorrhagic blister formation, 24 hours after injury.

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FIGURE 8.—Wet type of severe high-altitude frostbite. Cast desquamation of tips of fingers followed severe blistering.

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FIGURE 9.—Photomicrograph of section of skin from blister in wet type of moderately severe high-altitude frostbite. Note separation of epidermis from dermis and, in particular, loss of basal germinal layer with epidermis.

THE SPECTRUM OF COLD INJURY

Injuries caused by cold may be roughly grouped according to their primary causes. In frostbite and freezing of the tissues, cold is the sole agent. In immersion foot, cold and wet both play roles, with wetness occupying the predominant role. In trenchfoot, cold and wet play approximately equal parts.

It is possible to postulate a range or spectrum of cold injury, beginning with mild chilblains and ending with severe frostbite at low temperatures and death from freezing of the deep tissues. While the place of the various injuries in the spectrum is determined by the degree of cold, the effect of cold may be greatly intensified by contributing factors, such as wet in trenchfoot and immersion foot, and anoxemia in high-altitude frostbite.

Precise data gathered by long observation and study have made possible the quantitative evaluation of disease. A range from inapparent disease on the one hand through fulminating disease on the other can be easily demonstrated in relation to deaths. Data collected in World War II and from other sources do not support a similar gradient of cold trauma, though the explanation may well be the shortcomings of the available data rather than any defect in the principle itself. The variety of contributing factors also helps to explain why it is difficult to formulate a gradient of cold trauma. Epidemiologically, the establishment of such a gradient would be highly desirable. Future experience must supply the data required and overcome other difficulties. Meantime, it is possible to postulate the probable behavior of cold trauma (chart 2).

Many factors come into play in a cold-trauma gradient. Each component constitutes a gradient to itself, and each is influenced by multiple properties of the agent, the host, and the environment. The development and interpretation

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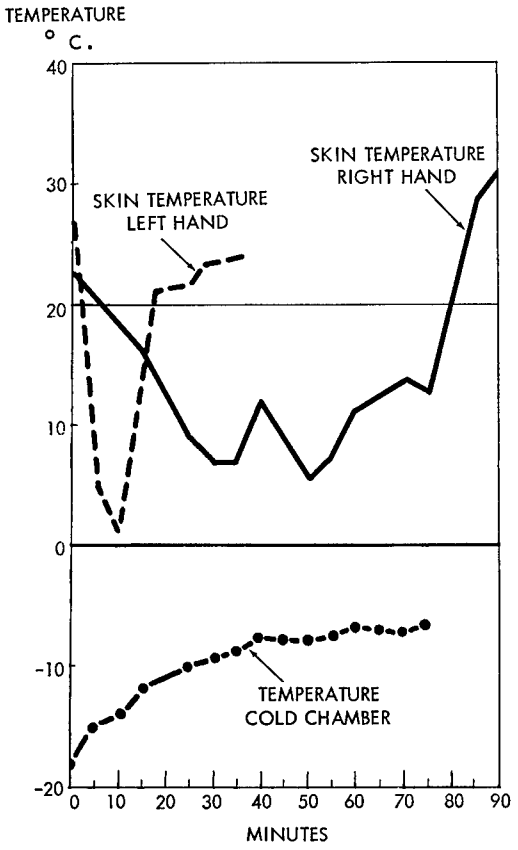
CHART 1.—*Graph showing cold tolerance of normal right hand and frostbitten left hand*



The curves shown represent the mean of the skin temperatures taken from the four fingers by electrothermocouples. Note that the temperature of the normal right hand could not be reduced below 5° C. (41° F.) after 50 minutes in the cold chamber. At that point, the hand began to warm spontaneously, and in 25 minutes the skin temperature rose 4° C. (7.2° F.). After its removal from the cold chamber (after 75 minutes), the hand quickly reached a temperature 8° higher than in the beginning. In contrast, after 10 minutes in the cold chamber, the skin temperature of the frostbitten left hand fell almost to zero, and the hand became so painful that it had to be removed from the chamber. The skin temperature of this hand did not then return to the original level.

of the gradient of cold injury are influenced by the degree of cold, the degree of wetness, individual susceptibility, the duration of exposure, the use of protective measures and equipment, and other modifying factors.

If the relationships illustrated in the gradient which has been postulated (chart 2) are correct, the total area of cold trauma is divided, though not equally, into four principal components. Severity or degree of injury varies in each component; it is least for chilblains and greatest for freezing of deep tissues, thus forming an ascending gradient of severity from left to right. Trenchfoot

FIGURE 10.—Persistent hypesthesia in high-altitude frostbite, sustained at temperature of −40° C. (−40° F.). Solid lines represent limits of hypesthesia and dotted lines limits of hypalgesia 7 hours after exposure. There was complete loss of pain and touch over the distal phalanges of the index and little fingers.

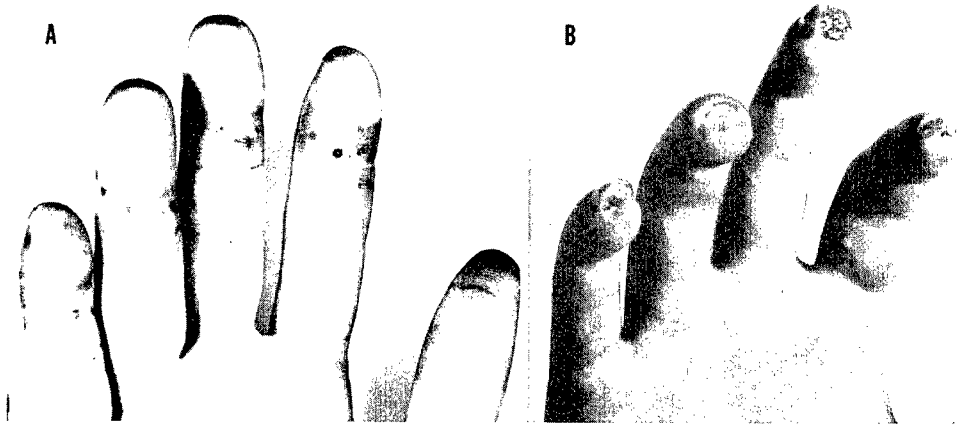


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FIGURE 11.—Dry type of mild high-altitude frostbite. A. Early stage. Blistering has not occurred but note ground-glass appearance of skin of fingertips. The deeper underlying tissues were under great tension and were quite painful. Gangrene of the affected parts followed. B. Hand shown in view A 5 months later, showing loss of nails and tissue of fingertips.

and immersion foot occupy the largest area and chilblains the smallest in terms of defect or more severe injury. This is the precise proportionate relationship of these cold injuries in terms of their military importance. Few, if any, deaths are caused by chilblains, and the disability they cause is not great. Though deep freezing of the tissues is accompanied by a high case fatality rate and by some disability in the survivors, its importance, in terms of numbers of cases, is far less than that of trenchfoot and immersion foot, as shown by the

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FIGURE 12.—Dry type of severe high-altitude frostbite. A. Early stage (1 hour after injury). B. Hand shown in view A 3 days later. Note almost total absence of blistering. C. Hand shown in view B 3 weeks later, showing far-advanced dry gangrene.

comparable areas in the schema. Trenchfoot and immersion foot are responsible for few deaths but for much temporary and permanent disability. Frostbite, while it carries a higher case fatality rate than either trenchfoot or immersion foot, is proportionately less important in terms of temporary and permanent disability or defect and over-all military cost.

It should be emphasized that these assumptions hold only for military operations conducted in winter in a temperate climate, such as that of western Europe. They would be greatly altered for operations conducted in the intense and sustained cold of the Arctic.

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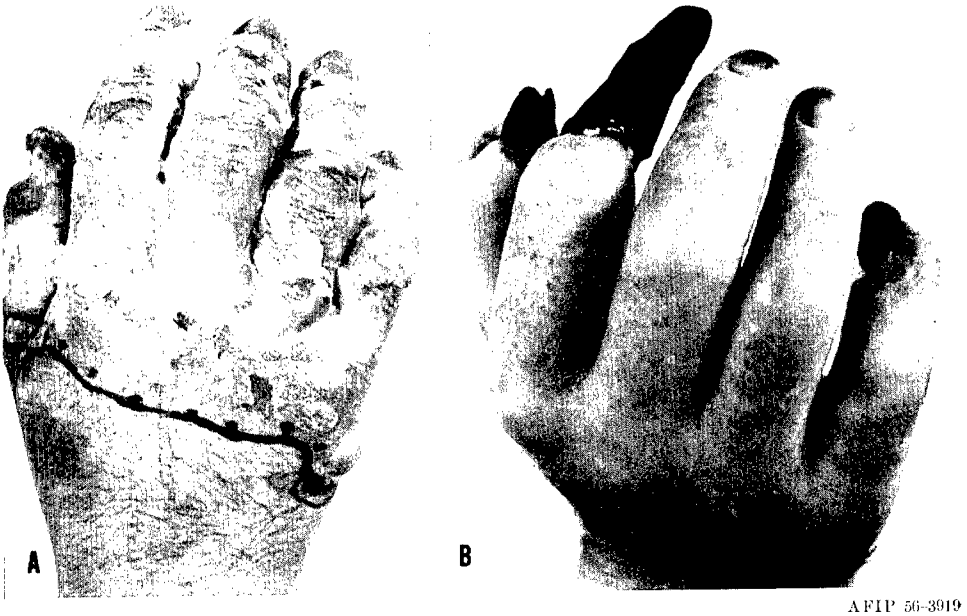

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FIGURE 13.—Dry type of severe high-altitude frostbite. A. Photograph 10 hours after injury. The hand has been dressed with sulfanilamide powder. B. Hand shown in view A 5 weeks later, showing spontaneous amputation of tissues as result of dry gangrene.

The specific causative agent in cold injury is cold,[17] but evaluation of the World War II experience makes it clear that wet, because it speeds loss of body heat, is closely related. The influence of wetness, however, is entirely synergistic. It cannot of itself cause cold injury. Factors related to the soldier himself and to his environment also play a part in the total causation of cold injury. Recognized human factors include the status of individual training, the individual nutritional status, fatigue, previous experience with cold injury, and inherent constitutional and psychosocial qualities, in addition to the mechanical factors of posture and dependency. Elements of the physical environment which enter the picture are the weather (that is, temperature, precipitation, and wind), the altitude, the terrain, and thawing. Socioeconomic influences include clothing supply and equipment, foot discipline, command leadership and attitude, training and experience as applied to the unit, and rotation of personnel.

[17] See footnote 3, p. 7.

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FIGURE 14.—Dry type of severe high-altitude frostbite. A. Early stages of mummification and dry gangrene 10 days after injury. B. Hands shown in view A 1 month later, after guillotine amputation of gangrenous parts.

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FIGURE 15.—Dry type of severe high-altitude frostbite. A. Photograph 10 days after injury. Note developing dry gangrene in little finger of left hand and absence of blistering. The thumb and index fingers of the right hand show the late stage of hemorrhagic blistering; the skin has turned hard and black, and to the uninitiated the changes could easily be mistaken for gangrene. B. Hands shown in view A 5 months later.

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FIGURE 16.—Mixed wet and dry types of severe high-altitude frostbite. A. Huge vesicular blister 72 hours after injury. B. Hand shown in view A 10 days later, showing developing dry gangrene in deeper tissues of fingertips. C. Hand shown in view B 5 months later.

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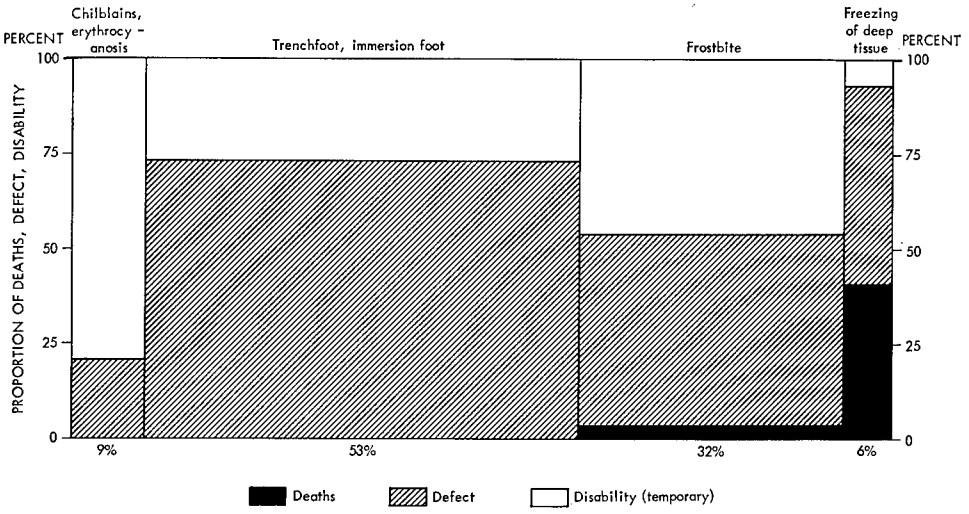
CHART 2.—*Gradient of cold injury (schematic)*



PROPORTION OF COLD-INJURY INCIDENCE BY DIAGNOSIS

All of these factors enter into the total causation of cold injury. Effective prevention and control, however, can be established only by evaluating the weight of each factor by studying each of them in individual units. The control of mass injury or disease depends upon methods and measures directed at causes. Analyses of cause and effect provide the only means for developing a concerted plan for meeting the problem in any future war.

The simple, sound epidemiologic methods used in the field in World War II to identify the several components in the total causation of cold injury demonstrate that only a few of these components are amenable to practical control and preventive practices. Thus, the type of combat action, terrain, and weather are universal causes which influence the incidence of cold trauma wherever it occurs but which are not amenable to control. On the other hand, as field studies during World War II clearly demonstrated, the level of the clothing supply, individual and unit discipline, rotation policies and practices, and the training and experience of troops, all of which exert a variable influence upon the incidence of cold injury, are all subject to control within the limits of the tactical situation. Further study and research should be directed to the intangible causative factors, which are not susceptible to precise measurement, to determine whether the base of practical control of cold injury can be broadened.

NOTE.—For statistical purposes, trenchfoot and frostbite are not always separated in Army reports. Clinically, as already indicated, they are often indistinguishable. Practically, it would have been better if no attempt had been made to differentiate them (p. 303). Generally speaking, whatever is said about one in the following pages may be regarded as equally applicable to the other unless specific exception is made. Similarly, whatever is said about cold injuries of the feet may be regarded as equally applicable to cold injuries of the hands, which, as a practical consideration, are affected in only a very small proportion of the injuries of this type.

CHAPTER III

Historical Note

With the single, and notable, exception of Larrey's[1] observations during the Napoleonic Wars, injuries of warfare caused by cold and exposure were not recorded in any great detail until fairly modern times, more particularly until World War I. Numerous brief references, however, indicate that this type of injury was responsible for an important loss of manpower in early military history. Thus, there are references to frostbite in the writings of Hippocrates, Aristotle, and Galen. The armies of Alexander of Macedon experienced casualties from this cause.[2] According to Grattan,[3] Xenophon, in the Anabasis, mentions cold injury as a significant problem in the Greek armies operating in western Armenia late in the fourth and early in the third centuries B. C.

In more modern times, Thatcher described serious losses from cold injury.[4] In 1777, 2,900 of an army of 10,000 men were unfit for duty because of sickness and lack of clothing. By February of the following year, the number of casualties had been increased by nearly a thousand men who, according to General Washington, "had been left to perish by winter cold and nakedness." In January 1780, some 20 percent of 2,500 men sent from Elizabethtown to attack the British on Staten Island also suffered cold injuries. Thatcher writes: "The party passed over on the ice * * * but the enemy having received intelligence of their design returned into their strongworks * * * . The snow was three or four feet deep, the weather extremely cold, and American troops continued on the island for twenty-four hours without cover. About 500 were slightly frozen."

Benjamin Rush,[5] who was physician general to the military hospitals of the United States during the Revolutionary War, contributed, perhaps unwittingly, some useful advice in the prevention of cold injury. In a small pamphlet of directions for preserving the health of soldiers, he wrote: "The

[1] Larrey, D. J.: Memoirs of Military Surgery and Campaigns of the French Armies, on the Rhine, in Corsica, Catalonia, Egypt, and Syria; at Boulogne, Ulm, and Austerlitz; in Saxony, Prussia, Poland, Spain, and Austria. Translated by Richard Willmott Hall, with notes by the translator. First American edition from the second Paris edition. Baltimore: Joseph Cushing, 1814, 2: 153–164; 205–224; passim.

[2] Ariev, T. V.: Fundamental Outlines of Present Day Knowledge of Frostbite. Medgiz: Moscow, 1943. This is one of a series of 16 papers originally published in Russia from 1939 to 1944 and translated into English and published by Earl R. Hope, in Ottawa, Canada, in 1950 under the title "Frostbite."

[3] Grattan, H. W.: Trench Foot. *In* History of the Great War Based on Official Documents. Medical Services. Surgery of the War. London: His Majesty's Stationery Office, 1922, 1:169–177.

[4] Thatcher, James: Military Journal of the American Revolution. Hartford: Hurlburt Williams and Co., 1862, pp. 127, 188.

[5] Rush, Benjamin: Directions for Preserving the Health of Soldiers, Addressed to the Officers of the Army of the United States. Published by order of the Board of War, 1777. Pennsylvania Packet, No. 284.

commanding officer should take the utmost care never to suffer a soldier to sleep, or even to sit down in his tent with wet clothes, nor to lie down in a wet blanket or upon damp straw. The utmost vigilance will be necessary to guard against this fruitful source of diseases among soldiers."

THE NAPOLEONIC WARS

The role of cold as such in the production of injuries to the body tissues was vividly, and for the most part correctly, described by Baron Larrey, surgeon to the French armies in the Napoleonic Wars. His classic description of the part played by frostbite and "congelation" in the defeat of these armies in Poland in 1812 is an accurate and affecting résumé of the tactical and clinical effects of injuries caused by cold. It is of sufficient importance, in fact, to be related in considerable detail.

Baron Larrey began his military medical career in the French Navy, serving in waters in which immersion foot might well have been observed. At the end of 2 years, chiefly because of his susceptibility to seasickness, he transferred to the army, in which he became a division surgeon. In this new position, he quickly perceived that the previously accepted practice of waiting to care for the wounded and dispose of the dead until the battle had moved on was resulting in great, and for the most part unnecessary, loss of life and limb. To remedy the situation, he devised a field medical organization in which light ambulances, together with field stations, brought medical care to the wounded immediately behind the lines. He eventually developed this service to such a point that it was often possible to have all the wounded off the field and cared for by military surgeons within 24 hours after a battle had ended. The development of this effective divisional medical service gained such recognition for Larrey that he was withdrawn from his division and charged with the responsibility of developing a similar system for the whole army. Shortly afterward, he was ordered to join the army commanded by Napoleon, with whom he served for many years, eventually becoming chief surgeon of the Grande Armée which was to invade Russia.

The principles and practices of military medicine laid down by Larrey are essentially those used in modern military field medicine. He was, in addition to being an administrative genius, a skillful and accomplished surgeon, and it is not surprising, therefore, that his description of frostbite and of the changes underlying its clinical manifestations comes very close to the present concept of the causation and pathogenicity of injuries of warfare caused by cold.

Causes of cold injury.—Physicians who had previously written on this type of "mortification," Larrey pointed out, believed cold to be the exciting cause of the gangrene. Attention to the time at which the gangrene occurred, however, as well as to its progress and the phenomena which accompanied it, would make it clear that cold was only the predisposing cause. Between the 5th and

9th of February 1807, before the battle at Eylau, in Prussia, not a single soldier in the French Army complained of frostbite, although the temperature ranged from −10° to −15° R. (Reaumur thermometer) or from 9.5° to −1.8° F. and during this period they had spent all of their days and most of their nights in the snow and in most severe frost. Even the Imperial Guard, which had been on duty for more than 24 hours, in the snow, without much exercise, did not suffer frostbitten feet.

During the night of 9 and 10 Februrary, the temperature suddenly rose to 3°–5° R. (38.8°–43.2° F.). On 10 February, a copious fall of sleet occurred, and the following day a thaw set in and continued for some time. Almost immediately, a number of soldiers of both the guard and the line began to complain of their feet. Their first symptoms were "acute pains in the feet, torpour, heaviness, and a disagreeable pricking in the extremities, which were slightly swelled and of a dark red." In some instances, the base of the toes and the upper surface of the foot were slightly reddened. Sometimes, the toes were without any sensation, heat, or motion and were black and "in a manner dried."

Without exception, the affected soldiers assured Larrey that they had felt no pain or other untoward sensations during the severe cold in bivouac on 5–9 February and that it was not until 10 February, when the temperature rose by 18° to 20° R. (40.5°–45° F.), that they began to experience "congelation." The first symptoms were not severe. Painful, pricking sensations were succeeded by numbness, stiffness, immobility, and a sense of heaviness as well as of cold. Those men—fortunately the greater number—who followed the advice of Larrey and his colleagues, to rub the affected parts immediately with snow and later with camphorated brandy, did not suffer from gangrene if it was not already present when treatment was begun. Those able to go into town, like those who approached the fire of the bivouac to warm themselves, were severely affected. Gangrene appeared almost abruptly and progressed rapidly in men who approached the fire. While it was generally limited to the toes and seldom rose above the ankle, in some instances it extended over half of the foot.

This type of "sphacelus of the foot," Larrey emphasized, should not be confused with gangrene of the skin. He had observed casualties in whom, while the skin of the foot was deprived of life to a greater or lesser degree, the vessels, deep-seated nerves, tendons, ligaments, and bones were not affected. The patient experienced pain when the subjacent parts were touched, but the foot retained its internal heat and could be moved. Gangrene of this type, Larrey continued, "* * * is superficial, and cannot be considered as similar to the sphacelus of the foot that deprives it of motion, of sensibility, and of all the phenomena of life. The patient cannot feel that he has a foot and it appears like a foreign body suspended to his leg."

Then followed the important warning that the nature of the disorder must be carefully ascertained before amputation was resorted to and that general remedies should always precede surgery.

Larrey's explanation of the progress and development of this gangrene, or, as he preferred to call it, of "the modus operandi of the causes which produce it," follows, in his own words:

Cold acts on the living parts by blunting the sensibility of those organs which are subjected to its immediate impression: the natural heat is absorbed, and a discharge and repercussion of calorick takes place: the pores are closed: the fibres and the capillary vessels fall into a state of contraction: the fluids are condensed, and flow more slowly. At first, the action of the cold is painful: the skin wrinkles and loses its natural colour. Yet, the animal heat and the vital powers resist this sedative and contracting power that opposes the return of the fluids: the capillary system is obstructed more easily when its extreme ramifications are *weakened*. The skin becomes red, its sensibility is blunted, and if the effects of the cold continue, it gradually becomes extinguished and torpour soon takes place. The parts may remain for a longer or shorter period in this state of *asphyxia* without losing their life; and if the cold be removed by degrees, or if the person affected by it pass gradually into a more elevated temperature, the equilibrium may be easily reestablished with the functions of the organs, and the disposition that the parts have to fall into gangrene is removed: but if on the contrary, persons who are thus affected by cold pass suddenly from a temperature at the freezing point to one more elevated, an obstruction of the parts affected must of necessity be produced; and if it be considerable, the vessels lose their elasticity altogether, become paralyzed, and sometimes burst, or are torn asunder: and hence follow blisters and cracks, or fissures of the part. The course of the fluids in the vessels is interrupted; there is a redundance of carbon, the parts turn black, and gangrene is abundant. Infection is propagated to all those parts which have been seized on, or affected by the cold. Thus the gangrene advances until it meets with resistance from the vital powers. Now the systaltick motion of the vessels, the irritability of the cellular substance of the membranes and of the skin, which had resisted the action of the cold, resist the principles of the gangrene, and far from absorbing them, the extremities of the capillary vessels which convey blood, and the lymphaticks being irritated by these heterogeneous qualities, become obstructed and inflamed: the gangrene is circumscribed, and a line of separation formed between the dead and the living parts. If the mortification be superficial, the sloughs are generally thrown off between the ninth and thirteenth days: they leave a wound or ulcer which soon heals. If the whole of a limb be deprived of life, nature of herself is not sufficient to remove the dead parts, because she has too many obstacles to surmount; at least she can seldom overcome them. The resistance almost always surpasses her power, and the patient sinks in consequence of the absorption that takes place when the sloughs are detached, and suppuration has opened the mouths of the absorbents. This absorption affects organick life: a slow fever ensues, with colliquative diarrhoea: the gaseous exhalations from the gangerened parts disorder the organs of respiration, and concur with the matter that has been absorbed, in producing a general debility of the functions, and death. After some time, gangrene may pass immediately to the neighbouring parts; but this can never happen before the ninth or tenth day, when the sloughs fall off: the vessels and the cellular tissue are then prepared to absorb, but that does not always take place, and then the disease may remain stationary: it becomes defined, and the dead parts separate from those which retain their vital power and action, and the general functions are not disturbed. The dead parts fall off, the sores which are the consequence, soon heal up, and the patient recovers.

Larrey concluded his description of these phenomena with the assertion that he was quite positive that they never appeared until the temperature was suddenly raised "from a very low to a very high degree above zero." He was convinced that "partial or general death" cannot take place merely from the severity of the weather in persons subjected to the influence of cold for a long

period, "even until they are seized with asphyxia, unless a second sedative or narcotick cause act internally in concert with it."

Numerous instances were cited to support this theory. Thus, travelers who crossed the Alps and the Pyrenees during intense frosts did not suffer harm as long as the level of cold remained the same. Larrey had had this experience himself. The Polonese chose "the time of the most regular cold" to undertake long and difficult journeys from Siberia but avoided travel when the temperature was variable because, they told Larrey, they feared "the effects of congelation." In May 1788, while Larrey and his companions were in North America, they found at Belle Isle, near Newfoundland, a number of persons who had been shipwrecked and who had passed several days lying under the snow during a period of intense cold. The victims suffered no accidents during this period; but when the temperature changed, on the day of their rescue, two died suddenly and the feet of several others "fell into gangrene."

At the end of the winter of 1795, when Larrey was with the Army of the Eastern Pyrenees, numerous soldiers suffered from frostbite when an extreme degree of cold was succeeded by an elevated temperature. The suffering was most extreme in men whose feet had already been frostbitten at the siege of Rosés. During the preceding 15 to 20 days of "rigorous cold" and up until the time the thaw commenced, Larrey had observed no frozen limbs in any of the ambulances over which he presided. Within 24 hours after the change of weather, some of the more advanced sentinels were found dead at their posts.

Larrey also related instances of gangrene caused by "congelation" in other parts of Europe. During the conquest of Holland, for instance, as he was informed by M. Paroisse, first surgeon to the King of Spain, a great number of soldiers had their feet frostbitten. The men had long been exposed to snow and ice, but gangrene did not appear until the thaw commenced.

Still another experience concerned the army which left Madrid on 22 December 1808 to cut off the retreat of the English Army on the road to Corunna. The next 2 days were spent crossing the Guadarrama Mountains. It had been snowing for several days, and, at the foot of the mountains, the wind blew directly from the north and the temperature was 9° below zero R. (11.75° F.). As the men ascended the mountains, the cold, already piercing, became still more intense, and thick whirlwinds of hoarfrost and snow made a halt imperative. During the overnight halt, the temperature rose several degrees. When fires were kindled, Larrey continued:

> * * * they were more injurious than useful * * *. For all who subjected their hands or feet to the warmth of the fire, were suddenly affected with gangrene from congelation, to a greater or less extent. But this gangrene appeared in no case among those who avoided the fire. One of the soldiers of our *ambulance*, having had his right hand affected with the cold as he climbed the mountain, suddenly approached the fire of bivouac, and chafed his hand near it. It instantly swelled in a surprising manner, like dough when put into a hot oven. When he rejoined his *ambulance* some hours after, his hand was entirely sphacelated, and I was obliged to amputate it at the wrist. This fact supports the opinion on which I advanced relative to gangrene from congelation.

Cold, Larrey concluded in the light of these various experiences, is only the *predisposing* cause of gangrene, which can be averted by taking care to remain away from heat and to avoid subjecting parts "benumbed by the cold to its sudden action." The exciting cause is heat "* * * suddenly applied to the parts which have been rendered torpid by cold * * *. Let this principle be once established and it will be easy to prevent the effects of congelation."

Data on injuries caused by cold among Russian troops in the campaign of 1812 are scanty. They probably suffered severely, though not as severely as the French, because, according to Ariev,[6] they were already acclimated to the severe weather and they had some knowledge of the elementary rules for combating frostbite. These factors, he thought, exerted a protective influence, although Russian soldiers, like French soldiers, were hungry, tired, and poorly clothed and thus were subject to the very conditions which might predispose to cold injury.

Therapy.—Except for the warning against the sudden application of heat to the affected part, which is still sound advice, Larrey's methods of treating cold injuries are merely of historic interest. First aid consisted of friction with snow or ablutions with water in which ice had been dissolved. If snow or ice could not be procured, cold red wine or vinegar and camphorated brandy were substituted or the parts were immersed in well water. Full details were given for the management of gangrenous limbs, but amputation, it was emphasized, was always a last resort.

THE CRIMEAN WAR

Many of Larrey's observations were made on soldiers who operated under conditions of extreme cold and who were facing, and later experienced, a disastrous defeat. In the course of the defeat and the retreat which followed, a large part of the army was lost as a consequence of cold and intercurrent disease. The military cold injuries next recorded, in the Crimean War of 1854–56,[7] arose on a very different basis, in that the cold in which they were sustained was not extreme and the military circumstances were different.

During the first winter of the war, fighting in the Crimea took the form of dogged trench warfare, with relatively little change in the position of either side. The campaign was fought by inexperienced soldiers, who were handicapped by lack of supplies, clothing, and food. Diarrhea and dysentery were prevalent and were attended with a high mortality, and 1,924 cases of frostbite were reported. Mr. Dumbreck, of the First Regiment, did not find this surprising. "I consider," he observed, "that many of the cases of denominated gelatio, were in reality gangrene from debility, many of the men having been

[6] See footnote 2, p. 29.

[7] Medical and Surgical History of the British Army During War Against Russia in Years 1854-56. London: His Majesty's Stationery Office, 1858, vol. 2.

attacked when the thermometer was between 40° and 50° Fahrenheit." Dr. Longmore shared his views. The frostbite which occurred during 1854 and 1855, he stated, "could not be attributed to the severity of the climate, but was chiefly owing to the exceedingly depressed vital power which characterized the general condition of the soldier at that period."

It seems reasonable to accept the opinion of these observers that the frostbite which occurred in the British Army during the first winter of the Crimean War was not primarily caused by cold. Through October, the weather was rather mild. In January, it is true, snow fell and there was much "frost," but low temperatures, in themselves, did not seem to produce cold injuries. Many, on the contrary, seemed to occur as a direct consequence of exposure to wet, especially when the winds blew from the northeast. Periods of thawing seemed particularly likely to produce cold injuries, which were notably frequent when frost by night alternated with thaw by day. Men in the trenches, especially the most forward trenches, experienced protracted exposure under the most unfavorable possible conditions. They often had to stand knee-deep in mud and water as well as in snow. Their movements were restricted because of the vigilance of the enemy. Often, to protect themselves, they had to seek shelter in the bottom of the trenches, where the bad conditions under which they ordinarily existed were likely to be worse. They sometimes remained in such situations for 12 to 24 hours. In addition, their hands sometimes became gangrenous from handling "wet metallic substances."

The authors of the official history of the Crimean War recorded other deficiencies. The soldiers' boots were defective and quite unsuited for this type of operation. Often, they had been fitted in too small sizes, and the men were afraid to remove them for fear that they would not be able to replace them. Shelter and bedding were equally unsatisfactory. Tents were of single-thickness canvas, with flaps that were difficult to close. The allotment of blankets was one to a man. Straw, hay, reeds, boards, stretchers, and similar makeshifts had to be used for beds. Firewood to be used for the preparation of food was difficult to come by, and the partial inadequacy of nutrition was evidenced by the high incidence of scurvy. The chronic fatigue of the men, as well as the high incidence of diarrhea and dysentery, has already been mentioned.

It has already been pointed out that during the winter of 1854–55, in a force of slightly less than 50,000 men, there were 1,924 cases of cold injury, of which 457 (23.75 percent) were fatal. During the winter of 1855–56, there were only 474 reported cases, of which only 6 (1.3 percent) were fatal. Since weather conditions and precipitation were essentially the same in both years, one must look elsewhere for the explanation of the improvement in the second winter of the war. The clue is found in the medical records of the British experience, which describe two distinct types of cold injury. The first, which

was caused by cold in conjunction with debility, occurred during the first winter of the war. The second, which was caused by cold alone, occurred during the second winter. Furthermore, the high death rate recorded for the first winter was not the result of cold injury alone; it was caused also by enteric diseases and typhus fever, which often developed when the soldiers were hospitalized for their cold injuries.

The authors of the history of the Crimean War supply numerous details which explain the improvement in the second winter of fighting. During the summer, the troops in the Crimea regained most of their physical vigor and "ability to resist the affection." They were no longer the "raw unformed lads" who had made up a large part of the fighting force the previous winter. Instead, they were seasoned, hardened troops. While the type of combat action in the winter of 1855–56 did not differ greatly from the action in the preceding winter, men had to spend less time in the forward trenches. Finally, living conditions were better, food supplies were much more adequate, and the individual soldier had gained some understanding of how to protect himself against the cold.

A number of other perspicacious observations on cold injury are found in the official history of the Crimean War. It was the authors' opinion that even higher rates of injury might have been experienced had the type of warfare been mobile instead of static and had there not been opportunities of "receiving reinforcements from the seaboard." A reconnaissance in force made in the midst of a severe storm from which the men returned very cold and greatly exhausted is described in this history. The authors noted that, if Sir Colin Campbell and the officers of the regiment had permitted the men in this operation to rest and had not taken the precaution of keeping them constantly in motion, many more cases of frostbite might have resulted. British military surgeons were fully cognizant of the effect of alcohol in cold injury and remarked on the high rates in drunken men.They were also aware of the underreporting of cases, some of them mild cases and others more severe gangrenous cases associated with infectious diseases, to which death was likely to be attributed. Finally, the British surgeons noticed that there was a disproportionately larger incidence of cold injury in the Infantry then in the Cavalry and Ordnance. The relative strengths of these arms is not recorded, but the distribution of fatalities is significant—5 in the Cavalry, 27 in the Ordnance, and 431 in the Infantry.

During this same 2-year period (1854–56), according to Sonnenburg and Tschmarke (cited by Ariev), the 309,000 French troops in the Crimea experienced 5,215 cases of frostbite, of which 1,178 (22.6 percent) were fatal. Holmer, Hulke, and Florcken (also cited by Ariev), reported that during 2 consecutive nights in Sevastopol, 2,800 cases of frostbite occurred, of which 900 were fatal.

THE WAR OF THE REBELLION

The official history of the War of the Rebellion [8] does not describe frostbite as a distinct entity of medicomilitary importance nor are any statistics supplied for the incidence. It is possible, however, to derive some information from notes on amputations for gangrene attributable to frostbite or freezing, as well as from individual case histories under this heading.

A large number of the 15,273 "other accidents and injuries" not caused by combat were instances of frostbite. There were 1,075 fatalities in this group (7.03 percent). In 259 amputations of the leg, in which there were 78 known deaths and 180 known recoveries, 147 of the operations were done for fractures, 44 for frostbite, 17 for gangrene, and the remainder for various other accidents and diseases. Twenty-two of fifty-one amputations of the feet were required for frostbite. One amputation was performed for gangrene caused by wearing tight boots and another for hospital gangrene. In 122 amputations of the toes, there were 6 known deaths and 109 known recoveries. The indications for operation are stated only in the following case:

A 49-year-old hospital steward suffered frostbite of both feet when his tent blew down and his feet were exposed in intensely cold weather. Although he was immediately aware, on awakening, that the foreparts of both feet were frozen, he received no treatment until he was hospitalized a month later. Then, dry gangrene of the toes of both feet was present (fig. 17), with destruction of the soft parts. Although the patient was in good spirits and doing well, disarticulation of the toes was regarded as indicated. A year later, he was discharged from service for disability and was pensioned. Twelve years later,

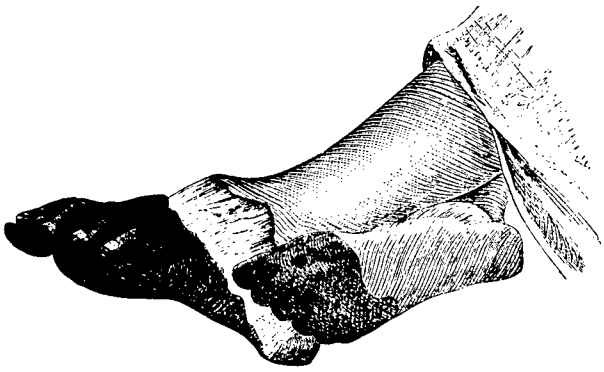


FIGURE 17.—Dry gangrene of toes of both feet, resulting from freezing, and extending on the left side to the metatarsal bones, with destruction of the soft parts.

[8] Medical and Surgical History of the War of the Rebellion. Surgical History. Washington: Government Printing Office, 1883, pt. III, vol. II, pp. 670-679, passim.

he appeared before an examining board, which certified to his condition as follows:

He has had all the toes of the right foot amputated through the metatarso-phalangeal articulation except the little toe, which is drawn into the cicatrix. The foot is defective in circulation and there are chronic ulcers of the leg extending from the ankle to within four and a half inches below the knee, being very offensive and requiring constant care and attention. This condition no doubt is due to anaesthesia of the foot and leg. The cicatrices extend around the leg and are constantly scaling. There is also varix above to a slight extent. The toes of the left foot were amputated at the tarso-metatarsal articulation, the stump showing a good horny cicatrix; hyperaesthesia of foot or stump; atrophy of leg; stump alleged to be painful during changes of weather.

OTHER WARS OF THE 19TH CENTURY

During the Franco-Prussian War of 1870, there were 1,450 cases of severe frostbite among 92,067 Prussian troops. Pirogov (cited by Ariev) observed 2,632 cases among 16,000 patients in the "gare de perruche" hospital, while in General Burback's military hospitals there were 610 cases in a total of 5,944 casualties.

During the Russo-Turkish War of 1877–78, 4,500 patients suffering from frostbite passed through the evacuation points in Jassy and Bendiara. These casualties represented 1.5 percent of the total Russian expeditionary force of 300,000 troops in Bulgaria and 5.1 percent of the 87,989 evacuated casualties.

THE RUSSO-JAPANESE WAR

The British medical observers attached to the Japanese Army during the Russo-Japanese War made a detailed report on the cold injuries sustained during the battle of Hei-kou-tai from 25 through 29 January 1905. According to MacPherson,[9] 300 men from one division and 205 from another were hospitalized for frostbite. Toke [10] stated that 300 men were hospitalized for frostbite and that 173 others, who were not hospitalized, also sustained cold injuries. It was additionally reported that about half of the men hospitalized for other causes during the period of this engagement were likewise suffering "more or less" from frostbite. Total casualties numbered 7,742, which makes the ratio of uncomplicated frostbite to battle wounds about 1:15. The toes were affected in 67 percent of the cold injury cases and the fingers in 28 percent, but the injury was usually mild and amputation of either fingers or toes was seldom required.

On 23 January, 2 days before the engagement began, the weather suddenly changed. The temperature fell to a low point, the relative humidity in-

[9] MacPherson, W. H.: The Russo-Japanese War. Medical and Sanitary Reports from Officers Attached to the Japanese Forces in the Field. London: His Majesty's Stationery Office, 1908, pp. 242, 349.

[10] Toke, R. T.: The Effects of Cold During the Battle of Hei-kou-tai, 25–29 January 1905. In the Russo-Japanese War. Medical and Sanitary Reports from Officers Attached to the Japanese Forces in the Field. London: His Majesty's Stationery Office, 1908, p. 201.

creased, and the wind began to blow from the north. Snow fell on 26 January, the second day of the engagement. The high humidity persisted, and the weather continued bad during the remaining days of the battle. Most of the casualties occurred on 27 and 28 January, and most of them occurred at night. The temperatures for the whole period ranged from a maximum of 17.8° F. (−7.9° C.) on 26 January to a minimum of −11° F. (−24° C.) on 29 January.

The British observers listed as predisposing causes of the cold injuries wet feet resulting from the penetration of melting snow through the stitching of the welts of the boots; constriction of the feet and interference with the circulation as the leather of the boots became hard and frozen; lack of food; the frequent night fighting, with resulting fatigue from lack of sleep; the inability of the men to move from their fixed positions in the snow, so that they had no way of stimulating the circulation in their feet; and their inability to light fires for warmth because of the close proximity of the enemy.

After the unfortunate experience at the battle of Hei-kou-tai, certain preventive measures were instituted and were practiced during the battle of Mukden. This battle was fought from 1 through 10 March 1905, in temperatures varying from a minimum of 0° F. (−17.8° C.) to a maximum of 53° F. (11.7° C.). The men were given extra socks and gloves, so that they could change them when those they were wearing became wet. Boots were well greased. When there were halts for any period of time, the boots were removed and were replaced by Chinese felt or straw shoes. Finally, each man carried in his pocket an issue of sugar, to eat when he lay in position; this was a measure in which Japanese medical men had great faith. During the whole battle, only 70 patients were admitted to field hospitals for frostbite, and most of these had other wounds. The excessive number of deaths in battle, however, was attributed in part to deaths from cold as the wounded lay on the battlefield before they could be picked up.

In contradistinction to the reports of the British observers which have just been cited, Ariev stated that the incidence of frostbite among Japanese troops was "staggering." To support his statement, he cited Lynch's report of between 1,200 and 1,600 amputations in a single month as the result of frostbite. Russian Army medical statistics, according to Ariev, show 1,021 cases of frostbite for the whole Russo-Japanese War; 410 of these were treated in hospital. Statistical tables from the same source record 1,469 cold injuries, of which 856 were severe. It was Ariev's opinion that the Russian incidence must have been higher than these figures indicate, since in the battle of Mukden alone there were well over a thousand casualties from this cause.

THE TIBET EXPEDITION OF 1903–4

Davys,[11] in 1904, recorded, without mentioning the exact number of cases, an experience with frostbite sustained during the winter of 1903–4 and during

[11] Davys, G. I.: Frost-bite in the Tibet Mission Force. Indian M. Gaz., 39: 245-247, July 1904.

the following spring, both by men who served with the Tibet Mission Force in the Chumbi Valley and by native inhabitants of the valley. The prime cause of the injury, Davys noted, was a combination of damp clothing and extreme cold. Simple dry cold was seldom a cause in itself, and the most serious lesions were, as in Larrey's experience, produced not by excessive cold but by carelessly applied heat.

Three degrees of cold injury were recognized: (1) Death of superficial layers of skin; (2) death of the whole thickness of the skin and sometimes of superficial fascia; and (3) death of deeper tissues, such as muscles and tendons. Examination of the patients during the first two (ischemic) stages revealed the affected parts to be cold, white, and painless. The third stage was characterized either by simple dry gangrene, or by moist gangrene, with which emphysema of the tissues was often associated.

Methods of treatment included putting the feet in cold water placed "near but not on a fire"; massage ("friction") to produce slow warming; and, in a few cases, wrapping the affected part very thickly in wool and bandages and placing it in a box of warm sand. All methods of warming, Davys warned, must be applied "*very* slowly." To prevent gangrene of the deeper tissues, he recommended that superficial dead skin be removed as early as possible; by this means, it was often possible to save fingers and toes which were apparently quite dead.

Connor,[12] while working in the Depôt Hospital of the 8th Gurkha Rifles at Shillong, treated some of the more severely injured men from the Tibet Mission Force for weeks and in some instances for months after the original injury. Like Davys, he emphasized the importance of extremely conservative surgery because he too found that dead, blackened skin was often only superficial and that the underlying tissues were viable. Connor also commented on the after-treatment of amputation stumps and recorded such sequelae as loss of tactile sensibility and "persistent stiffness of the adjacent joints."

In this connection, there might be quoted an unscientific but nonetheless significant observation on presumable cold injury in the British Army in India—"in the middle of the Tangi Pass it was"—at the turn of the century. Says Mulvaney, one of Kipling's famed "Soldiers Three":

> Our docthor, who knew our business as well as his own, he sez to me * * * "How often have I tould you that a marchin' man is no stronger than his feet—his feet—his feet," he sez. "Now to the hospital you go," he sez, "for three weeks, an expense to your Quane, an' a nuisance to your counthry. Next time," sez he, "perhaps you'll put some av the whiskey you pour down your throat and some av the tallow you put into your hair, into your sock," sez he. Faith, he was just a man!

[12] Connor, F. P.: Notes on Some Cases of Frost-bite. Indian M. Gaz., 39: 365-366, October 1904.

THE BALKAN WARS

According to Page,[13] large numbers of Turkish troops suffered from cold injury in the First Balkan War in the latter part of 1912, particularly near Tchatalja. Precise figures are not available, but it is known that the death rate was high, especially in men with the moist, spreading type of gangrene and in those who also had enteric disease or whose injuries were complicated by tetanus. The gangrene was symmetrical and practically always involved the feet; the fingers alone were seldom affected. The lesions varied from mere discoloration and blister formation of one or two toes to death en masse of the leg to the knee.

The temperature of the area in which the injuries were sustained was usually about 41° F. (5° C.). Page's opinion was that the trauma produced a vasomotor disturbance; but he advanced no explanation which would cover all cases, other than exposure to weather for long periods, frequently in wet trenches, combined with generally insufficient rations. About half of the men had enteritis. Their footgear varied. Some, but by no means all, had been wearing boots and puttees of the European type, and Page granted that in some instances they were tight enough to predispose to gangrene. He was unwilling however, to accept, at least in a universal application, Depage's theory that the pathologic process could be explained by compression from the puttees, which underwent shrinkage as they dried, though Dreyer, who reported on 31 cases observed in the German Hospital in Constantinople, was of Depage's opinion. A valid argument against this theory was that many of the Turkish soldiers who suffered frostbite wore the usual loose native footwear. The theory that gangrene was caused by the eating of infected rye bread could also be dismissed. The affected troops had had very little of this bread, for one thing, and, for another, there was a complete absence of this type of gangrene in the local population before the war, although the suspected rye bread had been a prominent article of diet in the area.

Page was familiar with the history of gangrene following frostbite among British troops in the Crimean War and regarded it as comparable to the gangrene observed in the Balkan war. Apparently, however, he did not consider the two conditions to be the same processes, nor did he seem to realize that, in both, cold and wet were the primary causative factors. This is curious, since both he and Dreyer agreed that in this type of gangrene, just as in frostbite, the arterial circulation of the affected men had been so impaired by starvation and fatigue that a temperature above freezing was able to produce stasis in the peripheral vessels. Page noted, but did not comment on, the fact that frequently soldiers dated the development of gangrene to the time of their arrival in the hospital for treatment for some other injury or disease. Often, the gangrenous process was clearly of much longer duration, and it seems not

[13] Page, C. M.: Gangrene in War. Brit. M. J. 2: 386–388, 30 Aug. 1914.

unreasonable to postulate an aggravation of the vascular disturbance when a warmer environment was reached.

Ariev cites a number of other observations on the high incidence of frostbite in the Balkan wars of 1912–14: Meyer and Kohlschutter reported on 150 cases, all terminating in gangrene, and Wieting recorded 300 cases. Kosogledova, who reported 400 cases, stated that at one time no less than 2,000 casualties from frostbite were in Sofia and that whole trainloads of other men with this type of injury were en route to base hospitals.

WORLD WAR I

The British Experience

Cold injury is recorded in considerable detail in the official British history of World War I [14] as well as in the large periodical literature of the war years.[15] It should be noted again that up to this time, except for the classic description of cold injury by Larrey (p. 30) during the Napoleonic Wars and the briefer but equally careful observations of British medical officers during the Crimean War (p. 36), there had been no critical appreciation of the military significance of this type of injury.

That the British had not fully profited by their experience in the Crimean War is indicated by the high incidence of cold injuries in their expeditionary forces in the first winter of World War I. At this time, in spite of Larrey's emphasis upon this combination of causes, the role of wet in conjunction with moderate temperatures was not clearly understood, as is evident from the nomenclature employed for cold injuries early in World War I. All through the first months of the war, these injuries were reported as frostbite, water bite, footbite, cold bite, puttee bite, trench bite, N.Y.D. feet, chilled (or cold) feet, effects of exposure, or merely as "feet cases." It was not until after the first winter of fighting that the term "trenchfoot" began to come into general use. Although trench warfare was the exception in World War II, the term was retained in it, partly for lack of a better one and partly because its implications were so generally understood.

In spite of their lack of experience with cold injury, British Army surgeons and nonmedical military officers alike promptly realized the enormous military significance and the potential loss of manpower from trenchfoot, as well as the

[14] (1) General History of the Medical Services. Hygiene of the War. London: His Majesty's Stationery Office, vol. 2, 1931. (2) See footnote 3, p. 29. Except as otherwise indicated, all data concerning the British experience in World War I are derived from Grattan's chapter on trenchfoot in History of the Great War Based on Official Documents.

[15] (1) Lawson, C. B.: Frost-Bite. Brit. J. Surg. 2: 703–705, April 1915. (2) Frost, H. M.: Trench-Foot. Boston M. & S. J. 176: 301–304, 1 Mar. 1917. (3) Trench Foot by a Military Observer. Mil. Surgeon 41: 598–609, November 1917. (4) Hughes, B.: The Causes and Prevention of Trench Foot. Brit. M. J. 1: 712–714, 20 May 1916. (5) Delepine, S.: The Prevention of Frost-Bites. Lancet 1: 271–272. 6 Feb. 1915. (6) Johns, F. A.: A Note on the After-Treatment of So-Called "Frostbite." Brit. J. Surg. 4: 336–337, October 1916. (7) Levick, G. M.: Electrical Treatment of Muscles in "Trench Feet." Brit. M. J. 1: 370–371, 30 Mar. 1918. (8) Moynihan, B.: Frostbite (correspondence). Lancet 1: 401, 20 Feb. 1915.

strictly financial consideration that these casualties, quite as much as battle casualties, would be entitled to pensions. Three points were generally emphasized in the first reports: (1) The number of men permanently lost to combat from this type of injury; (2) the amount of time lost from service by the men eventually able to return (in mild cases, 2 to 3 weeks and in more severe cases, 5 to 7 weeks or sometimes much more); and (3) the possibility of recurrence in men sent back to the same environment in which their original injuries had been sustained.

The high incidence of cold injury and the long duration of the hospital stay, which often reached several months, both proved the intractable nature of injuries caused by cold and their impact upon military campaigns.

Incidence.—Cold injury began insidiously among British troops in France and Belgium in the first months of fighting in World War I. The incidence of frostbite, as it was then termed, rose from 1 case in August 1914, 1 in September, and 11 in October, to 1,555 in November and 4,823 in December. In December, the term "trenchfoot" first appeared in the medical reports, though only eight cases were so listed.

All of the cases reported as frostbite from August through December, inclusive, were cases in which cold injury was the only injury or disease present. Over the same period, frostbite was reported in association with rheumatism (306 cases), myalgia (69 cases), bronchitis (22 cases), and gunshot wounds (170 cases).

The highest incidence of cold injury was among infantrymen. Officers had a somewhat lower rate of occurrence than enlisted men. Indian troops as well as Europeans were affected.

According to official records,[16] the total cases of frostbite and trenchfoot for the whole war, in all theaters of operations and all bases, including the United Kingdom, numbered 115,361. During 1915, when frostbite and trenchfoot were differentiated in the returns (as they were not thereafter), there were 30,691 hospital admissions for frostbite and 29,172 for trenchfoot. Total cold injuries treated in hospitals in France and Flanders, practically all of them in the first 2 years of the war, amounted to 97,414 cases. Only 443 cases were shown on hospital records during 1916–18.

Reports of individual observers [17] during the first months of the war are as significant as are the mass statistics. Thus Lawson recorded that, over a 6-week period, 1,131 men with frostbite were admitted to a single hospital in Rouen. Gangrene was present in 24 of 180 cases which he treated personally. Frost mentioned 120 cases in a convoy of 160 casualties received at the Meerut Stationary Hospital in Boulogne. A military observer wrote in the *Military Surgeon* for November 1917 that 400 men in a single British battalion, many of whom later required amputation, had been disabled from cold injury in 48 hours.

[16] See footnote 14 (1), p. 42.
[17] See footnote 15 (1), (2), and (3), p. 42.

Weekly divisional records for the First British Army from 12 December 1914 to 28 February 1915 are indicative of what happened as trenchfoot gradually came under control. For the first week of this period, 579 cases were recorded, and 530 cases were recorded for the third week. By the eighth week, the number had fallen to 70 cases, and only 63 were recorded for the last week. The total for the 10-week period was 3,013 cases. While the incidence of trenchfoot was thus decreasing in the First Army coincidently with the institution of "strong disciplinary measures," cold injury continued to occur in large numbers in the Second British Army, which was then fighting in the Ypres salient.

Frostbite case rates per 1,000 strength in France and Flanders were 33.93 for 1914 and 27.50 for 1915.[18] Trenchfoot case rates for the same years were, respectively, 33.97 and 38.43. Thereafter, the case rates for cold injury fell progressively to 12.82 in 1916, 11.34 in 1917, and 3.82 in 1918. Death rates per 1,000 in Europe ranged from a maximum of 0.06 in 1914 to zero in 1917 and 1918.

The statistics for cold injury in the British forces in the Middle East are far less reliable than those for the Western Front. Many of the available sources for the winter of 1915 in Gallipoli are diaries, which merely state that "many" or "several" cases were observed. In the Dardanelles,[19] for the period April 1915 to January 1916 inclusive, there were 14,584 admissions for cold injury, of which 6,602 were for frostbite and the remainder for trenchfoot. For the 10-month period, the frostbite case rate was 56.39 per 1,000 average strength and the trenchfoot case rate 68.18.

In Macedonia, from October through December 1915, there were 1,014 cases of frostbite and 1,125 cases of trenchfoot. The frostbite rate for this year was 16.65 cases per 1,000 average strength, against a rate of 18.48 cases per 1,000 average strength for trenchfoot. In subsequent years, the trenchfoot rates fell to less than 2 cases per 1,000 average strength. Weekly admissions to medical units were recorded only for the period from 25 March 1916 through 1 June 1918. During this time, there was a total of 43,838 admissions for cold injury, in 38,298 of which (87.36 percent) evacuation to the base was necessary.

Death rates for the campaign in Macedonia are not available. In the Dardanelles in 1915, the death rate for frostbite was 0.58 per 1,000 and for trenchfoot 0.67. These rates are approximately 10 times as high as the highest rates reported from Europe. It is interesting to speculate on the possible role of intercurrent diseases, especially dysentery, in the production of the higher rates in the Middle East.

Diagnosis.—When trenchfoot once began to be carried in mind as a possibility in British troops, its diagnosis seldom presented any difficulty. The circumstances of the injury, the characteristic symptoms of swelling, pain, and disturbances of sensation, and the physical findings, including color changes and edema, seldom left any doubt about the nature of the lesion. The occur-

[18] See footnote 14 (1), p. 42.
[19] See footnote 14 (1), p. 42.

rence of nocturnal pain was extremely significant. More than one observer suggested that if it was suspected that the man might be malingering, a tour of the wards at night would often provide the answer; if the patient was awake, sitting up in bed, and even crying with pain, there was no question about the genuineness of his diurnal complaints.

Prevention.—The methods of prevention employed by the British in World War I [20] were, in their fundamentals, the same as those they employed so successfully in World War II (p. 202). Because only a few medical officers had had previous experience with injuries caused by cold, these measures as well as the whole program of control had to be organized hastily, though they were ultimately developed methodically. They consisted, in essence, of (1) the maintenance of the men in as fit condition as possible; (2) the exercise of as wide hygienic control over the troops as was compatible with the conditions of trench warfare; (3) measures to protect the feet and legs from wet and cold and to keep the men as warm, as dry, and as clean as was possible under the circumstances; and (4) measures to improve the condition of the trenches. Provision of hot food for men in the trenches was always an important feature of the program.

Eventually, as the program developed, great emphasis was placed upon the supervision of troops by unit commanders. The records of all units were scrutinized daily and weekly to detect any rise in the incidence of trenchfoot; increases called for an explanation and sometimes for an investigation. Supervision of this kind was found to be indispensable and was strictly enforced when once it was realized (1) that even mild trenchfoot, without blister formation or gangrene, removed the soldier from service for weeks or months, and (2) that men who had sustained one attack of cold injury were much more susceptible to another attack. The solution of the problem was therefore twofold: (1) For the individual soldier to make a fine art of the toilet of the feet, and (2) for his leaders to see that he did so.

In December 1916, the Director General of Medical Services for the Western Front issued instructions that thereafter all patients with trenchfoot should receive tetanus antitoxin, whether or not the skin was broken. The same instructions had been issued the previous winter by the Director of Medical Services in Macedonia.

Therapy.—No really successful method of treatment of trenchfoot was ever developed by British medical officers in World War I. Furthermore, many of the methods used were empirical, particularly at the beginning of the outbreak in 1914 because most medical officers were entirely unfamilar with the condition. Lawson [21] relates what was probably a typical experience. When the first 63 casualties from trenchfoot were suddenly received in a British hospital in France on 23 November 1914, no one had any idea what to do for them. The following day, Lawson himself happened to remember that he had once read in Rose and Carless' Textbook of Surgery that Indians, lumbermen, and pros-

[20] See footnote 14 (1), p. 42.
[21] See footnote 15 (1) p. 42.

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pectors in northwest Canada treated cold injury by the liberal use of oil of turpentine. This method was at once applied to these military casualties; when the blebs broke and the pure oil proved too irritating, it was diluted with lanolin. Lawson reported excellent results, stating that when toxemia developed it was almost invariably found that the oil had not been assiduously applied. Nothing else seems to have been written about this special method, and many other equally empirical methods are mentioned only in single reports.

Among the numerous agents used at one time and another for local applications, with or without massage, were alcohol in various strengths; mercuric chloride (0.2 percent) in alcohol; chloral hydrate and camphor; carbolic acid (1:40) and camphorated oil; camphorated oil alone; tincture of iodine; picric acid; oil of wintergreen; evaporating solutions such as lead and opium; and dusting powders containing starch, zinc, boric acid, and salicylic acid. Elaborate methods of massage, radiant heat, and various kinds of electric stimulation were used in the later stages of trenchfoot.[22]

In February 1915, Moynihan [23] called attention to the pain inflicted in trenchfoot by the application of various ointments and liniments. Apart from the degree of pain which they caused, he said, there was no appreciable difference between one form of treatment and another. It was his opinion that the pain, which was always the outstanding complaint and which was sometimes so severe as to require morphine for relief, was not caused so much by actual damage to the tissues as by the general practice of wrapping the feet in bandages and wool; the discomfort, in fact, was almost exactly proportionate to the degree of warmth achieved. When the bandages and other wrappings were removed, men who had previously suffered nights of torture had relief within a few hours. Since progress toward recovery was practically always at the same rate, regardless of the method of treatment, it was Moynihan's feeling that relief of pain during healing should be the chief consideration. It therefore became the practice in the Rouen hospitals after this time (February 1915) to elevate the affected feet a few inches on a hard pillow and to cover them only with a thin layer of gauze and a sheet.

Eventually, a plan of treatment along much these general lines became standard practice for British casualties with trenchfoot.[24] The injured foot was carefully and thoroughly washed with soap and water, an antiseptic lotion was applied, and the skin was painted with a 1-percent solution of picric acid. In mild cases, additional treatment consisted only of bed rest, with the feet slightly elevated. If the feet were red and hot, they were left exposed, with all dressings omitted. If they were cold and numb, they were wrapped in cotton wool, which was removed at intervals so that they could be rubbed. If blistering was extensive, the bullae were punctured, and the feet were coated with ambrine or some other preparation of paraffin wax. Salicylates were used in large dosages for the control of pain. In the later stages of mild trench-

[22] See footnote 15 (6) and (7), p. 42.
[23] See footnote 15 (8), p. 42.
[24] See footnote 14, p. 42.

foot, the application of a high-frequency current together with massage was thought to be beneficial.

Immediate amputation was never considered justified, even when gangrene was evident, since even the early experience showed that in the majority of cases the part could be saved. In the moist type of gangrene, fairly prompt amputation was sometimes required, but, in the dry type, it was the practice to wait for a line of demarcation. Amputation through the leg was seldom necessary, since the Syme operation was usually practiced, even in severe cases.

The United States Army Experience [25]

Since the United States Army in World War I had little experience with trench warfare in cold weather, it had a correspondingly limited experience with trenchfoot. Most of the fighting in the trenches occurred at a time of year when exposure to combined cold and wet was not great. Noneffectiveness from this cause was therefore never important in the American Expeditionary Forces.

The majority of cases of trenchfoot occurred during the Meuse-Argonne operation, in October and November 1918, when fighting continued day after day for several weeks until the soldiers were exhausted as well as chilled and wet. It was difficult to bring relief troops forward; and the men, in addition to being without shelter and heat, suffered for lack of dry clothing and proper shoes.

With this exception, the majority of cases of trenchfoot observed in American troops in overseas hospitals arose from conditions not connected with trench warfare and would probably, in the absence of the previous British experience, have been diagnosed as chilblains or frostbite. Most of the lesions diagnosed as trenchfoot actually were instances of frostbite with minor grades of inflammation and with some ulceration and abrasion of the waterlogged skin. The deep sloughing and gangrene characteristic of much of the trenchfoot experienced by British troops in the first winter of the war were seldom observed in American troops.

Incidence.—The official history of the Medical Department of the United States Army in World War I [26] lists a total of 2,061 admissions for trenchfoot, including 27 among officers. Sixty-seven admissions, one an officer, occurred in training camps and other installations in the United States and Alaska. Most of the remaining admissions occurred in Europe.

The peak number of cases, as already mentioned, occurred in the fall of 1918, during the Meuse-Argonne offensive. The hospital-admission rate per 1,000 troops per annum was 0.50 for the whole Army and 1.17 for the troops in Europe, where the rate for officers was 0.35, and for enlisted personnel 1.21.

[25] Weed, Frank W.: Trench-Foot. *In* the Medical Department of the United States Army in the World War. Washington: Government Printing Office, 1925, vol. XI, pt. 1, pp. 290–293. Except as otherwise indicated, all data concerning the United States Army experience in World War I are derived from this source.

[26] Medical Department of the United States Army in the World War. Statistics. Medical and Casualty Statistics. Washington: Government Printing Office, 1925, vol. XV, pt. 2, passim.

The loss from trenchfoot for all classes of personnel in the United States Army amounted to 97,219 days, an average of 47 days per case. In Europe, the total loss was 92,249 days, an average of 47 days per case. The average loss of time for officers was 29 days; for white enlisted men, 49 days; and for colored enlisted men, 68 days. On the Western Front, the average loss per admission for enlisted men of all races was 48 days.

Prevention.—The United States Army in World War I, partly because of the comparatively favorable circumstances under which it fought and partly because it had the advantage of the previous British experience, did not have to learn by its own experience that trenchfoot can be prevented. In General Orders No. 11, General Headquarters, American Expeditionary Forces, issued on 17 January 1918, the causes were outlined, the prophylactic measures to be employed by American troops were fully described, and organization commanders were charged with responsibility for their implementation.

The predisposing and exciting causes of trenchfoot were grouped in General Orders No. 11 under two headings: Hygienic causes and causes of circulatory interference. Under hygienic causes were listed the existence of systemic disease; insufficient food, particularly the lack of hot food; insufficient sleep and comfort; and too infrequent changes of shoes and socks, which permitted the accumulation of bacteria-laden secretions and the consequent maceration of the skin of the feet. The causes of interference with the circulation were listed as the wearing of tight shoes, socks, leggings, puttees, and breeches; long-continued standing or sitting without exercise and with the feet and legs in strained positions; and prolonged exposure of the feet to the effects of cold and wet.

Commanding officers of all units were held personally responsible for seeing that the following routine was carried out under the personal supervision of commissioned officers:

1. Provision of clean, dry, well-fitting woolen socks, with further provision for replacements and laundry, sufficient to insure each man at least one change daily. The socks were to be pinned to the breeches with safety pins. Garters were prohibited.

2. Provision of not less than one change of shoes or boots for each man. The shoes were to be in serviceable condition, well fitted, thoroughly greased, and large enough for woolen socks to be worn with them.

3. Provision "at all times" of suitable rooms for drying footgear and other clothing.

4. Prohibition of the wearing of rubber boots for longer than a few hours at a time. Neither puttees nor leggings were to be worn under them. The disadvantages of this form of footgear were to be explained to the troops, who were to be shown also how to care for the boots after they were removed.

5. Provision, whenever possible, of a dry environment, even though it amounted only to trench drainage and the use of duckboards.

6. Vigorous rubbing of the feet with animal fat at least once daily.

7. Active foot exercises, supplemented from time to time by removal of shoes and socks so that the feet could be dried and massaged.

8. Regular inspections of the feet by the officers, to detect corns, ingrown nails, blisters, and inflammations. Men with such lesions were to be referred at once to a medical officer.

9. Inspections by company commanders before troops moved into forward areas, to be certain that all the provisions just listed had been complied with. At this time, the men were also to be warned against winding their puttees too tightly, since it had been found that a shrinkage of 3 percent occurred when dry puttees, which had been applied according to regulations, became wet.

10. Suitable arrangements for provision of hot food and drinks so that all men in forward areas had at least two hot meals daily.

The orders issued on 17 January 1918 also contained information about how to secure the various instructions and equipment necessary for carrying these orders into effect. Plans for improvising and constructing field cookers, kitchens, clothes driers, and other special equipment were to be furnished upon application to headquarters. Foot powders, oils, greases, and ointments were to be furnished by the Medical Department. Supplies for the lubrication of shoes and boots were to be secured from the quartermaster. Responsible officers were directed to prepare the necessary requisitions for these various items without delay.

For the most part, these policies remained unchanged throughout the war. The only important alteration was that whale oil and grease in general came to be looked upon with disfavor, since the coating which lubricants formed held back secretions and encouraged maceration of the skin. It therefore became the practice to use these agents only when gum boots were not available or when they had to be worn for unusually long periods of time.

Ashford [27] provided a significant account of the real value of these measures. In September 1917, shortly before he assumed the duties of commandant of a corps training school for American medical officers, he made a visit of a few hours to the French Sanitary School, and, just before he left, was briefed on trenchfoot by Col. Victor Raymond, of the Service de Santé of the French Army, who also provided him with the brochure he had written on the subject. This, wrote Ashford, "was the first notion I had had of the disease." The remainder of the story seems worth quoting in detail:

> A training school for line officers was established in the damp October chill * * *. Our division had arrived in July at their training area, and as most of us had been serving in tropical or subtropical countries we had little idea of the climate of the Haute-Marne. The army was just organizing, and we had little transportation and comparatively little wood for fires. A barrack cantonment for the line school sprang up overnight in a beautiful meadow, which in forty-eight hours became a sea of mud. The temperature ran between zero and 10° C. There had been no time to construct drying rooms. It rained for forty days and forty nights with persistence, and men and officers were so intent upon learning, that they forgot mud, water, and cold and trudged about all day with wet feet without sufficient means for drying their shoes at night. The result was that every one in a few days had all their foot-wear muddy and soaked through, and were obliged to put on wet shoes in the morning. A battalion on duty at this camp, a half mile from the town, were

[27] Ashford, B. K.: Trench Foot: Its Treatment. War Med. 2: 717-724, December 1918.

engaged in construction and were constantly wet through. From the very first, the commanding officer had been going to great lengths to secure fuel and to prevent the effects of exposure; but before anyone had time to do anything, the camp surgeon, on the first day I was given medical supervision over this camp, called my attention to a prevalent affection of the feet of the men working there, as well as of the student officers. These men had not been in the trenches, but the surgeon stated that the clinical picture resembled what he had seen described somewhere as "trenchfoot", and called me to go over the situation. By that time the battalion was seriously crippled by a large number of men who were actually unable to walk with any degree of comfort. I went over this organization, man by man and found that a good twenty-five percent had what they called "chilblains." One or two men had gone to the hospital with beginning necrosis, and those in quarters at the camp, as well as many still trying to do duty, were in the first or second stage of the affection.

That same day Colonel Raymond's brochure was abstracted, particularly that part relating to prophylaxis and treatment; efforts were redoubled, and this time with success, to provide more fuel; and the condition was reported to the Chief Surgeon with the diagnosis of trenchfoot, one of the first, if not the very first, made in our Army. Telegraphic authority was requested, and promptly obtained, for a good supply of whale oil, camphor, borate of soda, and green soap, secured in open market, and within three or four days the outbreak had declined as suddenly as it had appeared.

I have detailed the conditions under which the affection appeared, because the sudden and severe onset was evidently precipitated by those conditions, and troops who have to live under them here do not have to be in trenches to reap the results of exposure to moderate cold, with constantly wet and muddy footwear. The disease made its appearance under the very conditions considered by Raymond as favoring its development. It was a short lesson, but a striking one, at a propitious time for the American Army, and thanks to the energetic action of the Chief Surgeon of the American E. F. in acquainting the entire Army with its prevention and cure, it has never shown its head since as an important source of invaliding of soldiers.

In the meantime, we had personally followed the cases and had carried into effect the prophylaxis. In all, about 300 cases of some 1,000 strength were treated, all of which were promptly and completely cured without loss of tissue. In fact, not over three men had beginning necrosis, 15 percent blisters, and the rest merely the edematous, or first stage. The most notable result was seen in the rapid return to normal of all treated by the camphor and sodium borate fomentations. In forty-eight hours they were usually free from symptoms and ready for duty.

Ashford then quoted the first circular on the subject issued by the Army School, which contained essentially the same recommendations as those in General Orders No. 11, though in a few instances they were even more specific:

(1) The daily examination of the feet in each squad by squad leaders * * *. (2) The daily massage of the feet with camphorated oil * * *. This was to be done in the presence of the squad leader * * *. (5) Furnishing of well-fitting shoes, presence of officers during issue of same * * *.

When, about this time, a nearby division received orders to go into the trenches for the first time, the men were enjoined to carry out the provisions of the circular just cited and were also given special instructions for prophylaxis in the trenches. Again the instructions were somewhat more specific than those contained in General Orders No. 11. Among other things, the men were warned to exercise their feet and toes from time to time, "and always as often as possible if numbness should be perceived." They were also warned against warming affected feet before the fire.

These measures, Ashford stated, saved the division from "the fate of the training school," in addition to cutting short the outbreak in the school itself. Practically no cases were reported in the division, "although much worse predisposing conditions prevailed."

Therapy.—The treatment of trenchfoot in the American Expeditionary Forces was based chiefly on methods proposed by Raymond and Parisot of the French Army Medical Service.[28] The essentials were set forth in Memorandum No. 4, Army Sanitary School, American Expeditionary Forces, in the fall of 1917. The type of treatment depended upon the stage of the injury at which the patient was seen.

1. During the edematous stage, the feet were first bathed with green soap and water. Hot fomentations of camphor (1 part), sodium borate (15 parts), and boiled water (1,000 parts) were then applied. Finally, gauze compresses were applied, well above the upper limits of the edema, and were covered with some impermeable material such as oiled silk or oiled paper. Ashford reported that this treatment provided such prompt relief from pain that men previously unable to rest often fell asleep at once. He also recommended potassium iodide, which he said had almost a specific action in relieving the pain of trenchfoot.

2. In the second, or blister stage, treatment began with the excision of all blisters larger than one-half inch in diameter, after which their gelatinous bases were gently wiped with pledgets of sterile cotton. The application of compresses of camphor (30 parts) and ether (1,000 parts) was followed by the use of fomentations, as in the edematous stage. After edema had disappeared, treatment with camphorated ether was continued.

3. Sloughs, which occasionally formed in spite of these measures, were loosened by the application of compresses of camphor and ether and fomentations of alkaline camphor until access to the affected tissues beneath was possible. An acceptable variation was the use of the paraffin footbath, in which the affected feet, wrapped in cotton batting, were immersed for 30 to 60 minutes in a small footbath filled with paraffin heated to 140° F. (60° C.) or higher. When the feet were removed from the bath and exposed to the air, the paraffin taken up by the cotton batting hardened and the patient had what amounted to a pair of paraffin sabots. Treatments were given daily.

Surgery was conservative and limited to hard sloughs. These were incised down to the grumous layer, after which compresses were applied. "Blood letting" was avoided, and the cautery was not used.

Ashford warned that feeding soldiers with trenchfoot was an essential part of treatment, since they were apt to be weak, malnourished, and exhausted. He also warned that trenchfoot predisposes to tetanus and that failure to administer tetanus antitoxin to all patients who had passed beyond the first stage and to repeat the injection every 8 days until the lesion looked healthy, would certainly result in some preventable deaths.

[28] See footnote 25, p. 47.

Other Experiences in World War I

According to Tuffier (cited by Ariev), the 79,465 cases of trenchfoot in the French Army in World War I accounted for 3.02 percent of all battle casualties. There were 170 fatalities from trenchfoot. According to Mignon (also cited by Ariev), the average number of cases of trenchfoot per year was more than 30,000. Records, however, support this statement only for 1916, when there were 31,051 cases; 17,026 cases were recorded in 1915, and 15,870 in 1917. The French offensive at Verdun, which began on 15 December 1916, is known to have produced more than 3,600 cases; 1,869 cases occurred in a single division, the 38th, which had 1,971 battle casualties. French Senegalese troops fighting on the Aisne sustained 1,225 cold injuries between 15 and 17 April 1917.

The Italian Army, according to Bonomo (cited by Ariev), had almost 38,000 cases of frostbite during 1915–18. The Belgian Army seems to have had few casualties from this cause.

Statistical records of frostbite and other cold injuries are not available for the German Army in World War I, but the scope of the problem may be gathered from the fact that special hospitals were set up for the treatment of these injuries and that staff positions were set up in other hospitals for surgeons who specialized in their treatment. According to Schade (cited by Ariev), there were 12,848 casualties caused by cold injuries in a total of 500,000 sick and wounded in 1914 and 1915.

THE SPANISH CIVIL WAR

Trenchfoot does not seem to have been reported in any of the numerous hostilities which occurred between the close of World War I in 1918 and the outbreak of World War II in 1939. Ducuing, d'Harcourt, Folch, and Bonfill,[29] who made an extensive study of cold injuries during the Spanish Civil War, stated that they had seen nothing precisely comparable to the type of trenchfoot observed in World War I, although they had observed numerous cases which resembled it at some special time in their evolution. The troops who were chiefly affected were operating on the Sierra Palomera, then covered with snow, and were exposed for several days at a time. About 500 men were treated weekly for cold injuries of the lower extremities in a total exposed force of about 120,000, which gives a weekly rate of approximately 4.16 per 1,000 average strength and an annual rate of 216.32 per 1,000 average strength. This is very high in comparison to United States Army rates in World War II.

During the period covered by their observations, Ducuing and his associates also observed 10 cases of simultaneous freezing of the upper and lower extremities and 5 cases, all fatal, of total freezing.

[29] Ducuing, J., d'Harcourt, J., Folch, A., and Bonfill, J.: Les Troubles trophiques des Extrémités Produits par le Froid. Sec. en Pathologie de Guerre. J. de Chir. 55: 385-402, May 1940.

ETIOLOGIC CONSIDERATIONS

Although the theories of etiology advanced to explain cold injuries in the wars prior to 1914 have already been mentioned, it might be well to summarize them briefly. Larrey (p. 30) stated unequivocally that cold per se was merely the predisposing, not the exciting, cause; that the condition was not caused by a freezing temperature but occurred during a succeeding period of mild weather or in the course of a thaw; and that heat, suddenly applied, would promptly bring on gangrene from "congelation." Davys (p. 39), in recording the experiences of the Tibet Mission Force in 1904, also emphasized that the most serious results of cold injuries could be explained by carelessly applied heat, not by excessive cold. Page (p. 41), who compared the Balkan experience with that of the Crimean War, believed that gangrene which followed cold injury was on a vasomotor basis and could be explained by the effect of cold on an arterial circulation already impaired by starvation and fatigue. He pointed out that under these circumstances temperatures above freezing could cause tissue damage. He noted, but did not enlarge upon, the fact that in many instances the first complaints related to the extremities came after the men had been hospitalized. Their pain was very marked during the "period of reaction." Page granted the possible influence of tight boots and puttees in some cases but was unwilling to accept constriction as a universal explanation. Numerous early observers called attention to the possible indirect effects of hunger, exhaustion, and concurrent wounds and illness.

The realization that cold injuries could not be explained entirely by cold came early in World War I. In the first months of that war, British troops were obliged to march miles along wet and muddy roads in order to reach the entrance to communications trenches. When they arrived, cold, soaked to the skin, and already fatigued, they had to expend an immense amount of additional energy marching along the wet and muddy trenches to reach the forward trenches. Once they reached their station they were never really warm, dry, and comfortable until they were relieved; and that, in the early winter of 1914, might be a matter of weeks. Meantime, they remained almost immobile, in cold and mud, frequently in the rain, but not in freezing temperatures. The special correspondent in northern France [30] wrote in the *British Medical Journal* for 26 December 1914:

> The temperature so far has never been really low; in fact, there has never been more than a few degrees of frost for a limited number of hours, mainly at night. In all probability the actual temperature of the air at any given moment is only one of several factors in the production of the condition * * *. Apart from actual frost, the factors in question appear to be the soaking of the men's boots and socks either in freezing water or a mixture of mud and slushy snow, the absence of any local output of muscle heat owing to the fact that the men are standing still, and some tightness of their boots owing to the men putting on two or three pairs of socks which are thick even when dry and thicker still when wet. [Cottell [31] had previously made a similar observation about the wearing of extra socks.] With their legs

[30] Frostbite (The War). From a special correspondent in northern France. Brit. M. J. 2: 1115, 26 Dec. 1914.
[31] Cottell, A. B.: Frost-bite. Brit. M. J. 2: 992, 5 Dec. 1914.

thus chilled in advance, and the whole local circulation already reduced to a very low ebb, it is comprehensible that here and there in superficial areas it should be arrested for a time altogether. The usual history of these cases is that a man who has just got into his dug-out after standing for an hour or more with his rifle on the deck, has seen his way to a good rest and consequently has taken off his boots. On doing this he has noticed nothing the matter with his feet but subsequently has found that they have become so swollen that, apart from any question of pain, to get his boots on again is quite impossible.

In December 1915, Sir William Osler [32] called attention to another important cause of trenchfoot. The venous stasis which is the anatomic background, he wrote, is not simply the effect of cold, wet, or both. The feet may be aglow after a 10-mile tramp in snowshoes with the thermometer 20° below zero; and men actively at work on big lumber rafts in Canada have cold, wet feet for weeks at a time and yet suffer no injuries. It was not cold or wet, Osler concluded, and not puttees or boots which were doing the damage but the comparative inertia of the muscles of the leg. To keep the trenches dry and to use special kinds of socks might be useful, but the disabling effects of "cold bite" were inevitable in feet attached to legs whose muscles did not have play enough to maintain a circulation hampered by gravity and by cold and wet.

The principal causes of trenchfoot were thus clearly set forth many years before World War II as a combination of conditions and not a single condition. These causes included cold, wet, constriction, and immobilization. Cold injury could occur with the temperature above freezing and with frost present for limited periods only if at all. Lack of proper (principally warm) food and the influence of fatigue were other contributing causes. Tullidge,[33] who had been first an Austrian medical officer and then a military surgeon with the French Red Cross, advised recruiting physicians to remember that men with circulatory disorders and sluggish circulation were most susceptible to frostbite. If they were enlisted, he suggested that they be kept out of situations in which these injuries could be sustained.

A few other observers also called attention to a possible individual predisposition to cold injury, or, more correctly, to a possible individual variation in susceptibility, as evidenced by striking differences in the development of trenchfoot under the same environmental conditions. It was noted that, as a general rule, symptoms appeared within 3 or 4 days after exposure and that disability became marked within the next day or two. In some instances, however, men would be completely incapacitated within 24 hours after their first tour of duty in the trenches had begun, while others under precisely the same circumstances might not present symptoms for 5 or 6 days and might not be completely incapacitated for another 5 or 6 days.

A few other theories of the causation of trenchfoot were advanced in World War I in addition to the reasonable and generally accepted explanations just set forth. Fearnsides and Culpin,[34] although they agreed with the generally

[32] Osler, W.: Cold-bite+Muscle-inertia=Trench-foot. Lancet 2: 368, 18 Dec. 1915.
[33] Tullidge, E. K.: Frozen Limbs and Their Treatment in the Present War. M. Rec. 90: 11–14, 1 July 1916.
[34] Fearnsides, E. G., and Culpin, M.: Frost-bite. Brit. M. J. 1: 84, 9 Jan. 1915.

accepted theories, considered that apprehension and fear of a new disease were other possible causes.

Longridge's [35] elaborate theory of leakage of electricity from the foot to the earth, because the electrical resistance of the skin is enormously diminished when it is wet, was based on the researches of one A. E. Baines, who, shortly before the war, had published a book on electropathology. Longridge was so impressed by the concept that he "ventured to predict" that in the future the name of Baines would appear with those of Lister, Simpson, and Koch as among the benefactors of the human race. Recommendations for prevention based on the electrical theory of trenchfoot began with the wise, if unattainable, order not to get wet. Other advice included soaking the shoes, socks, and puttees in oil and applying dialectric oil (commercially available) directly to the feet. If trenchfoot had developed, the limb, from foot to knees, was to be wrapped in gamgee tissue soaked in dialectric oil. "I have seen enough of this treatment," concluded Longridge, "to justify the assertion that no serious case of trenchfoot necessitating amputation need take place." It would scarcely be necessary to refer to this curious item in a serious account of trenchfoot except that it was printed in the *Lancet* in January 1917, when the whole problem of cold injury was well under control in the British Army.

The French were in general agreement with the British that the important etiologic factors in trenchfoot were cold, wet, and lack of movement. Almost the only dissenters were Raymond and Parisot,[36] who argued that "gelure des pieds" is infectious. They reported in 1916 that they had isolated from the lesions a fungus identified as *Scopulariopsis komingü oudemans*, which was found in mud and straw and which came into contact with the feet by way of the mud of the trenches. Under the influence of more or less continuous immersion in cold water, this fungus became pathogenic and readily invaded the body through the macerated epidermis, frequently at the matrices of the nails. Although Raymond and Parisot claimed to have reproduced the lesions of trenchfoot by experimental animal inoculation of pure cultures of the fungus, their work was not generally accepted nor was it ever confirmed.

British theories of the etiology of trenchfoot were generally accepted by medical officers of the United States Army in World War I. The only deviation was a theory advanced by Sweet, Norris, and Wilmer,[37] who conducted comparative blood pressure studies on the upper and lower extremities, on the assumption that trenchfoot was analogous to Raynaud's disease and on the further assumption that Raynaud's disease can be explained by vasomotor spasm. While they found pressures in the leg considerably increased over pressures in the arm in casualties with trenchfoot, they were unable to determine whether the increase was the result of an excess of vasoconstrictor substance or

[35] Longridge, C. N.: A Note on the Cause and Prevention of Trench-Foot. Lancet 1: 62–63, 13 Jan. 1917.

[36] Raymond, V. V., and Parisot, J.: Etiologie Prophylaxie et Thérapeutique de l'Affection Dite "Gelure des Pieds." Presse méd. 24: 199, 4 May 1916.

[37] Sweet, J. E., Norris, G. W., and Wilmer, H. B.: The Etiology and Treatment of Trench-Foot. J. A. M. A. 70: 455–458, 16 Feb. 1918.

of a loss of vasodilator substance in the blood. Like Ashford (p. 49), they found that notable relief of pain could usually be secured (in 29 of their own 31 cases) by the administration of potassium iodide, which they employed as a "blood pressure reducing substance." Had they been able to obtain thyroid extract, they would have preferred to use it on the ground that the clinical picture in trenchfoot is the reverse of that in thyroid disease.

COLD INJURY OF THE HAND

In the great majority of cases of cold injury in World War I, only the feet were affected. Cold injuries of the hand, when they did occur, were seldom of consequence. Walther, however, reported an interesting exception in the experience of Péré and Boyé,[38] who observed, in 120 cases of "frostbite of the foot," 30 instances of frostbite of the hand (main de tranchées). The explanation was a particular series of circumstances. Because of the violence of the bombardment, the men had to remain crouched in the same position for several hours, without moving at all. Snow fell on their hands as they grasped their rifles, and they could not wipe it off. Many of them were then obliged to move on all fours for a considerable distance, over ground covered with snow and mud. When they had been relieved, they complained of pricking of the fingers and of difficulty in holding their rifles; some could not hold them at all. They also complained of edema of rapid development, which was apparently transient since it was not present when they reached the ambulance. Almost all of the lesions were bilateral and symmetrical. There were eight instances of gangrene, which in advanced cases extended almost to the metacarpophalangeal articulations.

[38] Péré et Boyé (reported by Charles Walther): Main de Tranchées. Bull. et Mem. Soc. de Chir. de Paris 43: 1483-1485, 4 July 1917.

CHAPTER IV

Actions Taken in Zone of Interior

MAY 1942–OCTOBER 1943

The first formal mention of cold injury in the Office of the Surgeon General after the United States entered World War II was contained in a note dated 12 May 1942 and addressed by Col. (later Brig. Gen.) James S. Simmons, MC, Chief, Preventive Medicine Division, to Dr. Lewis H. Weed, Chairman, Division of Medical Sciences, National Research Council. In this note, three points were made: (1) United States troops were already operating in Arctic regions, (2) the chances were that their operations in these areas would be expanded, and (3) it was therefore necessary to institute studies on health and sanitation in a cold environment. Frostbite was specifically mentioned in this letter, but trenchfoot was not. In view of the circumstances listed, the National Research Council was requested to set up a committee to study these problems. Copies of available field manuals were forwarded with the letter, together with a bibliography on cold injury and a letter and comments from the noted Arctic explorer, Vilhjalmur Stefansson. The activities of the committee set up by the National Research Council in response to this request are reported later in this chapter.

The next recognition of the ground type of cold injury as a medicomilitary problem was early in 1943, in the Surgical Division, Office of the Surgeon General. The essential pathologic process in this type of injury is vascular, and the interest of this division in it stemmed from the fact that several of the surgical consultants had had a wide experience with vascular diseases in civilian practice. At this particular time, unfortunatley, no similar interest was manifested by any of the other divisions which later concerned themselves with the matter, and the opportunity was therefore lost to plan and provide for a coordinated program of prevention before cases [1] of cold injury developed.

During the first months of 1943, reports on cases of cold injury in the Air Force in England and on immersion foot in shipwrecked Navy and other personnel began to come into the Office of the Surgeon General. These reports were followed by the reports of a large number of cases of exposure to cold during the Attu campaign in May and June 1943 (p. 84). This experience was the subject of extensive correspondence between the Surgical Division, Office of the Surgeon General, and the Surgeon, Alaska Defense Command. Correspondence was

[1] During World War II, it was frequently customary to refer to patients with cold injury as casualties. Current Army regulations (AR 600-400, 23 Aug. 1954) direct that injuries or illnesses due to the elements, exhaustion, or self-inflicted wound or injuries will not be considered casualties.

also conducted with the Office of the Base Surgeon, Greenland, and with surgeons in various hospitals which had received patients from the Attu campaign. The implications of the Attu experience, in terms of future military operations in other theaters, caused great concern in the Office of the Surgeon General among the medical officers who had already begun to interest themselves in cold injury.

Survey of official publications.—Among the first activities in this Office was a review of the whole subject of cold injury as it had been reported in the medical and other literature in previous wars (p. 29). This review concerned both the clinical aspects of these injuries and the military responsibility for their prevention. Methods of treatment were also reviewed in an endeavor to bring together whatever authoritative knowledge was then available. At the same time, two other reviews were undertaken. One had to do with the Army equipment available for use in conditions of combat in wet and cold. The other was a review of current official publications, such as training manuals, in which it might be expected that preventive and therapeutic measures would be emphasized.

When these reviews had been completed, a memorandum was addressed by Lt. Col. (later Col.) B. Noland Carter, MC, Chief, Surgery Branch, Surgical Division, to Brig. Gen. Charles C. Hillman, Chief, Professional Service, Office of the Surgeon General. In this memorandum, dated 23 August 1943, it was pointed out that measures currently recommended for the control of cold injury were completely inadequate. It was also emphasized that (1) current military publications dealing with operations under conditions of extreme cold contained a number of contradictions; (2) many of the measures advocated for the treatment of cold injuries were not in accord with current authoritative concepts of rational therapy; and (3) no reference at all was made to immersion foot, trenchfoot, or shelterleg in any of the technical manuals then current except in FM 21–11, First Aid for Soldiers. In view of these findings, it was recommended that the deficiencies listed be brought to the attention of appropriate agencies in the Surgeon General's Office so that data published concerning cold injuries might be corrected and brought up to date.

On the receipt of this memorandum, General Hillman requested the Training Division, Office of the Surgeon General, to confer with the Surgical Division on these various matters. The report of this conference, which was held on 27 August 1943, contained recommendations for the changes necessary to bring the publications dealing with the prophylactic and therapeutic aspects of cold injury into accord with current principles and practices. Changes made in the manuals as the war progressed are discussed elsewhere in this chapter (p. 68).

Conferences on exposure to cold.—A conference on exposure to cold, organized by the Division of Medical Sciences, acting for the Committee on Medical Research, Office of Scientific Research and Development, was held on 28 July 1943. It was attended by representatives of the United States Army, the United States Navy, the United States Public Health Service; representatives of the Royal Navy, the Royal Air Force, the Royal Canadian Navy, and

the National Research Council of Canada; and a number of physicians and surgeons with civilian experience in the management of vascular diseases. The conference was under the chairmanship of Dr. E. M. Landis, Professor of Physiology, Harvard University Medical School.

At this meeting, three points were especially emphasized: (1) Standard clothing and equipment, particularly footgear, had not been entirely efficient in combat under cold conditions to date; (2) more important, both clothing and equipment had been more satisfactory than the manner in which they had been employed, for the reason that troops had been only poorly trained or not trained at all in the personal precautions necessary under Arctic conditions; and (3) War Department publications, if they mentioned cold injury at all, were universally inadequate and were frequently contradictory.

The conference recommended that military personnel should be trained in the prevention of cold injury. Preventive measures and basic first-aid measures were outlined. Representatives from the Offices of the Surgeons General of the Army and the Navy were appointed to prepare articles on immersion foot, frostbite, and trenchfoot and to draw up instructions for the prevention and treatment of these injuries so that as much information as possible might be disseminated concerning them.

At a second conference on cold injury held on 1 October 1943, the material which had been prepared as recommended by the first conference was reviewed in detail, approved by the whole conference, and recommended to the Surgeons General of the Army and the Navy for publication as the official policy on trenchfoot, immersion foot, and frostbite. The articles were published in the *Bulletin of the United States Army Medical Department* [2] and in *Health*.[3]

OCTOBER 1943–MARCH 1945 [4]

In a further attempt to emphasize the significance of cold injury and the extreme hazards inherent in military operations in conditions of cold and wet, another memorandum on the subject of frostbite, trenchfoot, and immersion foot was addressed to General Hillman by Colonel Carter, on 16 October 1943, as follows:

1. The Attu experience was outlined, and reports from the Northwest Service Command and the Base Surgeon, Greenland, were cited and commented on.

[2] (1) Immersion Foot. Bull. U. S. Army M. Dept. No. 70, pp. 26–33, November 1943. (2) Frostbite. Bull. U. S. Army M. Dept. No. 71, pp. 24–27, December 1943.

[3] Monthly Progress Report, Army Service Forces, War Department, 31 Dec. 1943, Section 7: Health.

Health was a monthly publication, entirely informative in nature, prepared in the Office of the Surgeon General, chiefly for the benefit of Medical Department personnel. It dealt with certain matters of health, including their statistical aspects. It was not a command publication, and its circulation was necessarily limited. It was not likely to have been widely received or read at lower echelons where the control of trenchfoot had to be initiated and implemented.

[4] In addition to the publications mentioned in this section, articles prepared in the Office of the Surgeon General on the subject of trenchfoot appeared in the *Bulletin of the United States Army Medical Department* for March, June, and December 1944 and for February, April, May, June, September, and October 1945.

2. The experience in England with cold injury of the high-altitude type in fliers was reviewed.

3. It was pointed out that, while cold injury was still not a serious problem in United States Army troops from the standpoint of either frequency or morbidity, the solution, as the experience in the Aleutians and in the Army Air Force in England had shown, lay in prevention of this form of trauma. The immediate requirements were the adoption of proper equipment for use in cold weather, training in its efficient use, and the education of military personnel in methods of protecting themselves against the hazards of exposure to cold.

4. The steps being taken to bring official publications into accord with modern principles and practices concerning cold injury were also reviewed.

The Office of the Surgeon General could not, of course, do more than advise concerning either equipment or training. These matters were the responsibility of the Army General Staff, especially the Assistant Chief of Staff, G–3 (operations and training). Clothing was the special responsibility of The Quartermaster General. The situation was admittedly difficult. The Army was expanding rapidly. New types of supplies required time for development, procurement, and distribution. The training load was at a peak, as to both the subjects to be taught and the number of men to be trained. Because of lack of time and space on the program, the introduction of additional required training subjects was not readily achieved. It is not surprising, therefore, that many frustrations were experienced by the medical officers who had quickly grasped the military, as well as the medical, significance of cold injury and the urgent necessity for the training of personnel and for the provision of appropriate protective equipment if costly losses were to be avoided in winter operations.

Impact of Experience in Mediterranean Theater

Less than a month after the memorandum of 16 October 1943 had been prepared, trenchfoot began to be reported from Italy where it rapidly assumed serious proportions (p. 101). The tremendous military significance of this type of injury immediately became apparent, even to those who had not previously considered it of much importance. It was obvious, however, in reports from Italy concerning United States casualties, that the importance of preventive measures was not well understood in that theater, and the lack of appreciation of their importance was further evident, although the comparisons were not always as valid as they seemed, in the contrasting experiences reported by British troops fighting in the same area and under much the same circumstances as United States troops.

As a result of the Italian experience, the whole problem of cold injury was repeatedly surveyed in *Health*. The first of this series of articles, published in December 1943, discussed trenchfoot, immersion foot, and frostbite, with particular reference to the incidence of this type of injury in previous wars,

the incidence in the Aleutians campaign, and the current situation on the Italian front. The article emphasized that the prophylaxis of cold injury is a command responsibility. The results obtained by the British by the use of preventive measures were summarized.

The medical aspects of the Italian campaign were analyzed in the February 1944 issue of *Health* from the standpoint of comparative battle casualties, neuropsychiatric casualties, and hospitalization for disease. The article closed with the statement that, while the surgical care of battle casualties had been exceptionally good, "the total rates for disease were high and jaundice, trenchfoot, malaria, and venereal disease were outstanding medical hazards over which it proved difficult to exercise sufficient control."

In the March 1944 issue of *Health*, the experience of the 1943–44 winter in Italy was analyzed in considerable detail. The discussion covered etiologic factors of cold injury with particular reference to the influence of terrain, the tactical situation, and climatic conditions; the disappointing results accomplished by the first corrective measures; the serious losses in combat strength because of the long periods of hospitalization usually necessary in trenchfoot; and the frequently poor end results. The United States Army experience was contrasted with the British experience; among British troops, the incidence of trenchfoot was very low, presumably because preventive measures were well established and strictly enforced. The inadequacies of the clothing which had been supplied United States troops for winter use were noted, and preventive measures were reviewed, with emphasis on command responsibilities.

The June 1944 issue of *Health* carried another analysis of the trenchfoot situation to date. It was pointed out in it that although the number of casualties in the Attu campaign was small, the incidence of cold injury was actually high. The small number of cases could be attributed more to the short period of time covered by the fighting and the small number of troops involved than to any other factor. In addition, certain of the troops engaged were accustomed to cold, wet weather, knew how to take care of themselves in it, and therefore did not develop this form of cold injury.

The article went on to say that, while medical officers were aware of the problem presented by trenchfoot, instruction concerning this type of injury had formed no part of the training for troops going overseas. Their ignorance of the risk helped to explain why they had become patients from cold trauma. The possibilities of prophylactic measures were again related to the British experiences in World War I and on the Italian front the previous winter. The several thousands cases which had occurred from United States Army troops in Italy were chiefly in frontline troops whose replacement was a military necessity. The average time lost from duty per man was in the neighborhood of from 7 to 8 weeks.

A program of control was outlined, in which it was stressed that trenchfoot, like venereal disease and malaria, can be prevented "only by the intelligent behavior of the individual soldier under conditions of exposure." The article

closed with the prophetic warning that "A winter campaign in northwestern Europe could create a trenchfoot problem of major importance if the lesson of Italy were not heeded."

Analysis of Reports From Overseas

Meantime, reports and special studies prepared in the Mediterranean theater were evaluated and analyzed in the Office of the Surgeon General with particular reference to methods of therapy and problems of prevention and control.

A memorandum, prepared by Brig. Gen. Fred W. Rankin, Chief Consultant in Surgery, and addressed to The Surgeon General on 17 March 1944, reviewed the experiences in Italy, as well as in the Aleutians, and summarized the activities concerning cold injury which had been undertaken to date in the Office of the Surgeon General. Preventive measures and management were outlined in the light of these experiences. Special emphasis was placed on the fact that it was not only preventive measures, but the rigidity with which they were enforced, that determined their effectiveness. In the final analysis, it was pointed out, their implementation "is a measure of discipline and is the responsibility of unit commanders."

The Essential Technical Medical Data report from the North African Theater of Operations for February 1944 had included the statement from the Office of the Surgeon, Fifth U. S. Army, that "No solution has been found for the trenchfoot problem." The Surgery Division, Office of the Surgeon General, recommended on 24 May 1944 that the reply to the theater should point out that the experience of previous wars and the British experience in Italy in the winter of 1943–44 had demonstrated that a solution to the problem did exist and that it lay in the bold, vigorous, and diligent application of well-established prophylactic measures. It is unfortunate, and perhaps indicative of the general lack of appreciation of cold injury in military operations, that this plain-spoken comment had been considerably watered down by the time it reached the theater in July.[5]

The March Essential Technical Medical Data report from the North African theater, which was extensive and comprehensive, revealed that a program of control was by this time well understood in the theater. Responsible theater personnel had concluded, in the light of the low incidence among British troops, that all troops should wear heavy wool socks; that their shoes should be well fitted over these socks; that dry socks should be taken to frontline troops with rations; that laundry facilities for washing socks should be available in divisional areas; that squad leaders should be directly responsible for enforcing proper care of the feet by the individual soldier; and that commanders should arrange for rotation of frontline troops. Requisitions for new winter equipment were placed by the theater in July 1944.

[5] Letter, Brig. Gen. R. W. Bliss, Chief, Operations Service, Office of the Surgeon General, to Commanding General, North African Theater of Operations, 16 June 1944, subject: ETMD.

In a memorandum addressed to The Surgeon General on 19 June 1944, by General Rankin, the whole experience in Italy during the winter of 1943–44 was reviewed. It was pointed out that inadequate instruction of personnel, failure to provide suitable equipment, especially shoes and socks, and failure to apply preventive measures consistently had been responsible for the heavy losses from cold injury in the Italian campaign. Since prevention was the responsibility of command, it was recommended that a vigorous program be instituted at once to include (1) dissemination of information to troops, with instruction in proper methods of prevention of cold injury, (2) provision of proper equipment and footgear, (3) dissemination of information to Medical Department personnel on first aid and definitive treatment, and (4) emphasis on command responsibility for prevention.

In the annual report of the Surgical Consultants Division, Office of the Surgeon General, for the fiscal year ending on 30 June 1944, trenchfoot was described as "perhaps the most unsatisfactory experience of the war." Much the same feeling had been expressed in General Rankin's memorandum to The Surgeon General dated 19 June 1944.

War Department Publications

On 29 May 1944, with the purpose of augmenting existing regulations governing care of the feet, as well as to prevent and control any further outbreaks of trenchfoot such as had occurred on Attu and in the Mediterranean theater, Lt. Gen. Brehon B. Somervell, Commanding General, Army Service Forces, directed The Surgeon General to prepare without delay a circular on the subject of trenchfoot, to include causes, symptoms, prevention, first aid, and treatment. It was desired that this publication be ready by 10 June, but, because of the number of divisions, offices, and special personnel whose assistance and concurrence were required, the date was extended.

War Department Circular No. 312, section IV, was issued 22 July 1944 as the official policy of the War Department in respect to trenchfoot. It read as follows:

IV. TRENCH FOOT.—1. Trench foot is the name given to a condition which results from—

a. Prolonged standing in water, wet snow, or mud under cold to freezing temperatures.

b. The continuous wearing of wet socks, shoes or boots. Trench foot is promoted by wearing shoes, socks, boots, leggings, or a combination of these which are too tight, and when the individual who is forced to stay in muddy trenches, fox holes, or shell holes for extended periods neglects exercising his feet and legs.

2. Signs and symptoms of trench foot usually develop as follows:

a. Numbness of the feet or toes. The feet feel like heavy blocks of wood and walking becomes difficult.

b. Burning or stinging pain in the feet or toes.

c. Aching of the ankles and bottoms of the feet.

d. Swelling of the feet, and the skin becomes pale and cold.

e. Development of blisters and blebs.

f. Finally, gangrene may occur.

3. Trench foot can be prevented by instructing the individual soldier in the proper care of the feet, by providing suitable footgear where conditions promoting trench foot are present, and by insuring that proper measures are carried out through use of disciplinary action, if necessary.

4. When conditions promoting trench foot exist, and in order to minimize the occurrence of trench foot, unit commanders will be held responsible that the following instructions are carried out:

a. Troops will be given the following specific instructions in the care of their feet:

(1) The feet must be kept dry. Damp soles (also, insoles, if worn) will be replaced by dry ones as soon as possible.

(2) An extra pair of heavy woolen socks (also, insoles, if worn) will be carried at all times to permit changing to dry ones once daily.

(3) Shoes will be removed at least once daily and the feet cleaned and dried. Foot powder will be dusted over the feet and into the socks and shoes.

(4) When shoes or leggings feel tight they must be loosened immediately. Tight footgear interferes with the circulation.

(5) If required to stand for long periods, the feet and legs will be exercised frequently. Conditions might require that this be only in the form of wiggling the toes within the shoes and bending the ankle. Positional exercises of the legs such as knee-bending when standing and elevating legs above level of body when sitting or lying down should be accomplished.

(6) Avoid standing in water, wet snow, or mud. Whenever feasible, the water in trenches, fox holes and shell holes should be bailed out, and rocks, pieces of wood, or tree branches used to stand on.

(7) When necessary to sleep while in sitting position, prop feet as high as possible to help blood circulation. Put on dry socks. Place wet or damp socks in trouser pockets or beneath the shirt to dry. Do not sleep wearing wet socks.

b. Before troops enter combat in cold, damp areas, unit commanders will insure that the troops have cleaned and dried their feet and dusted them with foot powder before putting on dry, heavy woolen socks and waterproof or water-resistant boots or shoes.

c. Arrangements will be made to furnish troops with a clean, dry pair of heavy woolen socks (also, insoles, if worn) once daily. This may be accomplished by bringing them up with the daily ration.

d. Proper waterproof or water-resistant footgear will be issued to the troops when fighting in cold, water-soaked terrain. Care will be taken that the footgear fits properly. The footgear should be loose enough to permit wearing heavy woolen socks without constricting circulation.

e. Foot inspections will be held frequently and the necessary corrective measures instituted.

Therapy was not covered in this circular, partly because treatment was regarded as a technical medical procedure and partly because it was to be covered in a technical medical bulletin on trenchfoot then in preparation. Suggestions that instructions be given to massage the feet, unless trenchfoot had already set in, and to use lanolin, were disapproved by The Surgeon General, on the ground that (1) the soldier could not himself determine whether or not he had already contracted trenchfoot; (2) he might do considerable damage to the tissues by massage; and (3) the use of oils and greases on the feet was of questionable value and could be harmful. The suggestion, made by the Quartermaster General, that the shoepac be recommended as the best footgear to prevent trenchfoot, was also disapproved, on the ground that the improper use of shoepacs could result in serious damage to the feet.

Revision of War Department Circular No. 312.—Shortly after War Department Circular No. 312 had been published, the Quartermaster General requested that it be revised in order to clarify the reference to heavy woolen socks, since too strict an interpretation of the instructions to use them might result in a sudden depletion of the supply.[6] All commanding generals at ports of embarkation had been notified 7 August 1944 that this circular was designed for the prevention of trenchfoot and was not to be construed as justification for an increase in the authorized allowances of socks.[7] Theaters served by the various ports were to be informed of this ruling.

The Surgeon General did not concur in the changes requested by the Quartermaster General, and a conference to discuss the matter was held 18 September 1944. Representatives of the Quartermaster General explained why they opposed the circular as it had been issued: If theater commanders should make requisitions for heavy woolen socks, to comply with its terms, the demand could not be met, since at that time these socks amounted to only 10 percent of the total sock procurement. Wool was available for additional supplies of socks, but machinery to make them was not and it could not be constructed in less than 6 or 8 months. It was agreed that before any action was taken in this matter, the Quartermaster General should inquire from the commanders in all theaters how many heavy woolen socks would be needed to comply with the terms of the circular. When it was learned from the European theater that the circular would have no effect upon the initial issue of this type of sock (although it was requested that the maintenance factor for cushion-sole socks be increased from 11 to 25 percent), War Department Circular No. 312 was thereupon modified[8] as follows, at the request of the Quartermaster General:

V. TRENCH FOOT. 1. Reference is made to section IV, Circular 312, WD 1944.

2. The provisions of paragraph 4, section IV, Circular 312, will not be considered as authorization for an increase in allowances of heavy wool socks, authorized in T/E 21, Clothing and Individual Equipment, 1 June 1944, as socks, wool, cushion sole; socks, wool, heavy; or socks, wool, ski. When increased allowances are required to comply with the provisions of Circular 312, requests will be submitted through channels.

War Department Technical Bulletin 81.—The publication of War Department Circular No. 312 on 22 July 1944 was followed by the publication of War Department Technical Bulletin (TB MED) 81, 4 August 1944. This bulletin (appendix A, pp. 509–515), which covered all phases of cold injury, with special emphasis on prophylactic measures, was largely based upon the experience, both in the clinical aspects of the condition and in its prevention, gained in the recent Italian campaign. Minor changes in therapy were suggested in an amended version published 3 October 1944 (appendix A, p. 515).

[6] (1) Memorandum, Director, Distribution Division, Army Service Forces, for Director, Military Training Division, 23 Aug. 1944, subject: Trench Foot. (2) Memorandum, Headquarters, Army Service Forces, for Quartermaster General, 23 Aug. 1944, subject: Heavy Woolen Socks.

[7] Telegram to all commanding generals at ports of embarkation from Lt. Gen. Brehon B. Somervell, dated 7 Aug. 1944.

[8] War Department Circular No. 459, 4 Dec. 1944.

The Assistant Secretary of War, Mr. John J. McCloy, wrote to The Surgeon General on 16 August 1944 to point out that in polls taken of the Army overseas and published in What the Soldier Thinks, 85 percent of those questioned felt that they had received too little training in how to avoid having trenchfoot and how to take care of it. The only other item in which the percentage was similarly high had to do with the handling of land mines. The Secretary felt that these figures were significant, though he was uninformed as to what The Surgeon General was doing in "training in the avoidance and treatment of trenchfoot."

The Surgeon General replied on 17 August that the soldier was indeed receiving too little instruction in the care of his feet but that prevention of trenchfoot was really a command function, to be carried out with medical advice. He sent the Secretary a copy of War Department Circular No. 312 and also described TB MED 81, then in production, which covered all phases of trenchfoot. A copy of this publication was sent to the Secretary 31 August 1944, just after it had been published and received from The Adjutant General.

Review and Evaluation of European Theater Problem

Either the lesson of the Italian campaign was not heeded in the European Theater of Operations, or appreciation of its significance came too late. The official publications of the War Department on the subject (War Department Circular No. 312 and TB MED 81) were not received in the European theater until after sporadic cases of trenchfoot had already occurred and only shortly before an outbreak of cold injury, of much greater gravity than the outbreak in Italy the previous winter, began in France and Germany.

During November 1944, approximately 11,000 cases of trenchfoot were reported in the European theater, more than 6,000 in the Third U. S. Army alone. The November rates for this theater, which were already in excess of those in January and February 1944 in the Fifth U. S. Army in Italy, were analyzed in the November 1944 issue of *Health*. The elements of a satisfactory control program, as outlined in War Department Circular No. 312 published in July 1944 and in TB MED 81 published the following month, were reviewed with special emphasis on the provision of suitable equipment, the avoidance of unnecessary risks, and the enforcement of adequate care of the feet. It was pointed out again that the solution of the problem lay in the assumption of the responsibility by commanders.

As described in detail elsewhere (p. 146), shortages of winter clothing and other winterizing equipment were at this time compounding the difficulties in the European theater. An urgent cable from Headquarters, Communications Zone, European Theater of Operations, to the War Department 6 December 1944, described the trenchfoot outbreak in detail and urged that the Department make all possible efforts to expedite supplies of shoepacs, socks, and winter clothing.

This cable gave rise to a series of meetings, all held 9 December.

The first of these meetings was held in the office of Brig. Gen. (later Maj. Gen.) Raymond W. Bliss, Chief, Operations Service, Office of the Surgeon General, to discuss in detail the situation in the European theater.

At the conclusion of this meeting, General Bliss and General Rankin met with Maj. Gen. Norman T. Kirk, The Surgeon General. General Rankin read a prepared summary of the efforts which had been made in the Surgical Consultants Division, Office of the Surgeon General, to set up an adequate program for the control of cold injury.[9] He concluded with the statement: "The most important factor in assuring the success of this program is enforcement of these elements [prevention and foot discipline] and this lies within the province of command rather than medical authority."

At the conclusion of the second meeting, a meeting was arranged between General Kirk, General Somervell, and Gen. George C. Marshall, Chief of Staff, to provide The Surgeon General with an opportunity to state the seriousness of the cold injury situation in the European theater and to emphasize the need for renewed command efforts to bring preventive measures into full implementation at all levels. Special emphasis was to be placed upon indoctrination of the smaller units. The recommended preventive measures also included (1) provision of suitable and properly fitted footgear and heavy woolen socks, (2) daily foot inspections and daily changes of socks, and (3) frequent rotation of troops who were serving under conditions predisposing to cold injury.[10] These measures are discussed in detail in the chapter dealing with cold injury in the European Theater of Operations (pp. 167 and 173).

In the December 1944 issue of *Health*, the current situation in the European theater was analyzed on the basis of the weekly rates and analyses cabled from it. It was noted that the incidence of cold injury was considerably higher in that theater in certain units than it had ever been during the Italian campaign, and the close parallel between tactical activity and cold injury was pointed out.

The situation in the European theater was again reviewed in the January 1945 issue of *Health*, and the increasing incidence was commented on. Control measures were being pushed vigorously, it was stated, but the tactical situation and the weather hampered their full implementation. The British experience was analyzed, and it was noted that the British attributed their comparative freedom from trenchfoot to the superior fit of the shoes provided for their troops and to their better foot discipline.

In the March 1945 issue of *Health*, the entire European experience was reviewed and it was pointed out that about 30 percent of the 45,000 predominantly frontline troops who had contracted cold injury in that theater would require evacuation to the Zone of Interior. Although estimates indicated that 55 percent of the wounded could be returned to frontline duty, it was doubted that this proportion of trenchfoot patients could be returned to combat. The British experience in the European theater was again reviewed.

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[9] Memorandum, Brig. Gen. F. W. Rankin, Chief Consultant in Surgery, Surgical Consultants Division, for The Surgeon General, 9 Dec. 1944, subject: Trench Foot.

[10] Memorandum, The Surgeon General for the Chief of Staff, 9 Dec. 1944, subject: Trench Foot.

Among other subjects discussed in this article were the advantages of control teams, the necessity for the allotment of additional time in the training schedule for instructions in the prevention of trenchfoot, the shortages of shoepacs in the European theater, the relationship between tactical activity and exposure to cold, and the necessity for advanced planning whenever there was a remote likelihood of combat under winter conditions.

TRAINING PROGRAM

Manuals

As has already been pointed out (p. 58), the various military publications current when the United States entered World War II were neither complete nor satisfactory from the standpoint of the discussion of cold injury, and they were often contradictory as well. For the record, they will be briefly mentioned, together with the revisions which they underwent in the course of the war.

Operations in Snow and Extreme Cold.—This manual (FM 31–15) was published on 18 September 1941 to supplement a training circular of the same title which did not contain full information on the subject. Changes were published on 16 April and on 29 September 1942. Frostbite was briefly discussed in this manual, and it was pointed out that wounded men need special protection against cold injury. Trenchfoot was not mentioned.

First Aid for Soldiers.—This manual (FM 21–11), which was published on 7 April 1943, contained extended discussions of frostbite and freezing, including diagnosis, first aid, treatment, and prevention. Trenchfoot, shelterleg, and immersion foot were briefly discussed. All three conditions, it was stated, resembled mild frostbite but could occur at higher temperatures. The causes were listed as standing or sitting still for long periods in wet trenches or shelters and letting the feet hang for long periods in water after shipwreck. Tight leggings and cramped positions of the legs were listed as contributing causes. The best methods of prevention, it was stated, were keeping the feet dry and exercising the extremities to increase the flow of blood in them. First-aid measures were the same as those recommended for frostbite. No changes were made in these sections when the manual was revised on 20 May 1943.

On 14 September 1944, The Surgeon General requested the Commandant, Medical Field Service School, Carlisle Barracks, Pa., to proceed at once with a complete revision of the text of First Aid for Soldiers, to bring it into accord with most recent doctrine.[11] In The Surgeon General's request for approval of the revision which went to the Director, Military Training, Army Service Forces, on 16 September 1944, trenchfoot was mentioned as one of the subjects requiring more extended attention. The same necessity was mentioned when The Surgeon General submitted the outline of the proposed revision to the

[11] An article on the subjects of frostbite, immersion foot, and trenchfoot had been published from this school (Wright, I. S., and Allen, E. V.: Frostbite, Immersion Foot, and Allied Conditions. Bull. U. S. Army M. Dept. No. 65, pp. 136–150, January 1943). This was a comprehensive article, dealing with all phases of these injuries, including prevention.

Commanding General, Army Service Forces, on 31 October 1944. On 29 January 1945, the Surgeon General's Office concurred in the plan to reprint the unrevised manual at this time, on the ground that it would be another 4 months before the revision then in progress could be accomplished.

Actually, the revised manual did not appear until 1 August 1946. In this revision, trenchfoot was described in detail in the light of the World War II experience, and special emphasis was put upon preventive measures including the care of the feet. It was recommended that the feet be kept clean and dry, that they be exercised and massaged, that constriction be avoided, and that the socks be changed at least once daily. Frostbite was also discussed in detail from the standpoint of prevention.

Field Sanitation.—This manual (FM 8–40), prepared under the direction of The Surgeon General and published by the War Department on 15 August 1940, did not mention either trenchfoot or frostbite in the original issue or in the three changes published in 1942.

Military Sanitation and First Aid.—This manual (FM 21–10), published on 31 July 1940, contained a full clinical discussion of frostbite but did not mention trenchfoot either in the original edition or in the seven changes made between the date of issue and 17 February 1944. Trenchfoot was also not mentioned in any of the correspondence, begun in October 1943, concerning revision of the text.

The revision was not completed until July 1945. Chapter 13, which deals with personal hygiene, contains an extensive discussion of trenchfoot, as well as of immersion foot and frostbite, with emphasis on the care of the feet, the proper use of clothing and footgear, and similar matters. The following paragraph is cited as an illustration that the lessons of the experiences in Italy and Europe had by this time been well learned:

> Remember that no single type of footgear or combination of shoes alone will keep the feet dry and warm under the varying conditions met in combat areas. Proper footgear is at best only a help in keeping the feet warm and dry. The prevention of trench foot depends on the care given the feet by constant attention to *all* the rules outlined above.

In May 1944, while the revision of this manual was in progress, General Bliss recommended that a pamphlet proposed by the Military Training Division, Army Service Forces, should not be published because the material, in substance, was included in this proposed revision and would also appear in Personal Health, a War Department pamphlet then in preparation. It was expected that this revision would also eliminate the need for FM 8–40, Field Sanitation. The request received by radiogram from Headquarters, European Theater of Operations, on 10 January 1945, for 200,000 copies of FM 21–10, Military Sanitation and First Aid, included a request for information concerning the revision which, as noted above, appeared too late to be of value in World War II.

Soldier's Handbook.—This manual (FM 21–100) was first published on 23 July 1941. The need for it had been realized much earlier, but funds could not be secured for publication. The distribution was Army-wide. The care of

clothing and the cleansing of boots and shoes were described, but the only mention of cold injury concerned the management of individuals exposed to freezing. Trenchfoot was not mentioned in the changes made in May and December 1942. A revision of this manual was planned in the summer of 1943, and several suggestions were made to the effect that the text should be more interesting, more easily comprehended, and more readable. The revision was not carried out, the manual being rescinded on 10 August 1944, because the material in it was either obsolete or was duplicated in other field manuals. Permission was given in War Department Circular No. 375, dated 15 September 1944, to use the handbook, with whatever corrections were necessary, until the pamphlet intended to replace it (War Department Pamphlet 21–13, Army Life) should become available. Army Life was published on 10 August 1944.

Principles of Cold Weather Clothing and Equipment.—This manual (TM 10–275) was prepared by the Office of the Quartermaster General on 26 October 1944. It had been in preparation for almost a year, a large part of the delay being for editorial reasons. Changes were initiated almost as soon as the manual appeared and were issued on 1 February 1945; they had to do with preferred types of footgear, including sock combinations. Excellent advice was given in this publication about the care of the feet, the importance of exercising them, and other preventive measures. Although the military experience had been that dubbing was not useful in the prevention of trenchfoot, instructions for its use were given in the changes in the manual issued in February 1945.

Medical Department Soldier's Handbook.—This manual (TM 8–220) replaced the earlier handbook prepared by Maj. Arnold D. Tuttle, MC, and published in 1927.[12] Frostbite, freezing, and chilblains were briefly discussed in the earlier text, but trenchfoot was not mentioned.

The Medical Department Soldier's Handbook, which was issued on 5 March 1941, contained clinical descriptions of the effects of prolonged exposure to extreme cold, descriptions of frostbite and chilblains, and instructions for the management of these lesions. Trenchfoot was not mentioned. Directions were given for the proper fitting of shoes and socks and for the care of the feet. In the third set of changes, issued in February 1944, the section on frostbite was considerably expanded and became substantially the same as the similar section in FM 21–11, First Aid for Soldiers. Also included was a section on immersion foot dealing with contributing factors, clinical considerations, preventive measures, and emergency management. Trenchfoot was not mentioned in any of these changes.

Guides to Therapy for Medical Officers.—This manual (TM 8–210), which was published 20 March 1942, contained an extended discussion of frostbite, covering prophylaxis, etiology, and treatment, but did not mention trenchfoot. Athlete's foot was also discussed. Details of foot hygiene were outlined,

[12] Tuttle, Arnold D.: Handbook for the Medical Soldier of the Regular Army, National Guard, Organized Reserves, and Enlisted Reserve Corps of the Army of the United States and Others Interested in National Medicomilitary Preparedness. New York: William Wood and Co., 1927.

including the care of the feet after long marches. The importance of wearing properly fitted shoes and socks was emphasized. Light wool socks were recommended, and it was specifically stated that the shoes should be laced snugly. This manual was rescinded in 1944, and the material which had previously appeared in it was thereafter published in medical technical bulletins.

Arctic Manual.—This manual (TM 1–240), which was published on 1 April 1942, superseded the two volumes of similar title published on 6 November 1940. It was specifically intended for the use of personnel in the North American Arctic region who were not assigned to permanent posts. Frostbite was described at some length in the 1940 publication, but neither frostbite nor trenchfoot was mentioned in the 1942 edition. When this manual was revised on 17 January 1944, an extensive discussion of all aspects of frostbite was included, but, again, trenchfoot was not mentioned.

Personal Health.—This publication (WD Pamphlet 8–9) was initiated as a manual in the fall of 1943. When it was learned that publication in this form would probably not be permitted, approval was requested for it as a pamphlet in the same format. When the material was sent to the Surgeon General's Office in August 1944 for review before publication, personnel in that office requested that a subtitle, An Eye to Your Future, be added, and that an illustration be provided for the cover.[13] The pamphlet, it was stated, contained much valuable material, and it was thought desirable to try to remove it from the category of routine War Department training manuals. The average soldier, the note pointed out, "considers that he has a sufficient knowledge of personal health without further advice, and often casts aside any document on personal health without reading it" unless it can be made attractive enough to stimulate his interest. In view of the urgent need for this pamphlet in the field, it was requested that its publication be expedited. It is not clear why work on this publication lapsed.

The Fitting of Shoes and Socks.—This manual (TM 10–228) was undertaken shortly before V–J Day but was not completed when the immediate necessity for it ceased.

Comment.—In analyzing the various publications of the War Department dealing with the health of the soldier and his training and equipment for cold weather, one is impressed, as has already been pointed out, with the inadequacy of the instructions for the prevention and management of cold injury, and with the inaccuracy of much of the material that was published. Trenchfoot was entirely ignored in the manuals current when the United States entered the war. When revisions of these manuals were undertaken, trenchfoot continued, for the most part, to be ignored. Revisions were initiated late, and many months usually passed before the concurrence of the various offices and personnel concerned could be secured. Many disagreements concerned trivia. Further delays ensued as the manuals were processed and issued. None of them reached the Mediterranean or the European theater in time to be useful

[13] Memorandum, The Surgeon General, for Office of The Adjutant General, 16 Aug. 1944, subject: WD Pamphlet 8–9 "Personal Health."

in the prevention and control of trenchfoot. Some of them, in fact, would probably not have been ready in time for cold weather operations in the Pacific had war in that theater continued into the fall and winter.

Posters

The difficulties just outlined, which attended the publication of field and technical manuals, also attended the preparation of posters and films designed to educate troops in the prevention of cold injuries. There would therefore be no point to a rehearsal of the details.

Multiple charts for company-size units were planned and prepared in the Training Division, Surgeon General's Office, on numerous subjects, including trenchfoot. They took time to prepare. Coordination with many offices was necessary. Additional time was required to make the changes required or desired to correct facts, alter emphasis, or change the method of presentation.

For these reasons, when urgent requests were received from the European theater in December 1944 for posters on cold injury for general distribution, the requests could not be filled. On 4 January 1945, General Bliss sent two posters to the Chief Surgeon, European theater, with a request that he order the number desired. One of these posters was an official War Department poster (GTA 8–16) in four colors, designed to drive home the necessity for daily individual foot care. The other had been prepared by units of Army Ground Forces, Fort Benning, Ga. Orders were placed on 19 January for 12,000 copies of each of these posters, half to come by air and half by fast boat shipment.

In the European theater, as in the Zone of Interior, when official posters were not available, many units prepared and displayed their own. Some were excellent, others were not too expert, but most were useful as well as immediately effective.

There was, of course, an element of danger in the local preparation of posters. An official observer from the Surgeon General's Office noted that he had recommended that one such poster which had come to his attention be removed and destroyed at once, on the ground that trenchfoot was not a subject to be treated humorously. Similar advice was given at another camp, where trenchfoot was presented as a form of athlete's foot and as preventable by the methods used for the prevention of that infection. Since the cause of cold injury was presented as a germ, and not as impairment of the blood supply to the feet, the soldier would naturally not understand that it could be prevented by exercise, massage of the feet, warmth, and the unloosing of constricting shoes, socks, and leggings.

The official observer just quoted stated in his report on this tour of inspection that the major reason for the difficulty in explaining the concept of trenchfoot was the fact that line officers had not read, and would not read and familiarize themselves with, the various directives on the condition. If, as the poster just described indicated, unit officers thought that cold injury was just

a severe case of athlete's foot, soldiers under their command would have the same ideas. The knowledge of trenchfoot, in short, was weak because of the average line officer's complete ignorance of the material contained in existing directives.[14]

Films

The film undertaken in the fall of 1942, under the title "Personal Health in Operations in Snow and Extreme Cold," was approved for release on 28 December 1943.

The Training Division, Office of the Surgeon General, requested authorization on 18 September 1944 for the production of a film bulletin on the cause and prevention of trenchfoot, to be based on the doctrine contained in War Department Circular No. 312. Although the film was put into production promptly, it was not finally approved until 17 February 1945 and was not released until March as Film Bulletin 180, subject: Trench Foot.

This film, which had a running time of 18 minutes, was intended to be shown to all ground troops before they went on maneuvers or into combat, the objective being to focus attention on proper care of the feet immediately before such care would abruptly become of the greatest importance. Troops were shown hiking through mud and snow and living in muddy foxholes. Cold, numb, wet feet, it was shown, could lead to trenchfoot, with cold, numbness, and stiffness the first symptoms, followed by blister formation; these relatively mild symptoms and signs, it was indicated, could lead to gangrene, with amputation the possible end result. Preventive measures were illustrated, such as the use of rocks and branches of trees in the bottom of foxholes, to keep the feet from direct contact with mud and water; daily removal of the shoes and daily changes of socks; vigorous massage of the feet, with the application of foot powder; sleeping with the legs elevated; and methods of drying the wet socks by body heat. It was repeatedly emphasized in the course of the presentation that only by adherence to these cardinal principles could the feet be kept warm and dry, and trenchfoot with its ghastly consequences be prevented. The message was driven home by repeated flashbacks to pictures of gangrenous feet which required amputation.

This vigorous presentation proved both useful and effective in the United States, where the film was widely distributed, and in the training program

[14] There were, of course, exceptions to this generalization. An occasional commander was wise before the event. An observer for the Army Ground Forces Board, NATOUSA, quoted the colonel of an infantry regiment as saying "I wrote a monograph at Benning in 1928-29 on the subject of the care of the feet. I thought it was an important subject then, though some other people did not. It is still one of the most important subjects for an infantry officer to know. Trenchfoot is one of the major causes of non-battle casualties. and a non-battle casualty reduces your combat strength just as much as does a battle casualty * * *. The remainder of this regiment [he excluded the Japanese-American component, p. 380] has consistently had the lowest trench-foot rate among the infantry of the division. This, I am sure, is largely due to the emphasis we have placed on care of the feet. I have personally conducted a school on care of the feet for the junior officers of the regiment. We require every man to go into combat with a clean, dry pair of socks inside his shirt and we require platoon leaders to see that their men change wet socks for dry ones, and massage their feet, whenever it is at all practicable. If Benning does not already have it in its officer-candidate course, it should include a short course on care of the feet. The instructor should be a competent doughboy who has done a lot of marching and knows how to take care of feet in wet, cold weather. I don't think that anything that Benning can teach its students is of more importance."

in the Pacific (p. 231). It was issued too late to be employed when it was most needed, in the Mediterranean and European Theaters of Operations. Repeated requests for films on the subject of trenchfoot were received from the European theater but could not be filled.

Indoctrination of Troops

Pearl Harbor–July 1944.—Instruction in the risks of cold injury and in methods of preventing it formed no part of the training of combat troops in the early days of the United States participation in World War II. It was not, in fact, until trenchfoot had become a major problem in combat operations in Italy in the winter of 1943–44 that a serious attempt was made to include indoctrination on cold injury as part of the combat training, and the war was almost over before satisfactory courses were set up. This was, of course, an error of the first magnitude, for which a heavy price was paid in loss of manpower and reduced combat efficiency.

On the other hand, it is only fair to point out certain facts in explanation, though not in excuse, for this situation. The United States had been quite as unprepared to enter World War II as it has been to enter World War I. In the space of months after Pearl Harbor, an army of approximately 1.6 million men became an army of several million. New troops had to be taught a great many things, many of them of the utmost importance. There was constant competition for space in the training program. Even after the importance of cold injury was fully realized, instruction in its prevention had to compete for room with other subjects. Furthermore, the Medical Department, which realized the dangerous possibilities of this sort of injury relatively early in the war, and which repeatedly called attention to them, could do no more than advise, and advise only indirectly (p. 81), since the prevention of trenchfoot is primarily a command, not a medical, function.

Cold injury in the training program was first conceived of as relating to combat operations in the Arctic. This is clear from the material contained in the manuals issued early in the war and already discussed (p. 68). The same concept is evident in the training outline prepared in October 1943; it provided only for 12 hours of instruction for training in operations in extreme cold, 8 devoted to sanitation and 4 to first aid.

War Department Circular No. 48, issued on 3 February 1944, provided that training schedules and courses of instruction be so planned as to insure minimum standards of proficiency in the care of the feet, including the prevention of trenchfoot. This circular was amplified on 17 March 1944, in a training directive which specified that unit schedules be revised to include such additional instruction as might be necessary to meet these requirements. Tests were prescribed to determine achievement of the required proficiency.

July 1944 toV–J Day.—Action in respect to training of troops became much more vigorous in the summer of 1944, as the full realization of the cost of the cold injury experience in Italy in 1943–44 became more general.

Weekly Directive No. 31, Headquarters, Army Ground Forces, dated 1 August 1944, pointed out that the alarming number of cases of trenchfoot could be attributed to lack of proper training and command supervision. Immediate and positive steps were to be taken by all commanders to eliminate this deficiency and to comply with current directives, which were listed.

A command letter from Headquarters, Army Ground Forces, was forwarded on 26 August 1944 to all subordinate commands. This letter, which was entitled "Trench Foot and Training in Foot Hygiene," stated that reports received at that headquarters had indicated unsatisfactory ratings in proficiency in the care of the feet and that investigation had showed that sample test questions often did not include this point. Meantime, the rate of trenchfoot cases was alarming. The military importance of such losses was stressed. Attention was called to the various publications available on cold injury, including TB MED 81, which would become available on 31 August. It was directed that "positive and immediate action" be undertaken by all command echelons "to insure adequate training, enforce proper hygiene, and fully indoctrinate all individuals."

Letters to the same effect were sent from Headquarters, Army Ground Forces, to the Commanding General, Second U. S. Army, on 24 October 1944 and to the Commanding General, Fourth U. S. Army, on 30 October 1944. Instruction to date, it was pointed out, had failed to impress the individual enlisted man with basic knowledge concerning cold injury. Additional effort to improve the situation was required. When necessary, further instruction and testing should be carried out on shipboard, en route to theaters of operations.

The information and instructions in this letter were relayed to all commands in the Second Army on 31 October 1944 and followed up the command letter which had been sent from Headquarters, Second Army, on 29 July 1944. In the latter letter, it had been pointed out that reports from overseas and tests conducted by this headquarters had shown a lack of knowledge and appreciation of the prevalence, seriousness, causes, and methods of prevention of trenchfoot. The causes, symptoms, first-aid management, and methods of prevention were briefly outlined, and attention was called to available publications on the subject. Division and separate unit commanders were directed to impress the seriousness of this type of injury upon all officers and noncommissioned officers of their commands.

All units in the Replacement and School Command, Army Ground Forces, received information and instructions concerning cold injury in a letter from Headquarters, Army Ground Forces, on 3 November 1944. The special periods at which this instruction was to be given were listed for the replacement training centers, infantry advanced-replacement training centers, and special-service schools.

At about this time, each division surgeon in the Zone of Interior also received a letter from Brig. Gen. Frederick A. Blesse, Surgeon, Army Ground Forces, emphasizing that instruction in trenchfoot must be given accurately,

must be clearly understood, and must be followed by application of the information, inspections, quizzes, and continuous correction of errors.

After the issuance of these letters, upon instructions of Lt. Gen. (later Gen.) Ben Lear, Commanding General, Army Ground Forces, staff officers from his headquarters, in their inspections of Ground Forces installations and replacement training centers, always put particular emphasis upon proficiency in the care of the feet and in knowledge of trenchfoot. General Lear's stated policy was that each company be given two foot inspections weekly, one by a commissioned officer and one by a noncommissioned officer. Inspecting officers from his headquarters were instructed to assure themselves that this policy was being carried out. They also made spot checks of the condition of the men's feet and of their knowledge of trenchfoot. Special emphasis was placed upon trenchfoot when a surgeon was added to the staff of each replacement center in December 1944, and instruction on medical subjects was increased.

In December 1944, the Office of the Surgeon General prepared an outline for a 15-hour program in military sanitation and hygiene, for a proposed revision of the courses in these subjects in the Army Service Forces officers candidate schools. Lesson No. 2, dealing with personal hygiene, laid special emphasis on foot care and the prevention of athlete's foot and trenchfoot.

An outline of the training program instituted in the European theater after the November 1944 outbreak of trenchfoot contained full information about the prevention of the condition, including both the proper use of clothing and the proper care of the feet. This outline was distributed by Headquarters, Army Ground Forces, as inclosure 1 to a letter dated 20 January 1945, on the subject of prevention of trenchfoot and frostbite (appendix B). A team of three specially qualified officers, one from G–4 (logistics), Army Ground Forces, and two from the Office of the Quartermaster General, was appointed to train instructors at each port of embarkation. The mission of these instructors was to insure that all military personnel passing through ports for overseas assignment received the indoctrination contained in this directive. No man was supposed to leave the port of embarkation for a combat area until his AG Form 20 or 66–1 bore the notation that he had received 2 hours of training in the prevention of cold injury and in the use of the winter combat uniform and other equipment, just as he could not leave without a record of the inoculations required in the area to which he was going.

When a sufficient number of instructors had been trained to cover the various ports of embarkation, similar training programs were set up at the large camps and training centers throughout the country. Courses were also conducted at both embarkation points and training centers for supply personnel, who were instructed how to requisition, fit, and issue the new clothing.

This program was continued until the end of the war. In all, more than 100,000 officers and men were trained by the original team and by the instructors who had been trained by this team. The need for the program was evident

in a single fact, that at no time did any team of instructors encounter units which had already been 100-percent trained.

In the meantime, training was continuing in Army installations throughout the country. A request was made 4 April 1945 by Brig. Gen. Stanhope Bayne-Jones, Acting Chief, Preventive Medicine Division, Office of the Surgeon General, to the Training Division to increase the time allotted to the teaching of sanitation in War Department Circular No. 48, 1944, from 20 hours to 22 hours, to permit increased emphasis upon certain subjects, including fungous infections of the feet and trenchfoot.

Training Memorandum No. 1, Headquarters, Army Ground Forces, 1 June 1945, reiterated the requirements specified in War Department Circular No. 48, 1944. Training Memorandum No. 5, issued from the same headquarters on 16 July 1945, directed that all personnel be given instruction in the capabilities, limitations, use, care, and preservation of clothing and equipment and in the principles of living in the cold. Instructional kits included a wet-cold kit, which contained a complete wet-cold uniform assembly (p. 222), as well as training aids. All of this information, it was stressed, was intimately related to the prevention of trenchfoot. Instruction was to consist of 2 hours for enlisted men and 4 hours for officers. A detailed question-and-answer guide was prepared by Headquarters, Army Ground Forces, and made available to Headquarters, Replacement and School Command, on 17 July 1945. This guide presented the minimum knowledge considered essential for proficiency in basic medical subjects, including trenchfoot.

Mobile Intelligence Training Units, whose function was to aid in the training of redeployed units in subjects of special importance in the Pacific, were set up and supervised by a specially qualified medical officer from Headquarters, Army Ground Forces. These units were trained to put particular emphasis upon the prevention and control of trenchfoot. It was contemplated that a team would be made available to each Army post at which Ground Forces units were receiving redeployment training, but the ending of the war terminated the necessity. At the end of the fighting, 7 teams had been trained and were ready to function, 10 more were in training, and arrangements were under way for the training of 13 others.

In a memorandum, dated 27 July 1945, to the Chief of Staff, Army Ground Forces, General Blesse summarized the steps which had been taken for the training of ground troops in the prevention of trenchfoot from February 1944 to 27 July 1945, as follows:

1. All War Department publications relative to the subject of cold injury and foot care were listed, including War Department Circulars No. 48, 1944, and No. 312, 1944; TB MED 81, 1944; publications in the Bulletin of the United States Army Medical Department; and publication in *Health*.

2. Measures taken by Headquarters, Army Ground Forces, to implement these publications and assure effective training were also listed. These measures included the training directives described earlier in this chapter, training aids,

posters, clinical photographs and models, letters to various divisions and other commands, inspection trips, and a proposed course of instruction in diseases likely to be encountered in the Pacific theater.

This memorandum to the Chief of Staff, Army Ground Forces, was accompanied by the draft of a letter which it was proposed should be sent by Gen. Jacob L. Devers, Commanding General, Army Ground Forces, to each of his major subordinate commanders. The letter reiterated the various points of importance concerning trenchfoot and stressed command and individual responsibility. Attached to it was an enclosure covering all of these points in detail.

General Devers approved the proposed letter and directed General Blesse to prepare a summary embodying the latest information on trenchfoot, to cover concepts and measures necessary for prevention. This was accomplished on 7 August 1945. The summary outlined the causes of trenchfoot, its clinical aspects, individual measures of prevention (clothing, footgear, and care of the feet), and a control program. In the directions for formal training, provision was made for trenchfoot control teams and control noncommissioned officers, in line with the system which had proved so effective in the European theater (p. 177). The facilities and training aids available for this program were listed. Command responsibility for trenchfoot, discipline, clothing, and rotation of troops was unequivocally stated.

The course of instruction mentioned in the correspondence with the Chief of Staff, Army Ground Forces, was to deal with diseases prevalent in the Pacific and was to be given to selected Medical Department officers. The allotment for trenchfoot was 4 hours. The plan was that student officers would indoctrinate their own organizations after they had completed the course. It was proposed that the course should begin on 13 August 1945 and that each course would last for 2 weeks. The plans were cancelled when the war ended on 14 August, and the text being prepared for use in the course in the Office of the Surgeon General was not completed.

HOSPITALIZATION OF TRENCHFOOT CASUALTIES

In the fall of 1944, the vascular center at Letterman General Hospital, San Francisco, Calif., Mayo General Hospital, Galesburg, Ill., and Ashford General Hospital, White Sulphur Springs, W. Va., were designated to receive trenchfoot cases. In January 1945, Brooke General Hospital, San Antonio, Tex., and the Army Service Forces hospitals at Camp Butner, N. C., and Camp Carson, Colo., were designated for the same purpose, with the expectation that one or two additional hospitals might be designated later. During the peak load, in the late winter and spring of 1945, trenchfoot patients were necessarily sent to other hospitals, but no others were formally designated as trenchfoot centers. The original plan was to handle all these patients on medical wards. Later it became evident that surgical wards would also have to be provided.

In planning for the management of trenchfoot cases received in the Zone of Interior, the Ashford experience was used as a sample.[15] Of 135 patients under treatment for cold injury in January 1945, 3 percent had gangrene and would probably require surgery. Sixty-two percent had moderately severe injuries which would require specialized treatment, probably including sympathectomy. The other 35 percent had mild injuries and could be managed in a convalescent hospital.

On the assumption that possibly half of the 18,000 cases of cold injury which had occurred in the European theater in December 1944 would require evacuation, it was estimated that facilities must be provided for from 7,000 to 9,000 casualties from this cause in Zone of Interior hospitals during the first 3 months of 1945. It was further estimated that 5,850 of these injuries would be severe or moderately severe. Since this would be an undesirable and impractical load for the vascular centers designated for the care of trenchfoot, it was suggested that the best plan might be to send all returning trenchfoot patients to the convalescent centers set up at Camp Butner and Camp Carson and to route them from there as beds become available, to the vascular centers for such specialized care as might be necessary.

Later, on 17 January 1945, it was proposed in a memorandum to the Resources and Planning Division, Office of the Surgeon General, from the chief consultants in surgery and medicine that the best plan of management for the minimum of 2,000 trenchfoot patients to be expected each month for the next 3 months would be, after triage at ports of embarkation, (1) to send all patients with gangrene and any loss of tissue, as well as those unable to walk or with serious subjective complaints, to vascular centers, and (2) to send all others to convalescent centers, preferably in a mild climate. This plan was, in effect, finally adopted.

INVESTIGATIONS

The Climatic Research Laboratory at Lawrence, Mass., had as one of its purposes the study of the physiologic effects of clothing and the influence of meteorologic conditions on health in cold climates. In January 1943, representatives of the Preventive Medicine Division, Office of the Surgeon General, began to work with the Research Clothing Board appointed from the Office of the Quartermaster General and already at work in this laboratory.

The Surgeon General, after a visit to the laboratory in December 1944, wrote to congratulate those in charge upon what was being accomplished.[16] He could not, however, agree with the investigations being conducted on trenchfoot. The place to study that condition, he emphasized, was in the field, where it could be determined whether foot discipline was being correctly carried out and whether the clothing recommended "is available to the doughboy in the trench

[15] Memorandum, Lt. Col. R. H. Turner, Medical Consultants Division, for Brig. Gen. Hugh J. Morgan, 13 Jan. 1945, subject: Hospitalization of Trench Foot Cases.

[16] Letter, The Surgeon General, to Col. J. H. Talbott, Climatic Research Laboratory, Lawrence, Mass., 9 Dec. 1944.

or whether it is on the shelves in the depots or in the dumps far to the rear." Trenchfoot was then epidemic in the European theater, The Surgeon General pointed out, in spite of the directives issued for its prevention.

Medical officers were eventually assigned to this laboratory, but the work accomplished there was of little practical value in the control of trenchfoot and came too late, anyway, to influence the situation in Europe.

In March 1945, plans were made for the investigation of certain phases of trenchfoot at the trenchfoot center at Camp Butner, particularly the extent and character of the lesion, the resulting disability, and the determination of objective criteria upon which to base the decision as to fitness for duty.[17] The following techniques were thought to be most promising: Lange's fluorescein procedures, both visual and instrumental; measurements of foot volume by the water-displacement technique, both before and after the foot had been subjected to heat, cold, and the stress of physical activity; changes in the temperature and color of the skin of the extremities in response to posture and environmental temperature as measured by the electric skin thermometer; capillary microscopy, in spite of the known limitations of this technique; foot-pattern studies by the technique of Silverman and Howell, to trace the relation between nerve injury and abnormal sweating; plethysmography, with special reference to the toes; and the histamine wheal.

Since it was obviously impossible for the staff of a single center to undertake all of these studies, it was decided that the investigations at Camp Butner should be limited to the fluorescein technique in severe trenchfoot; foot volume studies in milder trenchfoot; and studies in sweating, including plethysmographic studies, in an attempt to throw light upon the nerve and vascular lesions of trenchfoot. The war ended before any of these special studies were set up.

CONCLUSION

The annual report of the Surgical Consultants Division to The Surgeon General for the fiscal year ending 30 June 1945 read, in part, as follows:

> During the two winters when American forces were suffering heavy casualties from trench foot much was written, said, and done about this condition. In fact, an uncritical observer might readily conclude that despite all that was done a high incidence of the condition resulted and that trench foot, after all, is not preventable. Any historian or student of the subject who in the future may be reviewing the trench foot experiences of American Armies during this war in order to maintain a proper perspective must constantly ask himself two questions:
>
> (1) What was the situation at the time this publication was printed or this action taken?
>
> (2) Was the information in this publication or this action felt by line officers and soldiers in the field at a time when it would be effective?
>
> Trench foot does not occur during summer months. It is a condition which occurs as a result of prolonged uninterrupted exposure to cold and wetness. In order for troops to pro-

[17] Memorandum, Medical Consultants Division for Brig. Gen. Hugh J. Morgan, 31 Mar. 1945, subject: Trench Foot Studies.

tect themselves, they must be thoroughly educated and informed on the subject *before* these weather conditions are encountered. Training troops on a subject of this type after they are engaged in intensive combat is less effective than training them during a period prior to such action. The main concern of men engaged in combat is the preservation of their lives. Attempts to teach men under such conditions measures for preventing trench foot, which to them is seemingly unimportant at the moment, are not likely to meet with any great degree of success.

For all practical purposes, this quotation summarizes the experience of the United States Army with cold injury in World War II and points the way to its prevention in any future war. No one realized the significance of this type of injury early in the war. Many did not appreciate it until very late. The Surgical Consultants Division, in the Office of the Surgeon General, first appreciated the danger and for some time was the only division of that office to study and report cold injury and to recommend the appropriate command and staff action.

The prevention of trenchfoot, as has been repeatedly stated, is primarily a command, not a medical, responsibility. Higher command and staff echelons were in the beginning almost totally unaware of the medicomilitary dangers of cold injury. Until losses from it became serious, they did not fully accept their responsibilities for it.

The Surgeon General had the responsibility for the health and medical care of the Army, but he could normally convey his recommendations to the highest echelons of the War Department only through what were, in effect, command and logistic channels. By virtue of his position on the staff of the Commanding General, Army Services Forces, he was responsible to, and reported to, that officer. As a consequence, he had, as a rule, little direct access to the Chief of Staff or to the Secretary of War.

An additional difficulty arose from the fact that the activities of The Surgeon General and, indeed of the entire Medical Department, were, of necessity, closely allied with logistics. Frequently, and for obvious reasons, logistic personnel without medical knowledge failed to realize that medical care, in its broadest definition, cannot be placed in the same status, or administered in the same fashion, as rations or ammunition.

In the opinion of many observers, the situation just described considerably reduced The Surgeon General's authority and diminished the effectiveness of such actions as he could take or recommend. This fact unquestionably played a part in the cold injury epidemics which occurred in World War II. Close liaison did not exist between his office and that of the Chief of Staff. When The Surgeon General made recommendations pertaining to the prevention of cold injury, they normally reached the Chief of Staff or the Secretary of War only through command channels, that is, through the Commanding General, Army Service Forces. Considerable evidence exists to show that until planning for the final operations in the Pacific was begun The Surgeon General's numerous warnings did not reach higher authority and that none of them reached the theaters of operations. It is quite conceivable that, if these plainly worded

warnings, many of which antedated the official publications (WD Circular No. 312 and TB MED 81), had fulfilled their purpose, the incidence of cold injury might have been a great deal lower than it was.

Many of the medical lessons of World War I, like many of the strictly military lessons, had to be relearned in World War II because the experiences of the First World War were ignored. That was true of cold injury. Eventually, but only after grave losses had been suffered in the Aleutian Islands campaign and in the Mediterranean and European theaters, measures of prevention and control were instituted, and training in trenchfoot prevention became part of the training program of Army Ground Forces. All concerned must accept the responsibility for failure to institute them early enough to prevent most of the thousands of casualties which occurred from this cause during World War II. The influence of the Medical Department was exerted toward this end earlier than that of any other branch of service and was also exerted more continuously. The Surgeon General, however, was handicapped by the anomalous position which he occupied in respect to higher authority. Whether a greater effort should have been made to exert such influence as he possessed is a matter for debate. In retrospect, it seems that a more vigorous effort probably should have been made.

CHAPTER V

The Aleutians [1]

In February 1941, the Territory of Alaska, in which a United States Army garrison had been maintained for some 75 years, was designated as the Alaska Defense Command. The first surgeon of the command was appointed the following December.

The conditions under which troops originally served in this area in no way resembled combat conditions. The weather, on occasion, was extremely cold, but the barracks to which the men returned were warm and comfortable, and their food was always excellent.

The clothing which was used by troops in Alaska was patterned after that worn by the Eskimos and was made of furs, which could easily be provided in sufficient amounts for a limited number of soldiers. Both clothing and equipment were slightly revised in 1928, but otherwise the issue remained unchanged until 1940. In 1935, however, when the aggressive policies of Japan began to indicate the possibility of war and when developments in airpower made it clear that Alaska was highly vulnerable to air attack, clothing for cold weather became a subject for scientific research, and many new and improved items were available by the time of the Aleutians campaign in 1943 (fig. 18).

Throughout the war, occasional cases of frostbite occurred among United States troops stationed in Alaska, and some cases of immersion foot also occurred in this area in fliers forced down at sea. On the whole, however, cold injury was of no great consequence because the troops were well fed, they had superior equipment and used it correctly, and they were trained in techniques of prevention of cold trauma, especially frostbite. On one occasion, 17 of 21 men engaged in a practice maneuver over the Valdez Glacier were frostbitten, and on another similar maneuver, near Nome, 126 men, 23.6 percent of the total strength, were also frostbitten. In both instances the explanation was not only highly unfavorable weather conditions but also neglect of the precautions essential under such conditions. Elsewhere in the command, the number of cases was small because line officers and medical officers alike were very much aware of the necessity for such measures.

The situation in the Aleutians was very different from that in Alaska. Because of the location of these islands, far out in the Bering Sea, the dry cold of the Alaska Peninsula is replaced by wet cold. Most of the task force which invaded Attu had not been trained in the prevention of cold injuries. They had to subsist on combat rations instead of hot, regular meals. Many items of

[1] Unless otherwise indicated, all material in this chapter was secured from McNeil, Gordon H.: History of the Medical Department in Alaska in World War II, pp. 401–477. [Official record.]

U. S. Army photo

FIGURE 18.—Properly equipped and clothed soldier advancing in snow, in scout position, Aleutian Islands.

their clothing were unsatisfactory. The background of these difficulties and deficiencies was, of course, that the men were engaged in combat and not in the peacetime garrison duties in which the troops in Alaska had been engaged up to the outbreak of the war and in which, for all practical purposes, they continued to be engaged throughout the rest of the war.

THE ATTU CAMPAIGN

Attu and Kiska, where the first cold injuries were sustained by United States troops under combat conditions in World War II, were occupied by the Japanese, without opposition, in 1942. Attu was retaken by Allied (chiefly American) forces in May and June 1943, and Kiska was retaken, without opposition, by forces of approximately the same components in August of the same year.

The force which invaded Attu, consisting of about 15,300 men, required 22 days to take the island. It sustained a total of 3,829 casualties from all causes (table 2). Cold injuries, which numbered 1,200 up to 1 June, exceeded the number of casualties caused by wounds (1,148) and accounted for more than 31 percent of all casualties from all causes. After 1 June, only scattered cases occurred. Seven patients with cold injuries were admitted to the shore hospital on 12 May, 146 were admitted on 16 May, and 191 were admitted on 17 May.

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TABLE 2.—*Battle casualties and admissions for disease and nonbattle injury, Allied troops on Attu, 11 May through 1 June 1943*

[Rate expressed as number per day per 1,000 average strength]

Cause	Number	Rate
Battle casualties:		
Killed in action	549	1. 6
Wounded in action	1, 148	3. 4
Nonbattle admissions:		
Disease	614	1. 8
Nonbattle injury	1, 518	4. 5
Cold injury	[1](1, 200)	[1](3. 6)
Other	[1](318)	[1](. 9)
All causes	3, 829	11. 4

[1] Figures in parentheses are subtotals.

The invasion began 11 May. The theater policy was to evacuate to the Zone of Interior all patients who, it was thought, would require more than 21 days of hospital care, and by 1 June, 241 casualties from cold injury had left the island. By the same time, 691 had been returned to duty. Although this fact might suggest that many of these cold injuries were of mild degree, generalizations would not be warranted. Of 93 patients with trenchfoot treated at the 183d Station Hospital, Fort Richardson, Alaska, for instance, 14 were discharged to duty as cured and the other 79 were discharged as improved, but a considerable number of these men were unable to continue their duties and were subsequently returned to the hospital for further treatment.[2] Recurrence, or perhaps recrudescence, of their original injuries also explained many of the casualties from trenchfoot during the later Kiska operation (p. 99). Furthermore, during the winter of 1943–44, men who had been discharged as cured after the Attu experience began to appear with complaints of various subjective symptoms as well as with such objective signs as redness, cyanosis, and excessive perspiration.

Only 6 of the 93 cold injuries treated at the 183d Station Hospital were graded as third degree and only 1 as fourth degree. Nonetheless, in these 93 cases alone, a total of 5,827 days was lost from duty. The potential seriousness of this condition from the standpoint of military manpower is evident from these figures, which do not take into account the expenditure of medical care, including hospital bed space, and the tax on military transportation caused by these injuries.

[2] Annual Report, 183d Station Hospital, 1943.

Tactical Situation, Environment, and Weather

D-day on Attu was originally set for 7 May, the plan being that the troops should sail from Cold Bay on 4 May. Because of bad weather, the invasion had to be postponed to 11 May. The landing was unopposed, the enemy having withdrawn from the beaches to occupy the high central ridges. From these vantage points, they could descend to within the fog line, which was at times within 500 feet of sea level, where they could see without being seen and could effectively pin down attacking units in waterlogged foxholes in the boggy tundra.

As a result of the dense fogs, the landings began later than had been planned, and the second wave of troops was not landed until almost 8 hours after the first.[3] The operational plan, which was to take the island in 38 hours, thus proved completely unrealistic. Later, it was agreed that the task force would have done well if, within this time and without meeting any opposition at all, the troops had merely walked over the ground which they were scheduled to take.

Opposition from small-arms fire and mortars was encountered within 1,000 yards of the beach, and the initial main line of resistance from Massacre Bay was about 2,000 yards. For 6 days, there was practically no forward move-

U. S. Army photo

FIGURE 19.—Tractor and trailer mired down near the beach, Massacre Bay, Attu 19 May 1943.

[3] Orr, R. D.: Report on Attu Operations May 11-June 16, 1943, dated 30 July 1943.

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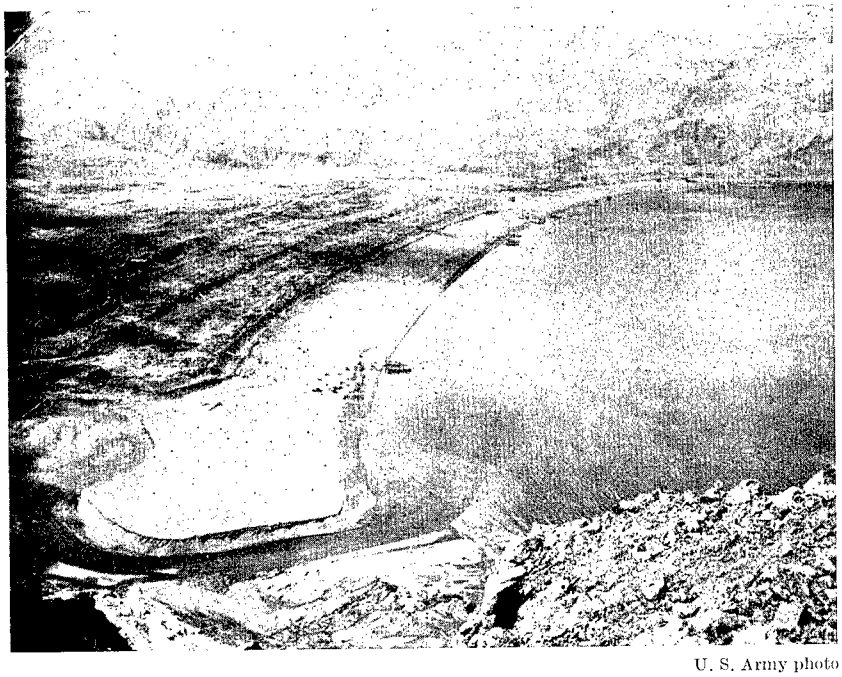
ment of American positions. The artillery never left the beaches because the guns could not be pulled over the tundra, and firing was at maximum ranges throughout the battle (fig. 19). The Japanese launched a desperation (banzai) attack on 29 May against American infantry positions and so exhausted their own fighting strength that by 2 June all organized resistance was at an end.

Both terrain and weather served to make the conquest of Attu an extremely difficult operation. Attu and Kiska are islands far out on the Aleutian chain, in the Bering Sea, about due north of Midway. The terrain on both is rugged and mountainous. The elevations are not particularly high, but when bad weather is added the conditions are comparable to those in altitudes twice as high in milder climates. On Attu, where peaks and ridges rise to 3,000 feet above sea level, the heavy winter snowfall remains on some of the higher points throughout the summer. There is an almost complete absence of natural shelter. The ground cover is boggy tundra, without trees (fig. 20).

The air on Attu is continuously cold, even on the occasional sunny days. There are long months of wind, fog, rain, snow, sleet, and mud. A man walking along a road on an ordinary day may suddenly, even when the sun is shining, be struck by a terrific gust of wind, which blows sand, snow, and rain in his face, all at the same time. An observer from the Office of the Quarter-



U. S. Army photo

FIGURE 20.—Landing beach in Holtz Bay area, Attu, seen from top of ridge separating Holtz Bay and Chichagof Bay. The steep, jagged crags, knifelike ridges, and boggy tundra greatly impeded the movement of the troops and made any extensive use of mechanized equipment entirely impractical.

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master General,[4] who had spent February, March, and April on other Aleutian Islands, commented on the weather of the region as follows:

> * * * one needs a pretty strong imagination to get the full flavor of it (even if you have previously heard of it). In one day I have seen it cold and snappy in the early morning with light snow on the ground, followed by warm, Springlike sunny weather, followed by a blizzard of very small hail-like snow, followed by sun, followed by rain, etc. The mud is often more than knee deep, and generally is of a very slushy type * * *. More often than not a biting wind whips the rain, snow and sand (where there is any) about all day and all night.

During the campaign, the weather, for the Aleutian Islands, was reasonably good.[5] Light rain is known to have fallen on 4 days between 22 and 27 May, from 4 to 12 hours at a time, and light snow fell on 23 May, for 12 hours. During the same period, the wind velocity ranged from 20 to 36 miles an hour most of the time. On 3 of the days between 22 and 27 May, there was fog for 8 hours at a time. Reports submitted by a vessel and weather station in the vicinity show that, between 11 and 27 May, the temperature averaged between 25° and 30° F. (−3.9° and −1.1° C.) in the valleys (1,000 feet) and between 33° and 37° F. (0.5° and 2.8° C.) at sea level. On the highest ridges, where there was considerable combat, the average temperature was 24° F. (−4.4° C.) and the minimum 10° F. (−12.2° C.). The men were constantly exposed to cold and dampness, often for several days at a time without relief. The foxholes were always filled with water, and the troops, of necessity, remained in them for hours at a time. There is evidence that many of the troops found the cold, damp, wet weather harder to endure than the enemy fire.

Medical Care and Evacuation

Planning for Attu called for medical care to be provided through aidmen, battalion aid stations, collecting platoons, clearing stations, field hospitals, shore-party medical sections, and the Navy medical service aboard ship. Revisions were inevitably made. The first principle of treatment of cold injuries is that the casualties should not be permitted to walk, even if they feel able to do so. Many of the injuries sustained on Attu were so severe that the men were scarcely able to walk, but, because of the difficulties of evacuation, many of them had to walk; some of them crawled. The wheeled litters which had been brought ashore were useless, and evacuation had to be by hand carry, because of the precipitous slopes of the mountainous terrain in which most of the fighting occurred. Aid which was but a few miles away in direct line was often hours away by litter carry. Casualties often had to be taken down cliffs by ropes, pulleys, and improvised elevators.

The task force surgeon, utilizing elements of the 14th Field Hospital and personnel from an antiaircraft artillery unit and a shore-party medical section, improvised and set up a small convalescent-type hospital on the west side of

[4] Letter, 1st Lt. Robert D. Orr, to the Quartermaster General, attention: Col. Georges F. Doriot, 17 Apr. 1943.
[5] See footnote 2, p. 85.

Massacre Bay on 16 May (fig. 21). Patients who had sustained moderately severe exposure were treated here after they had been evacuated from field hospitals. Evacuation from the island was by boat and plane to Adak and thence to Fort Mears, Fort Greely, and Fort Richardson. Most of the severely wounded casualties were evacuated by ship or were flown directly to the Zone of Interior. The air evacuation planned from Attu to Fort Richardson did not prove practical, but special flights were arranged from the 183d Station Hospital to Barnes General Hospital, Vancouver, Wash.

U. S. Army photo

FIGURE 21.—Field hospital on Attu. It was set up and in operation the day after the landing.

Clothing and Footgear

When the invasion of Attu was being planned and organized, cold-weather specialists from the Special Forces Section, Office of the Quartermaster General, were sent to the Alaska Defense Command for observation and for advisory purposes. They recommended that special types of footgear and clothing be selected for the invasion, but their advice was not accepted. The items used were chosen without sufficient consideration of the special environmental conditions certain to be encountered, as well as without due evaluation of the newly developed cold-weather equipment. The sole responsibility for the high incidence of casualties from cold injury cannot, of course, be placed upon a single erroneous decision, but later analyses indicated that failure to use the

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special Arctic equipment which was available was probably the explanation of many cases.

Clothing.—There were numerous adverse comments on some of the clothing supplied for the invasion, although, as just noted, the selection had been a deliberate command decision, and more efficient types had been available. Specific comments were as follows: [6]

The issue olive-drab woolen trousers did not provide the protection which kersey-lined trousers would have provided. The issue trousers had been waterproofed, but, under the conditions of combat and terrain, the material was not sufficiently durable to remain impervious to moisture for more than a few days.

The Arctic field jacket did not furnish the protection against wind and rain which the lightweight reversible ski parka would have provided. In addition, the field jacket had no hood.

Sweaters were not permitted, though experience in Alaska had shown them to be a real necessity in extreme cold.

The parka overcoat was not originally intended to be part of the equipment, but a certain number had been picked up at the rendezvous point when the task force first encountered the severity of the Aleutian weather. The supply, however, was not sufficient. Furthermore, while this overcoat furnished excellent protection for men who could remain relatively immobile, it was not satisfactory for active combat.

The troops were not permitted to wear their rainsuits ashore, and therefore, since their clothing was not water repellent, many of them were drenched immediately. The rainsuits were in rucksacks, which usually did not reach the men in the frontlines until several days after the initial landings.

Since rucksacks were entirely too bulky to be carried ashore by the troops, the operational plan was that they would be brought forward by nightfall of the first day of the invasion. The men would thus have sleeping bags, rainsuits, and other equipment, to supplement the small amount which they had carried ashore with them in the canvas field bags attached to their belts. The delays in landing and the difficulties of terrain and weather made the implementation of this plan completely impossible. Once supplies could be landed, ammunition and food had to be brought forward before clothing. As a matter of fact, few men in the frontlines ever received their rucksacks.

Whenever it was possible, sleeping bags were removed from the rucksacks on the shore and were sent forward as conditions permitted. Few troops, however, received them before the fourth or fifth day, and until that time the men had no protection during sleep, when sleep was possible, except from the shelter halves which they had carried ashore in their field bags. Had the sleeping bags been received earlier, it is highly probable that some cases of trenchfoot could have been prevented. One unit which obtained its bags on the second and third days and could hold on to them throughout the campaign experienced almost no cold injuries.

[6] See footnote 3, p. 86.

After the invasion,[7] it was suggested that the Arctic sleeping bag which had been used, and which was too bulky to be carried on the person, should be replaced by a model small enough to be carried into combat, with the same lining as the Arctic bag and with a waterproof outer covering. During his periods of rest, it was reasoned, the soldier equipped with this bag could rest in it with his boots and socks off and could dry his socks inside the bag by body heat. The Quartermaster General's Office,[8] replying to the criticism of the sleeping bag used during the Attu campaign, stated that the bag had been badly chosen. The model selected should have been either the inner lining of the Arctic bag or the mountain sleeping bag, both of which could be used with a water-repellent case. It was also pointed out that tests had shown that a fully waterproof covering for a sleeping bag was not practical, since condensation of moisture from the body within the bag would set up conditions favorable in themselves for the development of trenchfoot.

Footgear.—The shoepac recommended by the observers from the Quartermaster General's Office had a number of admitted defects, including lack of an arch support, but it was relatively waterproof, because of its rubber sole, and it kept the feet warm. The blucher boot for which it was passed over was a model which reached to about 4 inches below the knee (fig. 22). This boot had a number of disadvantages. It did not keep the feet warm. It was not waterproof, even when dubbing was regularly applied to it. It did not wear well; some soles were worn through in 4 to 6 weeks. Once it became wet, it could not be thoroughly dried under conditions of combat. The leather tended to contract, and the tight fit, combined with tight lacing, resulted in embarrassment of the circulation to the feet. Most of the fittings were originally too snug, since no attention had been paid to the plan that the boot be worn over two pairs of socks, one of them woolen. Finally, the steel support in the heel was not carried high enough, so that the boot broke against the Achilles' tendon and a severe traumatic tenosynovitis was sometimes added to the disability caused by cold. A possible explanation of this particular complaint was that many of the troops had been issued their boots on shipboard and had no opportunity to break them in before they were landed on the Attu shore.

The only troops equipped with shoepacs for the invasion of Attu were men who had had long service in Alaska. This type of footgear was therefore not universally tested in combat in the Aleutians (fig. 23).

Japanese clothing and footgear.—There is no evidence that the Japanese on Attu sustained cold injuries to anything like the degree that the Americans sustained them. The Japanese were favored by their occupation of higher ground, it is true, and were less often immobilized. On the other hand, they were more suitably clothed, and they seem to have had better footgear. They

[7] Memorandum, Maj. Gen. LeRoy Lutes, Director of Operations, Army Service Forces, for Quartermaster General, Army Service Forces, attention: Storage and Distribution Division, 3 Oct. 1943, subject: Report of Operations on Attu.

[8] Memorandum, Research and Development Branch, Military Planning Division, to Operations Branch, Military Planning Division, 13 Oct. 1943, subject: Report of Operations on Attu.

U. S. Army photo

FIGURE 22.—Combat-type boots supplied to infantrymen on Kiska after occupation. Staff sergeant supervises fitting, while private at right boxes ammunition.

wore hobnailed, fur-lined rubber boots, which extended to just below the knee. A rolled legging, applied outside the boot just below the top, kept most moisture out of the boot, even if the wearer stepped into water above boot-top level. Some American troops, in spite of the risk of being shot by their own comrades, equipped themselves with Japanese caps, hoods, and boots as they became available.

Training and Discipline

The task force which recaptured Attu consisted chiefly of units of the 7th Infantry Division, plus a battalion from the 4th Infantry Division, which had had 2 years of service previously in Alaska. The units which bore the brunt of the fighting had been trained as a motorized infantry division at Fort Ord, Calif., and in the Mojave Desert, and then had undergone amphibious training on the California coast. Nothing in their previous training and experience fitted these troops for the climate and terrain which they were to encounter on Attu.

Specifically, these troops had not been trained to care for their feet. They did not understand that they must remove their boots at frequent, regular intervals, change their socks, and dry their insoles. Some of them did not remove their boots for 5 days or even longer, after the landing. When they

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U. S. Army photo

FIGURE 23.—Shoepacs worn during occupation of Kiska. The soldier is treating them according to the method used by experienced Alaskan sourdoughs.

finally took them off, they could not replace them because their feet had swelled. Many soldiers threw away their wet socks without making any endeavor to dry them. Often, when the terrain made going hard, the men discarded their cold-weather clothing. Many of them, when they received their sleeping bags, made little or no effort to keep them dry.

Preventive measures are not easy to accomplish under the conditions in which these soldiers worked and fought, and the total accomplishment of such measures was obviously impossible. The underlying fault, however, was that none of the troops had been taught that every effort must be made to accomplish them, in spite of adverse circumstances. There is no doubt that the effort would have paid dividends in the prevention of trenchfoot.

Some of the troops trained at Fort Ord were brought from California by surface water transport and could change their shoes and socks regularly up until the time they entered combat.[9] Others, who were brought up by submarine, could not change their footgear during the journey because of cramped quarters and the constant alert status which had to be maintained. The advance troops, who were landed in rubber boats, were instructed to discard all of their equipment as soon as they made contact with the enemy. Their feet and legs became soaked as they landed, and, because additional boots and socks were lacking as the result of this order, they remained wet, even when

[9] Lesser, A.: Report on Immersion Foot Casualties from the Battle of Attu. Ann. Surg. 121: 257–271, March 1944.

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occasional opportunities would have permitted a change of footgear. The men spent most of their time in foxholes filled with icy water and cold slush, usually in cramped, inactive positions, with little food, and without any real physical rest or sleep during their whole stay on Attu. They had not been taught such simple precautions as moving their feet in their shoes or exercising their legs, and they therefore did not employ even the limited prophylactic activity which is possible under almost any conditions.

The differences between training and lack of training were immediately obvious.[10] A provisional battalion, consisting of the 7th Reconnaissance Troop and the 7th Scout Company, had a particularly hazardous mission, for which special clothing was requisitioned and supplied. These men were completely untrained for fighting in cold weather, and, by order of higher authorities, none of the special equipment just mentioned was issued except pistol covers. At the end of 5 days, 30 of these 350 men had been killed or wounded in action and only 40 of the remaining 320 were still able to walk.

In contrast, one of the battalions which spearheaded the attack had battle casualties as high as any unit engaged in the operation, but it had only eight casualties who required evacuation because of trenchfoot. The men in this battalion had been well taught. They had foot-care drills and were paired off in what they themselves termed the "buddy" system, whereby foot-conscious soldiers worked on each other's feet. Attempts were made to supply lubricants for their boots and ointment for their feet at least once daily, with the realization that the virtue of the application to the feet was in the massage and not in the agent used with it. Whenever possible, provision was made to relieve all the men, especially the outposts, for a few hours each day. During this interval of relief, the men removed and dried their shoes, changed their socks, and rested in their relatively dry sleeping bags.

Generally speaking, the severity of a cold injury was directly proportionate to the length of time during which the footgear was not changed.[11] Fifteen of twenty-five patients observed at McCaw General Hospital, Walla Walla, Wash., who had been taken to Attu by surface water transport, went from 3 to 6 days in combat on the island without change of footgear. All had rather mild degrees of trenchfoot. The other 10 men, taken to Attu by submarine, averaged an additional 10 days in combat without change of footgear, and all had severe injuries with gangrene.

Another illustration of the value of training is seen in the experience of a detachment of 30 men of the Alaskan Scouts, the combat intelligence platoon of G–2, Alaska Defense Command.[12] These men were trained for the climate and terrain. They were properly acclimated. They knew what to expect and how to take care of themselves. They fought through the entire Attu campaign under the most unfavorable possible environmental conditions, and they were still serving as a reconnaissance patrol long after the last organized Japanese

[10] See footnote 3, p. 86
[11] See footnote 9, p. 93.
[12] See footnote 3, p. 86.

resistance had ended. Their casualties consisted of 1 man killed in action, 2 wounded in action, and 1 with a slight cold injury.

Physical Status

Practically all of the men engaged in the Attu operation were young and in good general condition. They were free from such constitutional diseases as arteriosclerosis, cardiorenal disease, and diabetes, which complicate the majority of cases of peripheral vascular disease observed in civilian practice. They had not suffered from dysentery, malaria, and the other debilitating diseases which complicated the management of so many battle and nonbattle injuries in certain other theaters of operations.

Because these troops went directly into combat from a noncombat status, they had not previously been subjected to prolonged dietary insufficiencies, though they had hot food only infrequently during the period of active fighting. They did not, however, because of lack of training, make use of the concentrated rations with which they had been supplied. Because they had not been taught the importance of eating their rations, whether they liked them or not, and the necessity for eating them to keep up their resistance, they threw away whatever they did not like. Among the provisions, for instance, was fortified dried lemon juice, to provide vitamin C. It was not palatable, and most of the men threw it away. As a result, a few instances of incipient scurvy were observed before the campaign ended. There was apparently no relationship between this minor vitamin deficiency and the cold injuries which occurred, although it was speculated that such a correlation might have developed if the campaign had lasted much longer.

Individual Susceptibility

Wide variations in individual susceptibility to cold and wet were observed among the men taking part in the Attu operation. If a group of 3 soldiers spent the night in a forward observation post, 2 might return with no complaints, or with minimal complaints, while the third would have numb, mottled, swollen feet. Among 224 patients observed at Letterman General Hospital, San Francisco, Calif., the average duration of exposure was about 6.5 days.[13] One hundred and sixty-five (74 percent), with exposures varying from 3 to 14 days, presented only desquamation of the skin. Thirty-three (15 percent), with exposures varying from 4 to 11 days, had lost toenails, tips of toes, and thick layers of skin. Twenty-three (10 percent), with exposures varying from 4 to 9 days, had lost one or more toes or portions of their feet. Three men who required amputation of both feet had been exposed 4, 6, and 8 days, respectively.

[13] Patterson, R. H.: Effect of Prolonged Wet and Cold on the Extremities. Bull. U. S. Army M. Dept. No. 75, pp. 62–70, April 1944.

One patient at Letterman General Hospital, who had gangrene of both feet up to the level of the metatarsophalangeal junction, was found to have suffered previously in civilian life from frostbite of both feet.

Other Etiologic Factors

At least two other factors, in addition to those already discussed, played a part in the production of cold injuries on Attu:

1. Many of the men, in their natural desire to get warm as fast as possible, wrapped up their cold feet and exposed them to heat. Most of them had not been warned that this was the worst possible thing they could do.

2. The incidental trauma of walking over rough terrain on numb feet added to the damage already done by wet, cold, and constriction. It was recognized that walking was harmful, but it has already been pointed out that, as a matter of necessity, patients who could be ambulatory often had to be, since litter carries over tundra and down steep, snow-covered ridges were slow and exhausting work and personnel to move the injured were always in short supply.

THE OCCUPATION OF KISKA

The operation on Kiska, which began 15 August 1943 and was concluded 31 August 1943, was being planned and organized while Attu was under assault. The task force for this landing consisted of the 87th Mountain Infantry Regiment; the 184th Infantry Regiment, which had been trained at Fort Ord; the 17th Infantry Regiment (minus), which had been transferred from Attu; the 53d Infantry Regiment of the Alaska Defense Command; and the 13th Canadian Infantry Brigade. The last three components joined the force at Adak, just before the landing. The others had been assembled at Adak and Amchitka in the central Aleutians, for several weeks of training.

After these troops were landed, it was found that the enemy had fled before the invasion had occurred, though the fact of their evacuation was determined only after a slow, cautious search of the entire island. There were no true battle casualties, but there were 28 deaths and 50 injuries from accidents and from fire due to mistaken identity.

The terrain was difficult. The land everywhere was cut by fresh-water lakes and streams. Hills and valleys were covered with tundra, which a Royal Canadian Army surgeon [14] graphically described:

> Walking on this growth is like walking on a gigantic spring mattress, into which one's feet sink for a foot or more with each step that is taken * * *. During the warm weather the surface thaws to form a vast bog, or tundra-moor, which is probably unequaled anywhere in those qualities of cohesion and adhesions which make mud the objectionable surface that it is.

[14] Lane, G. A.: Medical Experience with the 13th Canadian Infantry Brigade at Kiska. J. Canad. M. Service 1:282–288, May 1944.

Although the terrain on Kiska, as this description suggests, resembled that on Attu, the general situation was not as difficult, chiefly because of the timing of the invasion. The invasion of Attu occurred in May, when there was snow on most of the hills and snow water running down all of them. During this invasion, there were no dry surface areas until after Japanese installations could be occupied. Level spaces were all marsh, and there was an incredible amount of moisture in and under the tundra on sharp declivities. The invasion of Kiska occurred in August, when there was no snow and when the runoff had largely stopped, except for springs and water courses. Since there was no combat, these could be avoided. Once the troops got away from the landing beaches and the adjacent swamps, they could be on fairly dry ground most of the time. Also, the sun shone for an hour or two daily during most of the period of occupation, and it was therefore possible to dry out in the sun.

Other circumstances were also much more favorable than on Attu. There had been an excellent liaison between the 7th Infantry Division units on Attu and the training authorities at Fort Ord, with the result that the troops who went to Kiska from that area were trained and equipped in the light of the Attu experience. Men physically and mentally unequipped for Army life had been cleared from the unit before it was dispatched to Kiska. The troops who had fought on Attu were acclimated and knew what to expect of weather and terrain. All the men had been given careful instruction for protecting themselves in cold, wet weather, had been trained in foot care, and had been given foot inspections before landing.

Clothing and footgear, although not entirely satisfactory, were a great improvement over what had been selected for the Attu landing.[15] The men went ashore with Alaskan field jackets, parkas, rainsuits, kersey-lined trousers, and tocques to protect the face. Their garments were all water repellent, though in the opinion of some observers only fully waterproofed garments would have been really adequate for the conditions encountered. Shoepacs were used universally. This was a wise decision, though the model employed was not satisfactory in many respects. Most of the men were fitted with such large sizes that their feet had little support. The shoepacs were also cut too low to furnish any protection when troops had to wear them ashore on the beaches, or when much activity in deep mud was required. The shoepacs were also less effective than the low leather boots worn by the Canadian brigade. Nonetheless, they were a great improvement over the blucher boots worn in the Attu invasion.[16]

In addition to the general indoctrination already described, troops who participated in the Kiska operation were furnished with a small handbook

[15] Memorandum, Director of Operations, Army Service Forces, for The Quartermaster General, attention: Military Planning Division, Col. G. F. Doriot, 7 Oct. 1943, subject: Report of Observer on Kiska Operation, Clothing and Equipment.

[16] A medical officer who participated in the occupation of Kiska wrote as follows about footgear: "My personal experience was that the best footwear for me was the regular Army boot over which I wore a standard overshoe (galosh). This assured relative protection from wet terrain and permitted me to open the overshoe and allow the feet to dry as soon as the opportunity presented. Thus, even though my feet tend to perspire readily, I was able to keep them dry most of the time and to allow proper circulation at all times. This combination was arrived at by trial and error, and proved much more satisfactory than the shoepac, combat boot or knee-length rubber boots. Of course, the latter would have been necessary if I had been standing in water of any depth."

entitled "Soldiers Manual (How To Get Along in the Field)." The foreword to the troops was written by Maj. Gen. Charles H. Corlett, who commanded the task force (ATF9). The suggestions had been collected by General Corlett's staff and had been compiled by Capt. (later Maj.) Roy L. Atteberry, Jr., who, said the introduction, "* * * has had much experience in our future hunting grounds. He knows the score."

The introduction pointed out that the soldier had two major jobs. The first was to do the military job he had been taught to do. The second was to spend the rest of his time keeping himself and his equipment in the best possible condition. It was to help in the second job, said the introduction, that this pamphlet had been prepared.

The pamphlet contained sensible instructions for the care of the feet before and during combat; instructions for the use and care of socks, including the statement that a pair of spare socks was the most valuable piece of extra clothing a soldier could possess; and a description of, and instructions for the use of, shoepacs. It was pointed out that, though the soldiers had probably never worn them before, shoepacs had been selected as the best type of footgear for mud and water; that they had been purposely fitted oversize to take care of extra socks and insoles; and that they should be laced loosely. Instructions were also given for moving the feet, toes, and legs, even in foxholes in combat. Noncommissioned officers were reminded that one of their most important duties was to see that their men took care of their feet.

Other sections of the pamphlet dealt with the proper use and care of clothing and other cold-weather equipment; with the importance of eating the rations that had been provided, heating them when possible, and saving what was left; with the importance of drinking tea, for which teabags could be used; and with the means of keeping foxholes dry. Two cartoons showed what happened to soldiers who left their equipment behind and suffered from the cold as a result.

Incidence of Cold Injury [17]

The approximately 28,450 troops who participated in the occupation of Kiska suffered a total of 130 cold injuries. In spite of the training given them before landing, some of these casualties admitted that they had failed to follow instructions given them and did not remove their shoepacs and socks for several days at a time.

The footgear used seemed to influence the incidence. The Canadian brigade, whose footgear was thought to be better than that worn by American troops, sustained only 1 trenchfoot casualty in their strength of 5,326 men. Their rate of 2 per 10,000 for the 15-day period of the operation was far lower than the comparable American rate of 55.6 per 10,000, according to the report submitted by the surgeon of the task force at the conclusion of the operation.

[17] Letter, Col. L. R. Moore, MC, Surgeon, Headquarters, Alaskan Department, to The Surgeon General, 4 Dec. 1943, subject: Medical Service, Occupation of Kiska, Alaska.

It is doubtful that the somewhat better weather in which the Canadians landed accounted for this considerable difference.

The use of lanolin for massage of the feet seemed of doubtful value. The 87th Mountain Infantry Regiment, which used it before disembarking, suffered 7 casualties from trenchfoot in a strength of 5,517 men. The 184th Infantry Regiment, with a strength of 5,999 men, did not use it and had 15 casualties from trenchfoot. This is not a significant difference.

The high incidence of cold injury in the 17th Infantry Regiment, which had 76 cases in a strength of 3,906 men, was thought to be related to their previous exposure on Attu. The environmental and other circumstances under under which they operated were no worse than those of any of the other troops, and it seemed logical to explain at least some of their injuries on the basis of pathologic changes present as the result of the earlier experience. A number of men in this regiment were evacuated and were classified as casualties due to cold because it was feared that their condition might be more serious than it seemed superficially.

SUMMARY

On Attu, the tactical and environmental hazard, improperly chosen equipment, and lack of individual and unit training in the proper use of equipment and in preventive measures against cold and exposure combined to set a pattern which was to be repeated, in varying degrees, during the remainder of the war. Within the next few months, trenchfoot occurred during the occupation of Kiska, but to a lesser degree. Within 6 months, there was a major epidemic of trenchfoot in Italy. Within the next 18 months, there was an even more explosive outbreak in Europe, on the Western Front.

While the actual number of cases of cold injury was small in the Attu operation, the incidence was high. Twelve hundred cold injuries occurred in 22 days, in a force of 15,300 men, which is an incidence rate for the period of about 80 per thousand. Expressed as an annual rate, this is 1,300 cases per thousand. An almost equal number of wounded-in-action cases occurred. The ratio of cold injuries to wounded-in-action cases was approximately 1:1, as compared with 1:5 in Italy in 1943–44 and about 1:4 in the European theater in the winter of 1944–45.

On Kiska, the troops were exposed to cold injury only for the short time required to establish that the enemy had withdrawn. Circumstances were favorable. Because the enemy had fled, there was no combat activity. The operation was started 3 months later than the Attu invasion, so that the weather was less severe. Equipment and footgear were better than what had been provided on Attu. Many of the men had fought on Attu and had learned by experience how to take care of themselves in cold, wet weather. The other troops had been specifically trained to care for their feet.

Yet, in spite of the brevity of their exposure and other favorable circumstances, the 28,450 troops who participated in the landing on Kiska sustained 130 cold injuries. What the incidence might have been if the enemy force, estimated at 10,000 men, had not abandoned the island before the allied troops arrived is a matter of conjecture. It would probably not have been as high as the incidence in the Attu operation, but it would undoubtedly have been considerably higher than it was in an unopposed landing.

NOTE.—Because the clinical observations in trenchfoot were essentially similar in all theaters, they are discussed elsewhere, under a single heading (p. 259). Treatment is also discussed under a single heading (p. 307). In the Attu campaign, treatment consisted of a variety of methods, depending upon the knowledge and preferences of the individual medical officer. There was no background of experience in cold injury, and no directives concerning its management had yet been issued.

CHAPTER VI

Mediterranean (Formerly North African) Theater of Operations [1]

Low temperatures and wet cold were no problem to United States Army ground troops in combat in North Africa in the winter of 1942–43, and the occasional cold injuries which occurred therefore attracted no particular attention. Cold injury was also not a problem in the fighting in Sicily in the summer of 1943. It was not until comparatively cold weather, which often was of the wet cold variety, was encountered in the Apennines in the fall of 1943 that United States troops of the Fifth U. S. Army were first subjected to the environmental conditions which constitute the essential, though by no means the entire, basis for the development of cold injuries in appreciable numbers of cases.

When these circumstances arose, the Office of the Surgeon, NATOUSA (North African Theater of Operations), was still without information concerning the cold injuries which United States troops had sustained in Attu in the spring of 1943, although these experiences had been investigated immediately in the Office of the Surgeon General (p. 57). Col. Edward D. Churchill, MC, Consultant in Surgery, Office of the Surgeon, NATOUSA, was, however, sufficiently aware of the possibilities of trouble to write the Surgeon on 31 October 1943 that, with the approach of cold weather during the forthcoming fighting in the Apennines, circulatory disturbances (trenchfoot) were to be anticipated. Even before this date, informal consultations had been held with a number of medical officers with combat units concerning the possible occurrence of cold injury and its dangerous potentialities.

INCIDENCE

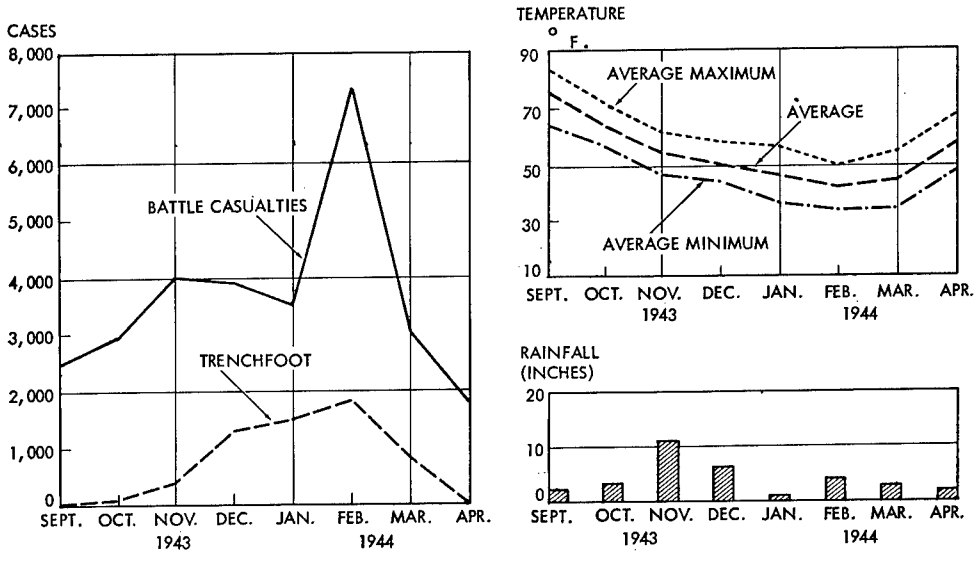
1943–44.—It was only a week after Colonel Churchill had alerted the Surgeon to the possibility of cold injuries that the first patients with trenchfoot to be observed in Italy passed through a clearing station south of Cassino. By 12 November, 6 cases are known to have occurred. Not all had been recognized immediately as instances of cold injury. One or two of the first casualties were thought to have suffered sprains and were treated with hot applications.

[1] Unless otherwise indicated, all material in this chapter is based on the cumulative report on trenchfoot in the Italian campaign, by Lt. Col. Fiorindo A. Simeone, MC, to the Surgeon, Fifth U. S. Army, 1945. Data collected during the wartime experience have been modified to utilize the more accurate data available after the war ended.

After trenchfoot once began to appear, the incidence increased rapidly, and, over the 6-month period ending on 30 April 1944, there were more than 5,700 casualties from this cause in the Fifth U. S. Army (chart 3, table 3). The alltime weekly high of 901 cases was recorded for the week ending on 18 February 1944. During the same 6-month period, casualties wounded in action totaled 27,602. The losses from cold injury occurred in a strength of 4 infantry divisions and 1 armored division.[2]

The mere statement of these figures does not, of course, tell the whole story. It does not indicate that losses from cold injury were, case for case, actually as serious as combat losses, because practically all cold injury occurred in combat troops, who are the most difficult to replace in all wars and who were always in extremely short supply during the Italian campaign. Losses from cold injury during the winter of 1943–44 amounted to about 7 percent of division strength,[3] and hospital admissions for this cause constituted 9 percent of all admissions for disease. The ratio of trenchfoot cases to battle casualties was 1:5 for the November 1943–April 1944 period. It varied from month to month and was highest in January 1944. Since the impact of cold injury can best be evaluated in comparison with casualties from combat operations, the figures leave no doubt that there was a major loss in effective Fifth U. S. Army fighting strength from trenchfoot during the winter of 1943–44.

CHART 3.—*Monthly incidence of trenchfoot in relation to battle casualties; maximum, minimum, and average temperatures; and rainfall, in Fifth U. S. Army in Italy, September 1943 through April 1944*



[2] Annual Report, Surgeon, Fifth U. S. Army, 1944.
[3] Annual Report, Surgeon, Fifth U. S. Army, 1945.

TABLE 3.—*Hospital and quarters cases of trenchfoot and of battle injuries and wounds, and average minimum temperature and average rainfall, by month, Fifth U. S. Army, November 1943 through April 1944* [1]

[Rate expressed as number per annum per 1,000 average strength]

Month and year	Trenchfoot		Battle injuries and wounds [2]		Ratio of trenchfoot to battle injuries and wounds	Average minimum temperature (° F.) [3]	Average rainfall (inches) [3]
	Cases	Rate	Cases	Rate			
1943							
November	371	24	3, 897	249	1:11	47	10. 2
December	1, 265	69	5, 020	274	1:4	44	6. 9
1944							
January	1, 490	96	4, 496	289	1:3	36	1. 6
February	1, 805	108	8, 378	500	1:5	34	5. 0
March	779	35	3, 685	167	1:5	36	3. 7
April	42	2	2, 126	121	1:51	49	2. 7
Total	5, 752	54	27, 602	261	1:5	---	---

[1] Data in this table, collected during the wartime experience, have been modified to utilize the more accurate data available after the war ended.

[2] Admissions; excludes killed in action.

[3] In Army forward areas.

1944–45.—The lessons of the 1943–44 experience in Italy were well learned, as will be pointed out shortly, and the incidence of cold injury during the winter of 1944–45 was far lower than during the preceding winter. The 1,572 injuries which occurred during the 6-month period ending on 31 March 1945 (chart 4, table 4) accounted for an admission rate of 20 per 1,000 men per year, which is a sharp decline from the rate of 54 (table 3) during the preceding winter. The annual rate for wounded in action also fell during the second winter of fighting in Italy because the front was frequently static, but the decrease was much less striking than the decrease in cold injuries.

As a matter of convenience, recurrent trenchfoot, which was a considerable problem during the second winter in Italy, as well as during the latter part of the first winter, is discussed elsewhere, under a single heading (p. 381). Precise figures are not available, but it is well established that a definite proportion of the cold injuries observed during the winter of 1944–45 represented recurrent cases. The proportion decreased, however, as medical officers began to realize, from hard experience, that return to full duty is possible in only a limited number of cases of trauma from cold.

The British experience.—A point of major interest in the story of cold injury in Italy is the comparative experiences of British and American troops. During the winter of 1943–44, the British 10 Corps was an integral component of the Fifth U. S. Army. It fought over the same terrain and for the same objectives. It is therefore possible to make valid comparisons of British and

CHART 4.—*Monthly incidence of trenchfoot in relation to battle casualties; maximum, minimum, and average temperatures; and rainfall, in Fifth U. S. Army in Italy, September 1944 through April 1945*

(There were 4 days of snow in December 1944 and 18 days of snow in January 1945)

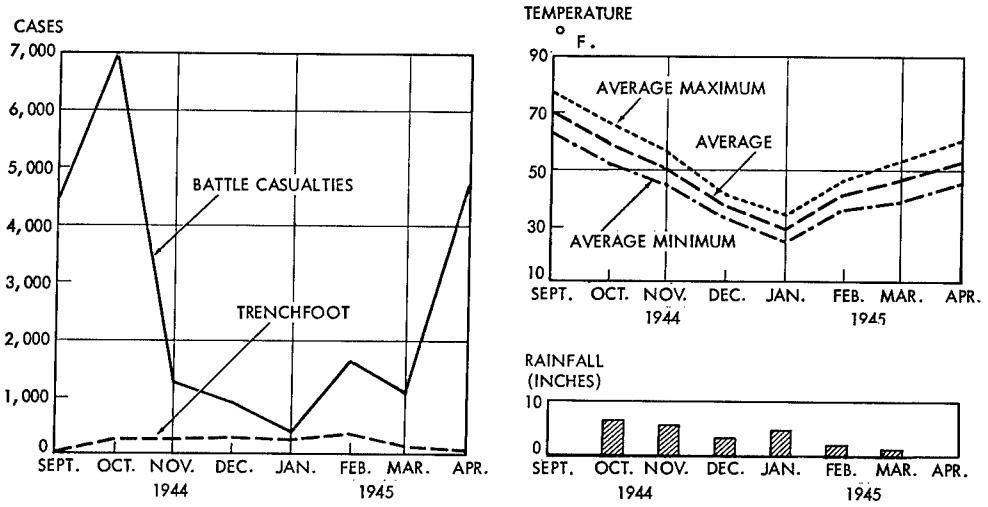


TABLE 4.—*Hospital and quarters cases of trenchfoot and of battle injuries and wounds, and average minimum temperature and average rainfall, by month, Fifth U. S. Army, October 1944 through March 1945* [1]

[Rate expressed as number per annum per 1,000 average strength]

Month and year	Trenchfoot		Battle injuries and wounds [2]		Ratio of trenchfoot to battle injuries and wounds	Average minimum temperature (° F.) [3]	Average rainfall (inches) [3]
	Cases	Rate	Cases	Rate			
1944							
October	258	24	8, 404	783	1:33	51	6. 5
November	274	25	2, 046	188	1:7	44	5. 7
December	305	22	1, 274	90	1:4	33	3. 3
1945							
January	309	26	561	48	1:2	25	4. 9
February	324	25	1, 966	154	1:6	36	1. 9
March	102	6	1, 613	97	1:16	39	1. 1
Total	1, 572	20	15, 864	206	1:10		

[1] Data in the table, collected during the wartime experience, have been modified to utilize the more accurate data available after the war ended.

[2] Admissions; excludes killed in action.

[3] In Army forward areas.

United States experiences. This is in contrast to the situation in the European Theater of Operations, where many comparisons are unsound because the troops of the two nations occupied entirely different positions and their tactical activity and deployment were also different.

Incidence of cold injury among British troops in Italy during 1943–44 was strikingly lower than among United States troops. Early in the fall of 1943, trenchfoot was apparently of so little consequence in British troops that it was not reported at all. Reports from the week ending on 4 December 1943 through the week ending on 19 February 1944 show a total of only 102 cold injuries in British troops, in contrast to 4,583 battle casualties, a ratio of 1:45. During the same period, there were 4,560 cold injuries and 17,894 battle casualties in Fifth U. S. Army troops, a ratio of 1:4.

TABLE 5.—*Cases of trenchfoot and battle casualties in British 10 Corps, for weeks ending 4 December 1943 through 19 February 1944*

Week ending—	Trenchfoot	Battle casualties	Ratio of trenchfoot to battle casualties
1943			
December 4	1	279	1:279
11	44	165	1:3.7
18	3	38	1:12.6
25	1	29	1:29
1944			
January 1	2	127	1:68.5
8	8	170	1:21.2
15	9	135	1:15
22	2	1,782	1:891
29	1	707	1:707
February 5	1	714	1:714
12	3	198	1:66
19	27	239	1:8.8
Total	102	4,583	1:45

The explanation of these differences is not entirely clear. Among the obvious reasons for the better British showing were the excellent boots with which British troops were provided; the heavy wool socks which they used, in contrast to the lighter socks provided for American troops; the daily sock exchange which was routine in the British Army; the British practice of keeping troops in the line for shorter periods of time than the American practice; and the very strict foot discipline enforced on British troops. An observer from the Office of the Quartermaster General considered that the British custom of

classifying cold injury, from the disciplinary point of view, as a self-inflicted wound had much to do with the lower British incidence.[4]

Milder cases of trenchfoot among British troops were likely to be treated in quarters and not to appear in formal statistics, whereas among United States troops practically every casualty with trenchfoot was either hospitalized, treated in quarters, or carded for the record, and included in the statistics. Any reasonable allowance for these different practices, however, could explain no more than a minor part of the very considerable difference in the incidence of cold injury in British and United States troops. The opinion was expressed by one corps surgeon (VI Corps) that the discrepancy would have been less notable if there had been taken into account the readiness of United States Army unit surgeons to evacuate all soldiers with cold injury, regardless of its degree.[5]

These various explanations may or may not be valid. The important fact remains that when the circumstances of combat were precisely the same, as they were on the Anzio beachhead, the disparity between the American and the British incidence of cold injury is very striking, as the Surgeon, VI Corps, pointed out in a report to the Surgeon, Fifth U. S. Army, on 13 April 1944, after a survey of that area:[6]

> During the months of February and March there was a total of 1,951 cases of "trench foot" reported among the American troops, and 103 in the British forces. The American forces on the beachhead are approximately twice the number of British troops. Thus there was one case of this disability occurring in the British troops to ten cases among the Americans. That is, the incidence of "trench foot" in the American forces was ten times that of the British—climatic and tactical conditions were the same for both forces.

General Blesse had made essentially the same point in a report to the Commanding General, NATOUSA, on 16 March 1944:[7] During the 10-day period ending on 17 February, 550 American soldiers were hospitalized from the southern sector and 501 from the Anzio beachhead. British troops on the beachhead, fighting under the same conditions as United States troops, had very few cases.

During the winter of 1944–45, recordkeeping practices in the British and American elements of the Fifth U. S. Army were the same, and comparisons of the cold injury rates are therefore valid (table 6). The average annual rate for trenchfoot per 1,000 men was again higher in American than in British troops (20.5 in contrast to 6.3). The average annual rate for battle casualties per 1,000 men was, however, higher in United States troops than in British troops, so that the ratio of cold injury rates to battle-casualty rates was really about the same in both groups (1:10 in United States troops; 1:11 in British troops).

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[4] Letter No. 57, Maj. Robert H. Bates, Quartermaster Observer with the Fifth U. S. Army, to General Doriot, Office of the Quartermaster General, 25 Apr. 1945.

[5] Annual Report, Surgeon, VI Corps, 1944, annex D.

[6] Ibid.

[7] Essential Technical Medical Data, Headquarters, NATOUSA, for February 1944. Appendix II, dated 16 Mar. 1944, subject: Health of Command for February 1944.

TABLE 6.—*Incidence rates for trenchfoot cases and battle casualties, United States and British elements, Fifth U. S. Army, for weeks ending 13 October 1944 through 7 April 1945*

[Rate expressed as number per annum per 1,000 average strength]

Week ending—	U. S. Army		British Army	
	Trenchfoot (rate)	Battle casualties (rate)	Trenchfoot (rate)	Battle casualties (rate)
1944				
October 13	45	913	0	255
20	7	874	0	307
27	7	505	0	300
November 3	52	296	22	80
10	32	166	2	97
17	24	176	10	35
24	8	159	2	78
December 1	19	112	20	89
8	19	78	10	89
15	4	110	3	157
22	22	80	14	41
29	35	70	13	33
1945				
January 5	33	75	11	50
12	25	33	23	18
19	17	36	13	12
26	16	44	10	6
February 2	22	34	7	3
9	19	212	5	33
16	37	135	0	16
23	19	234	0	8
March 2	11	112	0	1
9	8	223	0	1
16	8	73	0	1
23	2	45	0	21
30	2	36	0	18
April 7	8	111	0	26
Average	19. 3	190	6. 3	68. 3

TACTICAL SITUATION [8]

Although the winter of 1943–44 was not punctuated by the intervals of bitter combat which had occurred earlier, at the time of the Salerno landings, and which were to occur later, with the fall of Rome and the breach of the Gothic Line, combat was nonetheless sufficiently intensive for casualty rates

[8] Fifth Army History, pts. II–IV, 7 Oct. 1943–31 Mar. 1944.

to be high and for the tactical situation to require the exposure of troops to the risk of cold injury. Much of the fighting was in the mountains and was especially difficult and demanding. After the fall of Naples and the crossing of the Volturno River in October 1943, monthly casualty rates were continuously high; the maximum number of cases (8,378) occurred in February 1944 (table 3).

November and December 1943 found United States troops operating in wet cold over the mountainous terrain before the German winter line. In January, following the breakthrough on the winter line, the Rapido River was crossed, Cassino was approached, and new positions were established before the Gustav Line. Operations of the Fifth U. S. Army during this period can best be described as a continuous assault, over unfavorable terrain, upon prepared positions, with the enemy largely free to make such stands as he chose while he conducted an orderly withdrawal up the peninsula. The individual United States foot soldier, as a result of this type of combat, was often immobilized by enemy fire. The terrain was unfavorable, and dry shelter was almost impossible to find. Moreover, supply was a major problem. Cargo trucks could go only a short distance up the mountains after they had left the main roads, and food and ammunition had to be brought up by mule pack or, very often, by hand carry. As a result, days might pass without supplies of hot rations' being brought up.

Landings on the Anzio beachhead were undertaken in January 1944 in an effort to draw German strength away from the Gustav Line, which guarded the approaches to Rome. Conditions on the beachhead were simply an exaggeration of the conditions which prevailed throughout the Fifth U. S. Army area at this time. The VI Corps was contained within space roughly 15 miles long and 7 miles wide. Here it was raked by concentrated artillery fire and air attacks throughout the remainder of the winter and until the breakthrough in May, just before the fall of Rome. During this time, there were few quiet intervals. Heavy attacks by armor and infantry were repeatedly delivered by the Germans, under cover of merciless artillery fire from well-placed ground positions, and there were also heavy bombings from the air.

Under these circumstances, infantrymen were often obliged to spend days immobilized in water-filled foxholes, in icy weather, with no chance of relief. Because the beachhead, as just pointed out, was held from the first under very heavy opposition, Allied reverses were serious, and until almost a month after the landings the issue was in doubt. Although it then became clear that the position could be held, it was another 3 months before it could be extended. After 1 March and until the Allied breakthrough in May, the opposing forces maintained a state of no more than active defense of their respective positions, though conditions on the Anzio beachhead could never be described as truly static.

The battle for Cassino was another ordeal in which the individual soldier found himself obliged to take cover in isolated foxholes or other positions in

which his movement and communications were severely restricted. Here, as elsewhere in Italy, the tactical situation influenced the degree to which troops could be supplied with hot food, dry socks, shoes, clothing, and other necessities. In general, it fostered the type of exposure and other circumstances which would be most conducive to trenchfoot.

Nowhere in Italy during the winter of 1943–44 was controlled, frequent rotation of either units or individuals out of frontlines practiced by United State troops. This was in contrast to the rotation of both units and individuals regularly practiced, for preventive purposes, by British commanders. United States combat commanders in the Fifth U. S. Army explained the policy of nonrotation by the scarcity of combat replacements and the seriousness of the tactical situation. Whatever the causes, the long periods of duty in heavy combat, without relief, which were exacted of United States soldiers during the winter of 1943–44 favored the development of cold injury and helped to explain its high incidence. As an extreme illustration, one division spent 115 of its first 122 days in Italy in combat.

During the winter of 1944–45, the tactical situation was much less favorable to the development of cold injury. After the breach in the Gothic Line in October 1944, the front was comparatively inactive until the end of January 1945, when a large-scale offensive was undertaken by the Allied forces. Casualty rates during this period of inactivity were the lowest for any period of comparable length during the entire Italian campaign. The inactivity from the standpoint of combat was reflected in the decreased incidence of trenchfoot. Troops could be in relatively comfortable quarters. They had time to take care of themselves. They were more easily supplied. They had better food. In short, all the circumstances were far less conducive to trenchfoot than those which had prevailed in the winter of 1943–44. Tactical inactivity was, of course, only one of several factors which accounted for the decreased incidence; improvement in clothing and footgear and the institution of preventive measures also played a large part in it.

CLIMATIC FACTORS

The relationship between weather conditions and the incidence of cold injury was promptly evident in the Mediterranean theater (tables 3 and 4, charts 3 and 4). Cold injury was not reported before November 1943, as might have been expected. Up to that time, the temperature on the front had not fallen below 50° F. (10° C.) and there had been very little rain. In November, temperatures began to fall below this level, and rainfall was heavy. Climatic conditions were promptly reflected in the incidence of cold injury (table 3, chart 3). The average minimum temperatures were 47° F. (8.3° C.) in November, 44° F. (6.7° C.) in December, 36° F. (2.2° C.) in January, and 34° F. (1.1° C.) in February.

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An average of 10.2 inches of rain fell in the Fifth U. S. Army area in November, and an average of 6.9 inches in December. Between 14 and 19 November, heavy rains flooded the Volturno River and swept away all the bridges except the one at Capua. The environmental hazard was therefore enhanced by the difficulty of getting supplies to the front. On the Anzio beachhead, conditions were even worse. This area has a high water table, and, at the best of times, the ground is marshy and soggy. These naturally unfavorable conditions were made worse by the heavy rainfall. Here, as on other parts of the front, the weather was very cold and ice formation was frequent.

The combination of cold and wet invited trenchfoot. As already pointed out, the soldiers were forced to remain in water-filled foxholes or other ground positions for days, and sometimes for weeks, at a time. Even if they had been trained to care for their feet—as they had not been—foot care would have been extremely difficult under such circumstances. The removal and replacement of mud-caked shoes, boots, and leggings were not easy to accomplish and were frequently not even attempted.

The correlations between the occurrence of trenchfoot and the prevalence of cold, wet weather held all through the winter of 1943–44. The peak of the trenchfoot incidence in February 1944 (table 3, chart 3) followed a period of cold, rainy weather. Combat activity was also heavy at this time, as shown by the peak number of wounded in action, and troops were less able to take proper care of themselves and to practice foot hygiene.

Most of the fighting in the winter of 1943–44 had been south of Cassino. In the winter 1944–45, military operations were conducted in the northern Apennines and on the Ligurian coast, and cold weather came a month earlier than it had come the previous winter. In September 1944, the average minimum temperature in the Fifth U. S. Army sector north of Florence was 62° F. (16.7° C.), and the average rainfall was 2.7 inches. No cases of trenchfoot were reported. In October, when the average minimum temperature was 51° F. (10.6° C.) and the rainfall averaged 6.5 inches, trenchfoot began to reappear (table 4, chart 4), and cases were reported thereafter until the end of the winter, though the number, as already stated, was considerably less than during the preceding winter.

The course of events left no doubt of the influence of the combination of cold and wet in the production of trenchfoot. The correlation was demonstrated not only by the total figures for the Fifth U. S. Army but also by its daily and monthly incidence in individual combat divisions. In neither winter of fighting, however, did trenchfoot appear until the temperature had fallen to an average minimum of approximately 50° F. (10° C.) and until rainfall had become considerable.

CLOTHING AND FOOTGEAR

In general, neither clothing nor footgear worn by American troops in Italy during the winter of 1943–44 was entirely satisfactory.[9] Many items were in short supply until the winter was well advanced. Others, such as woolen socks, were not forthcoming in adequate quantities until the weather had become warmer and the environmental hazard of cold injury had been greatly reduced. These deficiencies played an important part in the incidence of trenchfoot in the winter of 1943–44, and the improved record in the following winter can be attributed in considerable part to their correction.

Clothing

When the deficiencies of clothing originally supplied to troops in Italy were realized, Maj. (later Lt. Col.) Robert H. Bates, QMC, an observer from the Office of the Quartermaster General, was sent to the theater, by request, to study the situation. His observations upon the clothing worn by the 3d Infantry Division on the Anzio beachhead resulted in the replacement of the unsatisfactory uniform worn the first winter by the M-1943 uniform, which was devised on the layering principle (fig. 24) (p. 430). Major Bates' observations also formed the basis of the requisitions placed for the winter of 1944–45 for both the Fifth and Seventh U. S. Armies. It is significant, in view of the delays which attended the placing of orders for these articles in the European theater (p. 143), that the requisitions for the Mediterranean theater for the winter of 1944–45 were placed in April 1944. The supplies reached the theater in September, and distribution was begun in October.[10]

The new items issued in the fall of 1944 included a field jacket with hood and field trousers, which, when worn together, provided a completely windproof and fairly water-repellent outer layer. Underneath this layer, the soldier wore a high-necked sweater and warm pile jacket, in addition to the wool shirt and wool underwear worn the preceding winter. Cotton field trousers worn over regulation wool trousers provided an additional layer of insulation and warmth, as well as additional protection against cold winds. For men in particularly exposed positions, the issue included a warm overcoat parka, with windproof exterior and thick pile lining, and a special rain outfit consisting of a hooded parka and completely waterproofed trousers. The leather gloves supplied had separate woolen linings, and fabric mittens had special wool inserts. Mufflers and down and feather sleeping bags were also issued.

[9] See footnote 8, p. 107.

[10] Annual Report, Surgeon, MTOUSA, 1944, vol. II, annex J.

U. S. Army photos

FIGURE 24.—Cold-weather uniform. A. Utilization of layering principle (note combat boots). B. Field jacket M-1943 (note buttoned collar). C. Same jacket as seen in B, with adjustable tie cord.

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Footgear

Socks.—When trenchfoot first began to appear in Italy in November 1943, United States troops were wearing the cotton socks or light wool socks which they had worn during the summer and early fall.[11] These socks, while satisfactory for warm-weather operations, were totally inadequate for winter fighting in the valleys and on the mountains between the Volturno, Garigliano, and Rapido Rivers (fig. 25). Furthermore, even these inadequate socks were in short supply. Only 10 percent of the requests made for them could be filled during October. At one time, it was possible to get together only 500 pairs for the 45th Infantry Division, which had requested 16,000 pairs. An investigation of 50 soldiers with trenchfoot in November 1943 showed that only 5 possessed more than 1 pair of socks. One man was wearing cotton socks, forty-eight were wearing light wool socks, and the only man who was wearing heavy wool socks had received them from his family. During periods of exposure, which had averaged 6 days, 45 of the 50 men had been unable to change their socks at all, and the other 5 had changed them only once.

Dry shoes could not, of course, be supplied in combat. On the other hand, if dry socks had been available and if the importance of substituting them for wet socks, even in wet shoes, had been understood by the soldiers, the dry socks would have provided a period of insulation before they in turn had become wet. Ski socks, which were used only with shoepacs or by moun-

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FIGURE 25.—Liri-Garigliano Valley in February 1945. Floods of the same extent played a role in the incidence of trenchfoot in the Fifth U. S. Army the previous winter.

[11] See footnote 8, p. 107.

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tain troops, became available late in the winter of 1943–44, when the need for them had almost ended, but they proved extremely useful in the following winter, when the troops had been taught to wear shoepacs efficiently.

Socks issued to United States troops late in the winter of 1943–44 and in the following winter were more satisfactory than the previous issue. At most, however, they contained only 50 percent wool, and they were never as efficient as the British-issue socks.

Socks were finally in sufficient supply in the theater for each man to carry 2, or even 3, extra pairs upon his person. It is indicative of the general lack of appreciation of the dangers of trenchfoot in an army in combat that as late as April 1944 the provision of a pair of socks daily with his ration for every soldier was being described as a luxury which could not be met from present resources.[12] The facts were undoubtedly as stated, but the language was unconsciously revealing.

The inner soles tested by an infantry division in January 1944 were thought to be of some benefit, but the impression was that their use would not significantly influence the incidence of cold injury.

Shoes and boots. —During the early winter of 1943–44, American soldiers in Italy wore the regulation enlisted man's service shoes (fig. 26), usually with

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FIGURE 26.—Service shoes, wet and covered with mud, removed from feet of soldier who contracted trenchfoot in fighting in Rapido River Valley, February 1944.

[12] Report, Brig. Gen. C. L. Adcock, GSC, Office of Assistant Chief of Staff, G-4, NATOUSA, dated 20 Apr. 1944, subject: Health of Command Report for February 1944.

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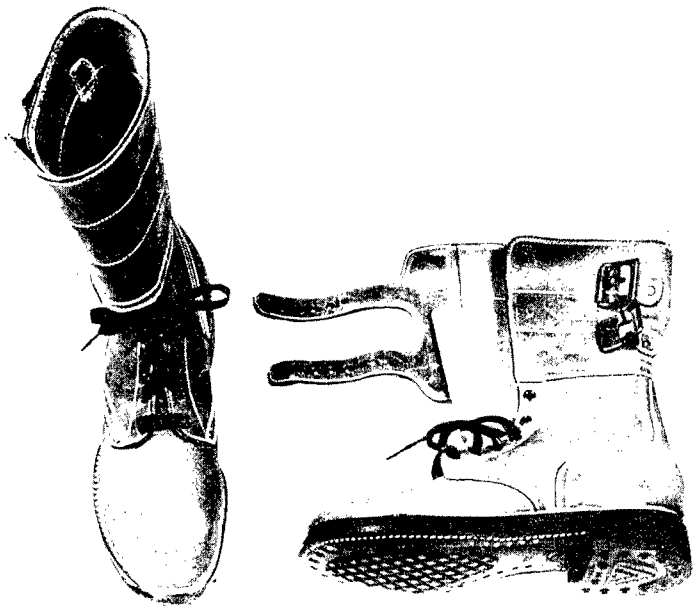

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FIGURE 27.—United States Army field combat boot.

leggings. Later, many wore combat boots (fig. 27) without leggings. From the standpoint of prevention of cold injury, the boots had few advantages over the service shoes, and both were open to the same general objections. Both were made on lasts which fitted the foot closely. Both were fitted too small, partly from carelessness and partly because of the habit of wearing tightly fitted shoes. Shoes fitted over cotton or lightweight wool socks were too tight when they were worn over wool socks, particularly after the leather had become wet and had shrunk. Both shoes and boots were usually laced too tightly, and when leggings were worn with service shoes another cause for circulatory insufficiency was provided, as well as another deterrent to removing the shoes to care for the feet.

The 12-inch blucher boot sometimes used in the first winter in Italy was more efficient than either the service shoe or the combat boot, both because of its construction and because it could be worn with ski socks and inner soles. When the leather became wet, however, whatever advantage the blucher boot might have had originally was promptly lost.

The ski mountain boot, which was issued to mountain troops, had a very high box toe, which made constriction of the foot practically impossible. This boot was designed to be worn with two pairs of heavy ski socks and with an inner sole as well. It was the warmest leather boot known to be in use by any army in World War II, but it was suitable only for mountain troops. It proved extremely satisfactory for mountain use under most dry cold conditions, but

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once the leather became wet some of the original advantages were lost, though the heavy ski socks worn with it still provided some protection against cold injury.

Dubbing was of no value in winter weather in Italy, and in the opinion of some observers its use made conditions worse.

Galoshes and rubber boots.—In December 1943, galoshes became available, but the quantities were limited and "sufficient to equip no more than a handful of troops." The need, which was estimated at 230,000 pairs, could not be met because of the rubber shortage. Such supplies as became available were issued to combat troops.[13]

Stationary troops found galoshes useful. Combat troops found them awkward, heavy, clumsy, noisy, and hot. They would not wear them on patrol or during combat, and many infantrymen threw them away rather than be burdened with them. Rubber boots were satisfactory for engineering units and other special organizations working in water but were not suitable for troops in combat and on the march.

The first 50 soldiers with trenchfoot who were studied in Italy did not have galoshes or rubber boots.

Shoepacs.—Four hundred pairs of shoepacs were issued on a trial basis to the 34th Infantry Division in January 1944, but they were not found satisfactory for a number of reasons. The model supplied did not grip the ankle, as did the service shoe. After prolonged activity in mild cold, the feet became uncomfortably hot, perspiration was profuse, and the skin eventually became macerated. Sizing was not satisfactory. There was an excess of very large sizes and a shortage of small sizes, so that men with small feet continued to have trenchfoot or developed blisters because the shoepacs they wore were too large. No instructions had been given as to how shoepacs were to be worn (with ski socks and insoles), and, when they were worn incorrectly, trenchfoot continued to occur. The complaint was general that shoepacs did not support the arch of the foot satisfactorily, although examination revealed no arch troubles among the men who were wearing them.[14]

In spite of the defects of the model provided and the objections raised to them, there was general agreement that shoepacs were preferable to any other type of footwear for use in short operations in cold weather in mud, water, and snow When they were provided in proper sizes and widths, were properly fitted, and were worn with the proper combination of socks and insoles, their popularity increased. They eventually became standard footgear in Italy for all United States troops who had to fight over terrain for which ski boots were not appropriate. They also proved the only really satisfactory type of footgear for climbing in rugged country with heavy loads; under these circumstances, the soldier wearing shoepacs could keep his feet reasonably dry. This was a most important consideration in Italy, in many parts of which the mountain terrain was so rugged that all supplies beyond muleheads had to be brought

[13] See footnote 8, p. 107.
[14] See footnote 4, p. 106.

forward by the troops themselves, in loads which often weighed 50 pounds or more.

Properly fitted shoepacs, worn with socks and insoles as intended, seemed to furnish real protection against cold injury, particularly when temperatures fell to 20° to 30° F. (−6.7° to −1.1° C.). Of 282 patents with trenchfoot observed in Fifth U. S. Army hospitals in November 1944, only 18 percent wore shoepacs. Of 327 observed in December, only 11 percent wore them with the correct socks. Another 27 percent of the December casualties wore shoepacs but did not have correct socks.[15] During the entire winter of 1944–45, 4 out of every 5 casualties from cold injury did not wear them.

There were also explanations for the apparent inefficiency of shoepacs in some cases: (1) A considerable number of the men who contracted cold injury while wearing them suffered from recurrences of earlier injuries and (2) another group failed to care for their feet after they had been in water over the tops of their shoepacs.

Training.—A significant result of the study on clothing conducted in Italy by Major Bates was the setting up of training courses on the supply and use of winter clothing and other equipment by the Quartermaster, Fifth U. S. Army. These courses were instituted in November 1944 when it was found that trenchfoot was still occurring in spite of the provision of satisfactory clothing and footgear, including shoepacs. The courses were conducted separately for line officers, combat troops, and quartermaster and supply officers and sergeants. Units which could not send representatives to the scheduled courses were visited later for instructional purposes. The lessons which were learned were transmitted through channels down to platoons, and by the end of the year about 50,000 officers and enlisted men had been indoctrinated.

During these courses, all items of clothing and footgear were explained, and their use was demonstrated. The layering principle in clothing and the proper sizing of shoes, shoepacs, and socks were also demonstrated. Demonstrations were given in the use of the sleeping bag and shelter halves, in the drying of wet socks and inner soles inside the sleeping bag or inside the shirt if dry substitutes were not available, in the fitting of shoepacs, and in the combinations of socks and inner soles to be worn with the shoepac. Simple devices were shown for keeping the feet from direct contact with wet ground, such as the use under the feet of food containers, packboards, and branches of trees. The importance of using these materials in foxholes at night was particularly emphasized. It was constantly stressed that the removal of shoes and socks, even for brief periods and even when dry socks were not available, was an essential of foot care.

When formal instruction was concluded, plans were made for continuation of instruction by the use of small mobile training teams. Particular attention was given to the instruction of fresh replacements from the United States.[16] These soldiers had had no instruction at all in these matters in the Zone of

[15] Essential Technical Medical Data, Headquarters, NATOUSA, for January 1945.
[16] See footnote 4, p. 106.

Interior, and they had not yet learned from contact with other troops, or from personal experience, how to protect themselves against exposure to cold and wet.[17]

An outgrowth of the courses for supply personnel was a program to correct the initial errors made in the fitting of shoepacs. These mistakes had arisen when distribution had to be effected to organizations already in the line. Each unit commander was directed to check his men and to make such exchanges within the unit as might correct errors of sizing. Sizes not available within the unit were drawn at the training center or were put on order for later issue.[18]

INDOCTRINATION AND TRAINING

When the early trenchfoot experience in Italy was analyzed, it promptly became evident that, while such basic factors as climatic conditions, intensity of combat, and deficiencies in clothing and equipment were responsible for the high incidence of cold injury, ignorance of the disastrous potentialities of this type of trauma and of methods of preventing it played an even more important role in its development.[19] In the winter of 1943–44, troops of the Fifth U. S. Army and their commanding officers were almost equally ignorant of cold injury and were almost totally unprepared to combat it.[20]

The annual report of the Medical Section, NATOUSA, for 1943 minced no words in setting forth these facts. Present Army regulations and instructional material on the care of the feet, said this report, were inadequate. Troops did not know how to carry out this important precaution. Commanding officers were equally ignorant of foot care and had not been impressed with the essential importance of foot discipline. Troops had not been trained in methods of drying shoes and socks under all conditions. They did not know how to care for minor foot ailments. Instruction in these matters, the report went on, should be a part of all training and should be followed up by frequent foot inspections. The prevention of trenchfoot and of other foot ailments depends primarily upon the care of the feet and only secondarily upon proper footgear and socks. A leaflet on foot care, it was noted, had been prepared in the theater and was being used for instructional purposes, and it was suggested that the War Department should prepare and issue a similar leaflet.

A sample group of 142 men with cold injuries were interviewed between 26 January and 12 February 1944 as they passed through a clearing station.[21] Not one of them had had any instruction in the prevention of this type of trauma. Not one of them understood the risk he ran from resting in the cold without removing and changing his wet socks and shoes. Not one of them

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[17] Report, Surgeon, 3d Infantry Division, to Surgeon, NATOUSA, 28 Mar. 1944.

[18] See footnote 4, p. 106.

[19] (1) See footnote 5, p. 106. (2) Annual Report, Surgeon, NATOUSA, 1943.

[20] See footnotes 4, p. 106, and 19 (2).

[21] Essential Technical Medical Data, Headquarters, NATOUSA, for February 1944, and inclosure, dated 8 Apr. 1944, subject: ETMD from Overseas Forces.

knew how to use overshoes to the best advantage. The few who were wearing heavy wool socks did not change them regularly; one man had changed his socks only 3 times in 6 weeks. The only man who was wearing shoepacs had never been told how to use them. He wore them with light socks, which promptly became soaked with perspiration, and he slept in the cold without changing to dry socks.

Later, in February 1944, an analysis of another group of 320 patients with trenchfoot showed that 59 percent had never received any instruction in how to prevent it.[22] The medical officer responsible for the special surveys on trenchfoot, Maj. (later Col.) Fiorindo A. Simeone, MC, wrote the Surgeon, Fifth U. S. Army, that under such circumstances "the incidence of trench foot will be entirely at the mercy of the weather."[23]

Trenchfoot was a particular menace in new, untrained troops. A survey of 129 cases in the 3d Infantry Division showed that 30 percent were in soldiers who had been overseas a month or less, although these new troops made up only 4 percent of the division strength, and that the incidence in this group of cases was 8 times the average division incidence.[24] The officer who prepared the basic report stated, "I have never seen a new replacement in this theater who had received instruction in the prevention of trenchfoot *prior* to joining the division."

A secondary result of the ignorance of trenchfoot was that soldiers who had sustained cold injuries often did not realize what had happened, or the possible consequences of the injury, and did not report to the aid station until the condition was far advanced.

Publications.—The first medical circular published on the subject of trenchfoot in the Mediterranean theater (Medical Circular No. 6) was dated 24 November 1943 (appendix C, p. 521). Although it was chiefly devoted to therapy, it emphasized that the best management of cold injury was prophylactic. It also noted that, of approximately 200 men with trenchfoot hospitalized during the previous 5 days, most had worn wet socks for from 3 to 14 days.

The material on trenchfoot which the Surgeon, NATOUSA, submitted in a memorandum to G–1 (personnel and administration), NATOUSA, on 1 December 1943, was still under discussion on 11 December. G–1 was unwilling to accept the material as a circular, as was proposed, and suggested that it appear as a training memorandum. G–3 (operations and training), NATOUSA, considered a training memorandum an inappropriate vehicle and suggested that the material appear as a circular or memorandum. G–1 then suggested that the material appear as a technical publication by the Surgeon, adding, "The material is largely, if not entirely, already in field manuals, etc."

[22] See footnote 17, p. 118.

[23] Letter, Maj. F. A. Simeone, MC, Headquarters, Fifth U. S. Army, to Surgeon, Fifth U. S. Army, 14 Feb. 1944, subject: Prevention of Trench Foot.

[24] See footnote 17, p. 118.

The Surgeon replied to the latter comment on 11 December as follows:

1. Very many cases of trench foot have occurred in troops of the 5th Army. With continued wet weather, this condition can be expected to be prevalent in the 5th Army as well as other commands. The material requested on the prevention of trench foot is not properly covered in existing field manuals. To minimize the occurrence of trench foot, troops must be informed of the cause of this condition and trained in the measures necessary for its prevention. Technical publications by the surgeon can not be expected to be used as a means of individual troop training and inspections required.

2. Since the prevention of disease is a command responsibility, and the medical department only recommends preventive measures, it is our opinion that this information should be disseminated through command channels.

The communication ended with the renewed request that the material be published in a NATOUSA circular. A communication from G–1 to the adjutant general of the theater on 15 December 1943 directed that it be published as soon as possible. Accordingly, on 21 December 1943, a letter on the subject of trenchfoot was sent from Headquarters, NATOUSA, to the commanding generals, Fifth and Seventh U. S. Armies and the Peninsular Base Section (appendix D, p. 523).

Meantime, the Fifth U. S. Army issued information on cold injury in a letter which was distributed to all units of this army on 5 December 1943. In this communication, it was pointed out that trenchfoot was likely to become a major cause of disability among United States troops unless unit commanders and medical officers used all the means at their disposal to prevent it. Unit commands were directed to exercise all possible ingenuity and vigilance to see that the following prophylactic measures were instituted and applied: (1) Rigid enforcement of the rules of foot hygiene with frequent foot inspections; (2) the use of foot powder on the feet and in the socks; (3) the wearing of fresh socks into combat, with at least one extra pair to be carried on the person; (4) loose fitting of shoes whenever possible and, when dry socks were not available, the removal of the shoes and the wringing of water out of the socks; (5) the use of overshoes in wet weather whenever combat conditions permitted; (6) muscular activity and simple exercises, designed to delay the development of cold injury; and (7) the rotation of frontline troops whenever possible after 48 hours on duty, so that they could wash and dry their feet and change into dry socks and shoes. This letter called the attention of the commanding generals to the increasing incidence of trenchfoot and to the importance of measures of prevention and first aid. Special emphasis was placed upon simple foot exercises, practical under combat conditions, and frequent foot inspections were ordered for troops subjected to exposure, to make certain that they were taking proper care of their feet.

Training Memorandum No. 9, NATOUSA, on the care of the feet was issued on 24 December 1943 from General Eisenhower's headquarters. It repeated the facts about trenchfoot already published in other forms and provided that unit commanders must include in their training programs at least 2 hours of formal instruction covering the care of the feet. Frequent foot inspections were again ordered.

The Surgeon, NATOUSA, in a comment on this memorandum, addressed to G–3 and dated 19 December 1943, raised the question of supplementing it with a leaflet on the care of the feet for individual distribution to all United States Army officers. The material was duly prepared, and, on 13 January 1944, publication in the form of a booklet was recommended.[25] In the recommendation from G–3 to the deputy theater commander, it was pointed out that the Surgeon considered the subject one of increasing importance and had recommended publication for the additional reason that War Department data were scattered, were difficult to piece together, and did not cover the subject matter satisfactorily.

The theater quartermaster concurred in the publication of the booklet with only minor changes. The Chief of Staff, NATOUSA, did not. He wrote the Surgeon on 19 January 1944 that, in discussions with the deputy theater commander, it had been concluded that "the problem was one which could best be solved by utilizing the services of unit surgeons, at the same time receiving the attention of unit commanders and their staffs." He also remarked: "It would seem that the necessary knowledge of the subject must exist in the Army, Divisions and other Commands, and that possibly better results would be attained by a short communication to Army and base section commanders, pointing out the need for personal attention in the matter." The Surgeon, NATOUSA, replied to this communication on 9 February 1944 that he could not concur with these arguments. The problem was essentially one of unit training and command responsibility, which could not be assumed primarily by the unit surgeon. He also stated that instructional matter presently in existence was incomplete and scattered. Finally, he said that many of the more than 2,000 trenchfoot casualties which had occurred since November of the previous year could have been prevented if troops had known how to care for their feet and if unit commanders had insisted upon proper preventive measures. The Surgeon doubted that a short communication to army and base surgeons would correct the situation and renewed his recommendation for publication of the proposed booklet.

This recommendation was accepted on 12 February 1944, and an issue of 14,000 copies was authorized on 25 February. Distribution was begun on 29 March 1944,[26] too late, however, to have any influence on the incidence of trenchfoot during the first winter of fighting in Italy.

Command responsibility.—As many of the facts just stated indicate, command responsibility for trenchfoot had not been realized early in the winter of 1943–44, and preventive measures were late in being put into effect. This error was not made during the following winter. The subject was kept alive, in fact, throughout the late spring and early summer.

A radiogram to the War Department from Headquarters, MTOUSA, on 31 May 1944 pointed out that training in the care of the feet and in foot disci-

[25] Memorandum (intraoffice), Headquarters, NATOUSA, comments 1–9 dated 13, 16, 18, and 19 Jan. 1944 and 9, 12, 15, 16, and 17 Feb. 1944, subject: Printing of Booklet on Care of Feet.

[26] Memorandum, Maj. Gen. Daniel Noce, GSC, Office of Assistant Chief of Staff, G–3 to G–4, 12 June 1944, subject: Trench Foot.

pline had not yet reached required standards. It was therefore recommended that the handbook prepared in NATOUSA be used as a basis for all unit training programs, which should include at least 4 hours of instruction in the care of the feet; that unit commanders and noncommissioned officers be given special training in foot care and be taught the fundamentals of foot inspection by unit medical officers; that a high incidence of cold injury be regarded as an indication of faulty leadership; that all replacement depots conduct schools in the care of the feet and certify that all men furnished to combat units had completed this course; that dry socks be brought up with individual rations; that laundry facilities for socks be provided for combat troops during wet, cold weather; and that commanders arrange, during cold weather, for men in frontlines to be released at frequent intervals, on the ground that without this precaution they could expect to lose 1 man with cold injury for every 3 or 4 battle casualties.

The Surgeon, NATOUSA, on 6 June 1944, sent the theater commander a letter in which he made the following points:

1. Trenchfoot during the previous winter accounted for 5,670 hospital admissions, or 9 percent of all admissions for disease to Fifth U. S. Army hospitals over this period. The ratio of trenchfoot to battle casualties was 1:3.8.

2. It was not likely that more than 60 percent of these men could return to duty, and a high rate of recurrence could be anticipated in those who did return.

3. Trenchfoot is primarily a training problem which involves the education and discipline of the individual soldier. Indoctrination and training are made more difficult by the fact that the infantry, which is the most susceptible group, has a high turnover and that the recruit must be taught to save himself from becoming a casualty from trenchfoot at the most tense moment of his life, when he is about to engage in combat for the first time. Experience during the previous winter had showed that replacements had not been properly trained in the prevention of cold injuries.

4. British troops in the theater had had less trenchfoot than United States troops, probably because of more efficient equipment, including better fitting shoes, a more effective sock exchange, and frequent rotation of troops in the line.

Medical Circular No. 14, which was issued by the Surgeon, Fifth U. S. Army, on 7 September 1944, contained one section (II) in which the facts of trenchfoot were reviewed in respect to etiology, clinical considerations, therapy, and disposition.

Training Memorandum No. 2, Headquarters, NATOUSA, 29 September 1944, was based on War Department Circular No. 312, section IV, dated 22 July 1944 (p. 63). This memorandum directed that the instruction of troops in preventive measures against cold injury should begin immediately upon the receipt of the communication. It stated unequivocally that the enforcement of precautions against trenchfoot was a command responsibility and that commanders would be held responsible for unreasonably high incidences.

This warning meant just what it said. As the winter progressed, commanding officers of various units were required to explain to higher authority why the incidence of trenchfoot in their units had exceeded certain levels and were informed that additional cases resulting from failure to carry out prescribed preventive measures would be considered to reflect a lack of discipline and training for which the unit commander would be held responsible.

In addition to the formal program of training in the prevention of cold injury, all possible devices were employed to make the soldier foot conscious. The effects of poor foot hygiene were illustrated by photographs of disabling early and late lesions. These pictures were furnished to battalion surgeons, who demonstrated them in classes held for enlisted men in their intervals out of the line. Spot radio announcements were made. Posters were displayed in the bathing facilities provided (figs. 28, 29, and 30). Small pamphlets of instructions listing "Cold Weather Don'ts" and "Cold Weather Do's" were distributed among the men to carry on their persons. No opportunity was spared to alert the soldier to the consequences of neglect of his feet and to school him in the precautions by which he could protect himself against cold injury.

Specifically, the training of the individual soldier was directed toward the following considerations:

1. Conserving body heat.

2. Keeping the feet warm and dry. This was to be accomplished by the avoidance of any form of constriction, immobility, dependency, and cramped

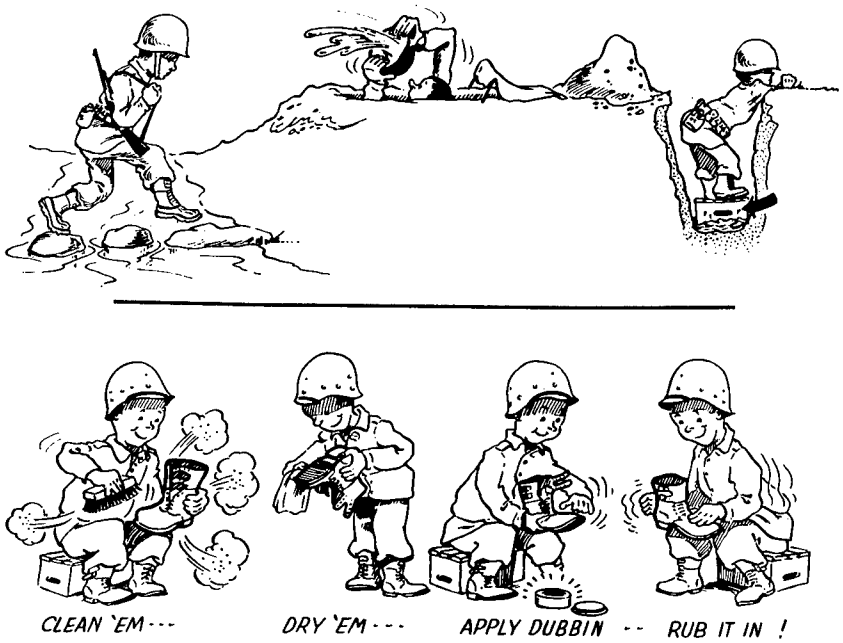

FIGURE 28.—Drawings used to instruct troops how to keep their feet dry and care for their shoes.

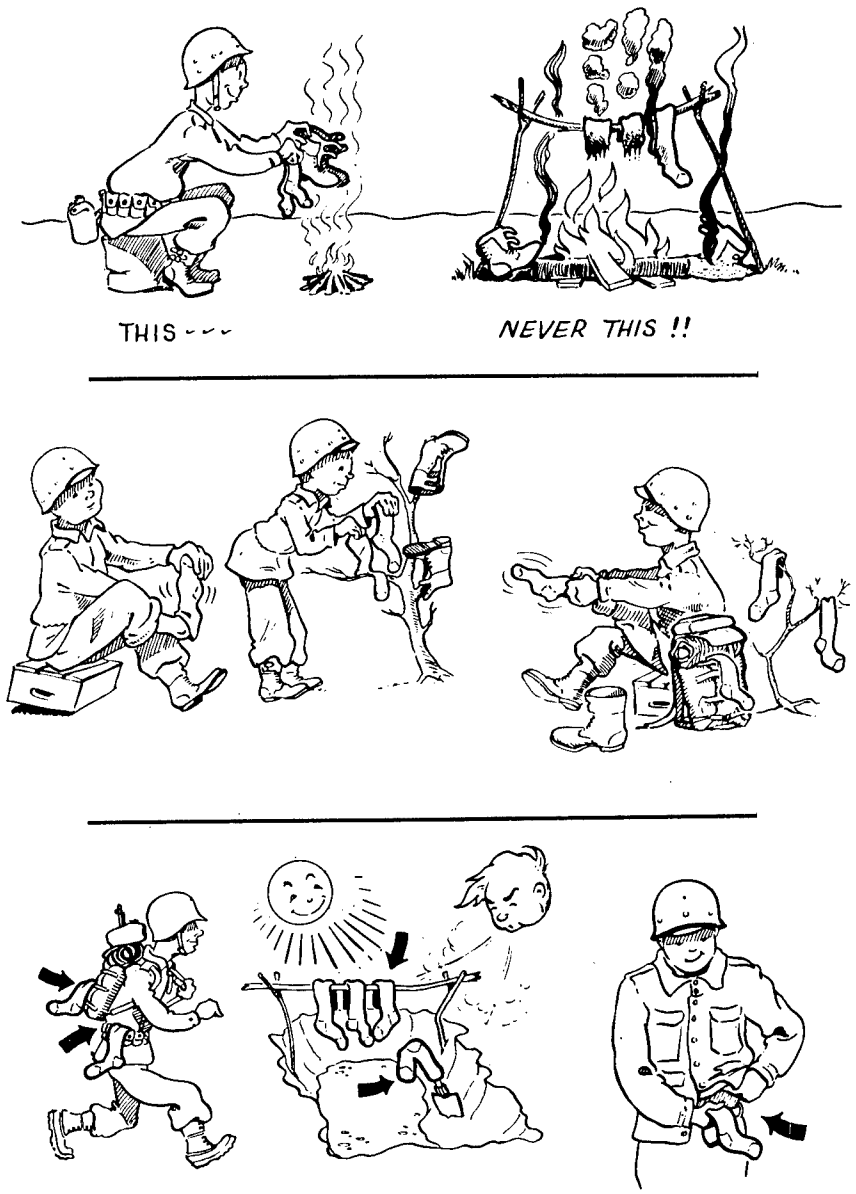

FIGURE 29.—Drawings used to instruct troops in care of wet shoes and socks.

position; by the promotion of circulation through exercises; and by periodic removal of the shoes and socks, and massage of the feet.

3. Using equipment to the best possible advantage, with particular emphasis on the correct use of overshoes and shoepacs.

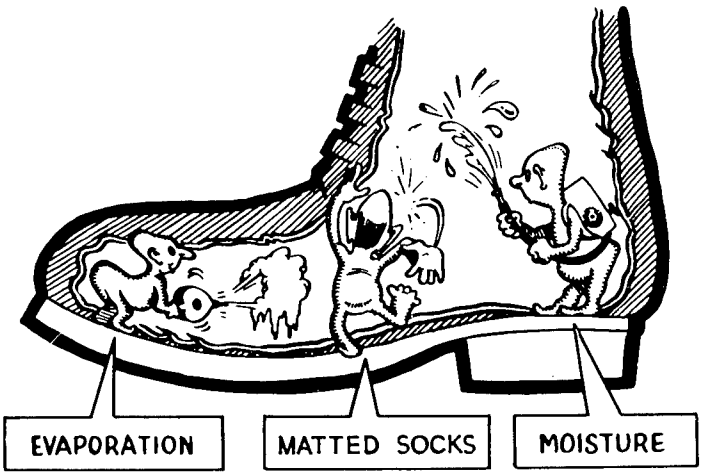

FIGURE 30.—Drawing used to instruct troops in causes of trenchfoot.

4. Changing shoes and socks frequently, particularly when they had become wet from rain, mud, or perspiration.

SUMMARY

The heavy losses from trenchfoot which occurred during the winter of 1943–44 in Italy were greatly reduced during the succeeding winter. It is quite true that during the second winter the front was frequently static, troops were not kept in the front lines for overlong periods, exposure to cold was therefore briefer, and men were evacuated promptly when they first complained of their feet. When, however, all due allowance is made for these considerations, there is still no doubt that the preventive measures devised and put into practice were fundamentally responsible for the improvement evident in the winter of 1944–45.

Between October 1944 and January 1945, inclusive, total trenchfoot casualties in infantry divisions amounted to only 1.3 percent of total infantry strength, as compared with 4 percent for the same period in the preceding winter.[27] Over this period, surveys had showed steady improvement, from month to month, in the use of preventive measures by the troops, and it was to the use of these measures, even more than to the provision of better clothing and footgear, that the decrease in trenchfoot was attributed. The schooling had been expensive, but the lessons of 1943–44, as the experience of the succeeding winter showed, had been well learned in the Mediterranean theater.

[27] Progress on the Trench Foot Problem. U. S. Army M. Dept. Bull. No. 88, May 1945, p. 3.

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CHAPTER VII

European Theater of Operations

Statistics collected during World War II indicate that approximately 46,000 cases of cold injury occurred in ETOUSA (European Theater of Operations, United States Army) during the fall and winter of 1944–45. This was about 5 percent of all admissions to medical treatment. The more complete statistics now available, which include not only cases of cold injury without other injuries but cases which occurred in association with other injuries, bring the number of casualties from this cause in the European theater to approximately 71,000 cases (p. 494).

Other armies which fought in Europe had no such incidence of cold trauma. Even when British troops fought under conditions very similar to those under which United States Army troops fought, their incidence of cold injury was negligible (p. 198).

The purpose of this chapter is twofold: (1) To tell the complete story of cold injury as it was encountered in ETOUSA during World War II, and (2) to attempt, as far as possible, to explain why cold injury occurred in this theater in what was truly an epidemic form.

There are a great many explanations for what happened, some of them more valid than others. If, however, the premise be accepted that cold injury is largely preventable, there is no real excuse for what happened. This is neither a new nor an unreasonable point of view. It was the considered opinion for instance, of the General Board, United States Forces, European theater (p. 208), which concluded its study of cold injury in that theater as follows:

> 29. *Cold injury, ground type, is to a great extent preventable.*
>
> 30. *The relatively high incidence of cold injury* * * * in the European Theater of Operations was due to inadequacy of clothing and footgear of types suitable for winter operation, unfavorable operational conditions and to the delay of many units in instituting a program with emphasis on and close supervision of the measures to be taken by the individual soldier.

Of the three factors listed by the General Board in their report entitled "Trench Foot" (Medical Section Study No. 94), as responsible for the incidence of cold injury in the European theater in the winter of 1944–45, only one, unfavorable operational conditions, is not susceptible to reasonably complete control, and even this condition is susceptible of some modification (p. 425).

If, however, there is no absolute excuse for the epidemics of cold injury which occurred in Europe, there are a number of reasons for them which will be set forth in more detail in the course of this chapter. It might be useful, for orientation purposes, to list and discuss briefly certain of these reasons in this

introductory section, after stating that the fundamental and all-pervading reason was that the lessons of the past had not been learned or heeded.

There were three major immediate reasons for these epidemics: (1) Operational conditions, (2) inadequacy of clothing and footgear, and (3) delay in instituting a program for the prevention of cold injury, ground type.

As has been pointed out many times in this volume, the experiences of the Aleutians (p. 83) and of the Mediterranean Theater of Operations (p. 101) either were not understood or were not considered applicable to the European theater. Furthermore, early experience in the European theater was ignored. The high-altitude cold injuries which had originally beset the Eighth Air Force (p. 130) were well under control by D-day, but the lessons implicit and explicit in them were not passed on to the Ground Forces, chiefly because there was as yet no general realization that all varieties of cold injury are of the same general etiology and are subject to the same general considerations of prevention and control.

The winter of 1944–45 was the coldest and wettest in years, and the wet cold, combined with the tactical situation (p. 136), created precisely the conditions most favorable for the development of trenchfoot and frostbite. Moreover, two points of view prevailed about the possibility of a winter campaign in Europe, neither of them conducive to preparations for the prevention of cold injury. Historically, decisive military campaigns had not been fought in western Europe during the cold winter months. On the other hand, it was the opinion, at least in certain circles, during the summer and early fall of 1944, that the war would end before winter. Thus, staffs were not psychologically attuned to the need for large supplies of special combat clothing, footgear, and other winterizing equipment (p. 147), or to the necessity for an extensive program for the prevention and control of cold injury when there was time. A calculated risk also was taken by command decision to bring forward ammunition, gasoline, and other combat requirements to the exclusion of winter clothing and footgear.

For a number of reasons, clothing and footgear, which play an important part in the prevention of cold injury, therefore were not in adequate supply and were of inadequate design, as it turned out. When adequate supplies were finally received, they came too late to be entirely useful, and they were not always used efficiently because troops had not been trained in their use (p. 160).

For some of the same reasons, the program of prevention which eventually was instituted comprehensively and effectively in the European theater was instituted too late to be as useful as it should have been (p. 169). Troops locked in mortal combat are concerned with saving their lives, not with learning how to take care of their feet.

Other factors inherent in the rapid buildup of strength, the organization of theater and field forces, and the development of operational plans contributed to lack of attention to preparedness for cold trauma. On 31 May 1942, for example, there were only 34,350 United States Army troops in Europe; when the war ended, on 8 May 1945, the United States Army strength in the

European theater totaled over 3,000,000 men under arms. This tremendous increase in strength involved hundreds of units, both large and small and in both combat and support roles. Efficient command and staff function to direct these units required repeated reorientation and sometimes reorganization of the higher theater headquarters, the integration of the several army headquarters into command structure, and the activation of lesser headquarters of the Communications Zone in the United Kingdom and, later, on the Continent. Inevitably, such expansion brought with it a shifting of key personnel and responsibilities.

The medical organization and personnel staffing understandably and necessarily underwent, in general, the same mushroom growth. As an example, from the meager nucleus of one medical officer who went to England with the Special Observers Group in May 1941, before the United States entered World War II, the total strength of the Medical Department in the European theater increased to 268,798 officers and men present in the theater on 30 April 1945.[1] No expansion of such magnitude could fail to have its weaknesses as well as its strengths.

Medical planning for the invasion of the Continent did not include extensive planning for the prevention of cold injuries. The Manual of Therapy, issued shortly before D-day, mentioned them only casually, and the precautions suggested after exposure to cold and moisture were somewhat impractical for men in combat or about to be engaged. They included a foot bath with soap and water, massage of the feet for 20 minutes, dry socks, and a change of shoes. The medical officers who were responsible for the medical planning for the invasion and for the preparation of the Manual of Therapy had almost without exception never seen cold injury, and few of them, for that matter, had had any medical combat experience.

It is against this background that the history of cold injury in ETOUSA must be read and evaluated. Other things seemed, and indeed were, far more pressing than possible trauma from cold. As the troop strength of the theater increased, repeated reorganizations of various headquarters were necessary. A multiplicity of staffs were involved. There was constant preoccupation with urgent military and over-all medicomilitary needs, including tactical planning, training, supply, and other matters connected with the normal support of the largest military operation ever to be undertaken. Priorities of effort had to be devoted to day-by-day problems, most of them, or so it then seemed, of far greater urgency than the prevention of trenchfoot. Finally, there was general inexperience, on the part of all concerned, with both the medical and the military aspects of cold trauma.

All of these considerations must be borne in mind in the reading and evaluation of the unfortunate story of trenchfoot and frostbite in ETOUSA in the fall and winter of 1944–45. The lessons then learned greatly influenced the planning and preparations for combat in cold and wet weather in Japan

[1] Strength of the Army, 1 May 1945. Prepared for War Department General Staff by Machine Records Branch Office of the Adjutant General, under direction of Statistical Branch.

and other parts of the Far East (p. 216). The European experience should always serve as a meaningful and instructive warning of the responsibility of staff, command, and medical and other technical services in preparation for all future military operations.

HIGH-ALTITUDE COLD INJURY IN THE EIGHTH AIR FORCE

Until the epidemics of cold injury occurred in the European theater in the fall and winter of 1944, frostbite among flying personnel had constituted the only important problem of this kind. Ground troops stationed in Ireland had encountered extremely cold weather, but under noncombat conditions, which in no way paralleled the conditions confronting troops on the Continent in the winter of 1944–45. The dangers which confronted the Army Air Forces were also not parallel to those which ground troops encountered, but certain aspects of the experience are sufficiently instructive to make it worthwhile to tell the story briefly.

Incidence

From the beginning of operations in Europe, in 1942, until the end of the fighting on the Continent, in May 1945, varying proportions of all casualties in airborne personnel of the Eighth Air Force could be attributed to high-altitude frostbite. It was pointed out in the August 1944 issue of *Health* [2] that, during the fiscal year 1943–44, more crew members returning from operational missions had sustained cold injuries than had sustained wounds from enemy action. These losses were serious. A third of all frostbite casualties required hospitalization, and, even when the injuries were mild, flying personnel had to be grounded for 4 to 14 days. A surgeon, speaking on the subject at a general hospital staff conference, warned that the situation constituted a real emergency, since many of the men hospitalized would not return to duty for months, if ever.

Annual reports for the years 1943, 1944, and 1945, by Col. (later Maj. Gen.) Malcolm C. Grow, MC, Surgeon, Eighth Air Force, contain analyses of the casualties from cold injuries, as follows:

For the 14-month period ending in December 1943, 1,634 men were removed from flying duty because of cold injuries incurred on high-altitude operational missions. Over the same period, 1,207 men were removed from flying duty because of injuries incurred in action against the enemy. In 1943, each casualty from cold injury lost an average of 10.5 days from flying duty, and 7 percent, according to an analysis of a sample of 200 consecutive casualties from this cause, were permanently lost to airborne crewmen.

In 1944, although the numbers of casualties from all causes increased as the rate of combat was stepped up, the situation in respect to cold injury was considerably improved; 1,685 men were lost from this cause in a total of 3,158 men

[2] Monthly Progress Report, Army Service Forces, War Department, 31 Aug. 1944, Section 7: Health.

removed from flying duty. The average number of days lost from duty because of cold injury fell to 4.7.

In 1945, the situation was still further improved. Between 1 January and the end of the fighting on 8 May, there were only 151 injuries from high-altitude cold in 149 crewmen, compared with 3,852 injuries from combat missiles.

Causes of Cold Injury

The occurrence of high-altitude cold injury was found, on analysis, to be related to a number of considerations. Some of them were obvious, such as the season of the year and the altitude. Most of the missions were carried out about 25,000 feet above sea level, where the free-air temperature, using December 1943 as an illustration, ranged from −22.4° to −45.4° F. (−30.2° to −43.6° C.). In 1944, temperatures as low as −60° F. (−51.1° C.) were encountered.

The position of the crew members in the plane had much to do both with their chances of contracting cold injury and with the location of the injury. In heavy bombers, waist, tail, and ball-turret gunners were particularly vulnerable. The two waist gunners occupied the most exposed position. Injuries from wind blast were frequent for several reasons. The wind entered through openings for gun mounts. The gunners removed the gun-cover assembly because it interfered with the operation of their guns. They left the waist hatch open for the same reason, as well as to reduce chances of surprise by enemy bombers. The radio operator also left the hatch open to avoid surprise.

In 1943, waist gunners and radio operators sustained considerably more frostbite of the face, neck, and ears than men in other positions, though injuries in these locations influenced losses from duty less than did injuries of the hands and feet. The upper-turret and ball-turret gunners were particularly likely to sustain injuries of the feet. Tail gunners suffered heavily from frostbite of the hands and feet but more often sustained frostbite of the face, neck, and ears. Ball-turret gunners suffered equally from frostbite of the hands and face but more heavily from injuries of the feet. Gunners in any position who removed their gloves to clean jammed guns or to change ammunition belts were instantly frostbitten when they touched cold metal with their bare hands.

During 1943, gunners in the waist, tail, ball turret, and upper turret of bombers, together with the radio operator, sustained 75 percent of all injuries from frostbite in the United States Army Air Forces in Europe. Gunners whose position was not stated in the reports sustained another 8 percent of cold injuries.[3] Waist gunners and tail gunners sustained 64 percent of all cold injuries. The number of casualties was reduced as time passed, but their proportionate distribution among crewmen did not alter materially during the war.

[3] Data on frostbite casualties were secured from the Weekly Care of the Flyer and Statistical Report rendered by group surgeons, who were required, as far as was practical, to state the cause of the injury, the part of the body affected, and the position of the injured man on the plane. Only frostbite severe enough to cause removal from flying duty was considered in these reports.

In 1945, the waist, tail, and ball-turret gunners sustained 99 of the 151 separate cold injuries which were reported, roughly two-thirds of the total number.

Up to July 1943, injuries of the hands accounted for more than half of all cold injuries in the Eighth Air Force (table 7) and injuries of the face, neck, and ears to less than a fifth. Thereafter, the proportions were reversed, and injuries of the face, neck, and ears accounted for the majority of these injuries. This was a decided improvement, since, as has been pointed out, injuries in these areas were less serious in terms of manpower losses.

TABLE 7.—*Changing bodily sites of high-altitude frostbite, 1942–45, Eighth Air Force*

Site of injury	December 1942–June 1943		July–December 1943		1944		1945	
	Cases	Percent	Cases	Percent	Cases	Percent	Cases	Percent
Face, neck, ears	58	17. 0	779	53. 0	1, 145	65. 0	79	52. 3
Hands, fingers	188	56. 0	425	28. 0	298	16. 8	39	25. 8
Feet, toes	87	26. 0	278	18. 0	304	17. 2	32	21. 2
Buttocks, groin	4	1. 0	7	1. 0	19	1. 0	1	. 7
Total	337	100. 0	1, 489	100. 0	1, 766	100. 0	151	100. 0

The largest single cause of high-altitude frostbite was wind blast, which was responsible for 39 percent of all cases in the 14-month period ending in December 1943 and for almost 55 percent of all cases in 1944. The remaining cases were due chiefly to lack of equipment, failure of equipment, and removal of equipment which should have continued in use. The first few months of aerial warfare in Europe clearly revealed that Air Force personnel, including medical personnel, had not been adequately trained in the prevention of cold injury. They had been fully alerted to such dangers as flak and air collisions, but most of them did not know how to protect themselves against the dangers of cold, nor, because they had not been instructed in its use, did they know the proper use of the equipment supplied to them. The highest incidence of cold injury occurred in new groups and in replacement crews in older groups; these men had not been trained in prevention and did not understand the use and maintenance of protective clothing.

Corrective and Preventive Measures

When once the factors contributing to the severe losses from high-altitude frostbite were understood, corrective measures were promptly instituted. An intensive investigation was carried out in March 1943, after a sharp increase in casualties from this cause had occurred in February. One of the principal causes was found to be shortages of electrically heated boots and gloves. Until additional American equipment could be supplied, the difficulty was tempo-

rarily relieved by modification of gloves and boots used by British airmen to permit their use with American flying suits. The investigation in March 1943 also revealed that failure of electricity in the planes was responsible for some failures of equipment, that large numbers of injuries were occurring because portions of the face and neck were unprotected, and that casualties in heavy bombardment aircraft were suffering from cold injury after wounding because of lack of warm blankets. It was also found that crewmen who occupied protected positions not infrequently suffered cold injuries from wind blast after damage to the plane by enemy missiles.

After these discoveries, a number of new items of equipment were devised by the Air Surgeon's Office and other service departments, working in cooperation. Among these new items were the following:

1. Protectors for the face and neck, so designed as to cover the oxygen mask. The crewmen had previously complained that the face masks supplied interfered with the use of the new type of oxygen mask and were also impractical because they allowed the goggles to cloud over.

2. A small, mufflike heated unit into which hands and feet could be inserted if the standard gloves and boots became useless because of failure of the plane's electrical system.

3. Electrically heated canvas bags, several of which were supplied to each heavy bomber, to keep the wounded warm, reduce shock, and prevent further cold injury.

4. Electrically heated blankets for the wounded to use if their electrically heated flying suits had to be cut away to control hemorrhage or if the heating system of the plane was destroyed by enemy action.

5. Warm, light, and flexible gloves (devised by the surgeon of the Eighth Air Force), which did not have to be removed to release jammed guns. The men were warned that their hands would be frostbitten if they removed their gloves, and it was demonstrated to them that a locked gun could usually be released just as readily with gloved as with ungloved hands.

During 1944, personal equipment was generally satisfactory, though early in the year there were some shortages in particular sizes, both large and small, of heated gloves and shoes, and not all the items supplied were satisfactory in either design or durability.

The investigation carried out in March 1943 revealed, as has been noted, many shortages, inadequacies, and failures of protective equipment. Originally, the maintenance of protective equipment had been among the numerous duties of the assistant squadron operations officers, who had neither the time nor the training for this task. On 19 March 1943, a directive was issued authorizing the assignment of equipment officers in each combat unit. These officers were trained by the Central Medical Establishment, Eighth Air Force, in 2-week courses. The first class, for 5 officers, was completed on 29 March; by the end of 1943, 275 officers had been trained in 23 classes.

The duties of these officers, who worked in close cooperation with medical officers, were as follows: (1) To provide facilities for drying, testing, and storing

all flying clothing; (2) to provide means for checking oxygen masks and systems; (3) to assist in all matters pertaining to procurement and alteration of protective flying equipment; and (4) to train airborne personnel in the correct use and maintenance of personal protective equipment.

After each command, division, group, and squadron had appointed equipment officers and these officers had been trained, problems arising from deficiencies and failures of protective equipment promptly decreased. During the latter part of 1944, a demand arose for special training of the enlisted men who assisted the equipment officers. Courses for them were organized at the Central Medical Establishment and were continued until eight enlisted men had been trained in each combat group.

Certain changes were also made in the aircraft themselves. By March 1944, most operational planes had been equipped with a modified closed radio room and modified gun hatches and waist window. Since the number of men who could wear electrically heated suits depended upon the amount of electricity available from the plane generators, the capacity of the generators was increased. The heating systems in bombers were also improved.

Educational training.—Lectures and demonstrations were given on a regular schedule to cover deficiencies in training. The subjects included first aid and methods of preventing cold injuries and anoxia. The proper use of flying clothing, especially electrically heated clothing, was explained and demonstrated. Educational charts to show the various stages of high-altitude frostbite, its symptoms and signs, and methods of management were prepared by the Medical Department and equipment officers under the general direction of the theater senior consultant in neurosurgery, Lt. Col. (later Col.) Loyal Davis, MC. These charts were distributed to all divisions, groups, and squadrons likely to be exposed to cold injury and were given routinely thereafter to all new units as they arrived in the theater.

There was considerable discussion concerning whether or not photographs showing the end results of high-altitude cold injury (that is, gangrene and amputation) should be used in the educational program. Eventually, the distribution of these photographs was limited to medical officers.

Special Investigations

In a memorandum dated 15 February 1943, Colonel Davis called the attention of Brig. Gen. (later Maj. Gen.) Paul R. Hawley, Chief Surgeon, ETOUSA, to a preliminary study of 14 cases of high-altitude frostbite which had been conducted on the neurosurgical service of the 2d General Hospital between 30 January and 9 February 1943. General Hawley sent this report to Colonel Grow, and arrangements were made to assign a neurosurgeon from the 2d General Hospital to temporary duty at one of the airfields, to permit immediate study of cold injuries in returning flying personnel.[4]

[4] Letter, Lt. Col. Loyal Davis, MC, Senior Consultant in Neurological Surgery, to Brig. Gen. Paul R. Hawley, Chief Surgeon, ETOUSA, 15 Feb. 1943, subject: Damage to the Extremities From Cold Among Flying Personnel of United States Army Air Forces.

Somewhat later, arrangements were made to transfer high-altitude cold injury casualties directly to the 2d General Hospital for special studies.[5] It is both interesting and significant that it was necessary to call the attention of all concerned to the fact that Circular Letter No. 12, dated 20 January 1943, Office of the Chief Surgeon, ETOUSA, although it dealt specifically with immersion foot, applied equally to injuries from high-altitude cold to Air Force personnel. Until this concept was appreciated and other details were clarified, transfers of cold injury casualties to the hospital were delayed, and, because of the delay, many of the opportunities for investigation, particularly early investigation, of these injuries were nullified.

By 31 August 1943, studies had been carried out on 93 high-altitude cold injuries in 86 patients; 57 injuries were on the hands and 25, including 6 caused by immersion, were on the feet.[6] The investigations covered the circumstances of injury, the factors contributing to the injury, complete clinical details, skin-temperature studies, capillary microscopy, oscillometry, studies of sweating, and sensory reactions to injury.[7] A complete photographic record, including colored photographs, was made in each case, and each patient was personally observed by Colonel Davis, who had himself gone on a practice raid mission to study the clinical effects of cold at 13,000 feet.

By 9 May 1943, it was noted that the number of casualties being admitted to the 2d General Hospital for high-altitude frostbite were beginning to decline, presumably because of insistence upon examination of equipment before missions and the enforcement of other preventive measures.

The clinical observations made in the course of this study and other considerations of cold injury sustained at high altitudes are discussed elsewhere (p. 13).

Summary

Because of the analysis of the situation and the various preventive and educational measures instituted, the problem of high-altitude cold injuries in the Eighth Air Force was well under control by the time that France was invaded on 6 June 1944. The lessons thus learned, however, were not passed on to the Ground Forces in the European theater, apparently chiefly because of the general failure to appreciate the fact that cold injuries sustained in high-altitude flights could have any relation to cold injuries sustained in ground fighting. The fundamental error was failure to appreciate that all cold injuries are merely separate phases of a single pathologic process, differing from each other in severity and rate of development but in no other way. Both high-altitude frostbite and the ground type of cold injury which occurred later were caused by the same etiologic factors and were brought under control by

[5] Memorandum, Maj. J. E. Scarff, for Chief, Professional Services Division, Office of the Chief Surgeon, ETOUSA, 22 Dec. 1943, subject: Hospitalization of Cases Suffering from High Altitude Frostbite.

[6] Memorandum, Lt. Col. Loyal Davis for Chief Surgeon, ETOUSA, 31 Aug. 1943, subject: Incidence of Cases of Cold Damage to the Tissues.

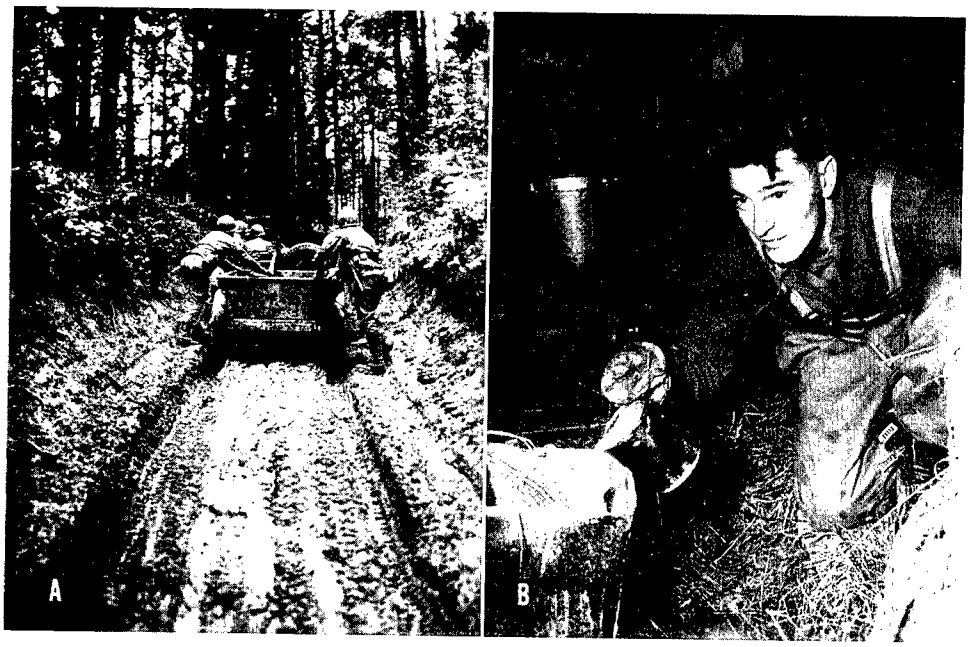
[7] Letter, Lt. Col. Loyal Davis, MC, Senior Consultant in Neurological Surgery, to Brig. Gen. Paul R. Hawley, Chief Surgeon, ETOUSA, 14 June 1943, subject: Cold Damage to Extremities.

the application of much the same epidemiologic principles. Hence, had the lessons of the Air Force experience been properly disseminated and utilized, they might have prevented many of the cold injuries which caused such heavy losses during the ground fighting in the winter of 1944–45.

TACTICAL AND ENVIRONMENTAL CONSIDERATIONS

The story of the ground type of cold injury in ETOUSA in 1944–45 begins just about the time that the pursuit of the German armies across France after D-day ended at the Siegfried Line and combat conditions had become more or less static. This was the middle of October 1944. Occasional cases of cold injury had been reported before this time (p. 138), but they were sporadic and their possible significance was not generally appreciated.

Up to 8 November, the front was comparatively quiet. On that date, the Third U. S. Army began a heavy drive to the east, in environmental circumstances highly favorable for the development of the ground type of cold injury. The weather on the Continent, which had been almost ideal from the beginning of the invasion until the end of September, then began to change. It proved to be the wettest winter, as well as the coldest, that Europe had experienced in 30 years. The heavy rains which began early in October con-



U. S. Army photos

FIGURE 31.—A. Infantrymen pushing jeep and trailer along muddy road in France, November 1944. B. Infantryman bailing out his dugout.

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tinued throughout the month. On the Third U. S. Army front, it rained 28 of the 31 days.[8]

The offensive was conducted in large part over wet and flooded terrain (fig. 31) and required the crossing of major rivers. The Moselle and other rivers were high because of the immoderate rains. By November, flood conditions had become general in all army areas. Fields and roads were water soaked, and irrigation ditches and small streams as well as rivers were all overflowing. The weather was always cold, and cold injuries, in the form of trenchfoot, occurred in great numbers.

A major counterattack was begun in the Ardennes by German forces on 16 December. For the preceding several days, the weather had been extremely cold, and the intense cold, combined with heavy fighting, often under adverse circumstances (fig. 32), produced a second major outbreak of cold injury, this time with more injuries in the form of frostbite.

U. S. Army photo

FIGURE 32.—2d Division infantrymen, 9th Regiment, First U. S. Army crouch in a snow-filled ditch, seeking shelter from a German artillery barrage during the Battle of the Bulge.

[8] United States Army in World War II. The European Theater of Operations. Logistical Support of the Armies, September 1944–May 1945, vol. II. [In preparation.]

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With the termination of the Battle of the Bulge, in January 1945, the German threat to the Western Front was, for all practical purposes, at an end. Thereafter, the tactical situation, as the result of an Allied counteroffensive, could best be described as the renewed pursuit of the German armies across Europe into the heart of Germany, the pursuit continuing until V–E Day, 8 May 1945.

Between 19 December 1944 and 31 January 1945, the average maximum temperature on the fighting front in Europe was 33.5° F. (0.83° C.), and the average minimum temperature 22.6° F. (−5.2° C.). The element of wetness, which had been responsible for the initial outbreak of cold injury in November, was absent during this period.

The cold began to moderate during the last days of January, and the thaw which set in on 1 February again altered the environment. Wetness now predominated, and the ground type of cold injury which occurred at this time was, as in the first outbreak, chiefly trenchfoot.

INCIDENCE

As the preceding brief summary of tactical and climatic conditions shows the development and prevalence of cold injury in ETOUSA in the winter of 1944–45 were clearly related to the degree of combat activity and to the environmental circumstances and changed as these conditions changed.

Cold injury did not become epidemic until the middle of November, though sporadic cases had been reported earlier. The first case of trenchfoot appeared on 27 August 1944, in a hospital unit attached to the Third U. S. Army.[9] By 12 October, 25 or 30 cases were reported in the 35th Infantry Division, Third U. S. Army.[10] Some of them, which were attributed to lack of overshoes, had occurred as early as 6 October. Col. (later Brig. Gen.) Elliott C. Cutler, MC, Chief Consultant in Surgery, Office of the Chief Surgeon, ETOUSA, noted in his official diary on 14 December that there had been no report of cold injury during the week ending on 27 September but that 140 cases had been reported for the week ending on 8 October and 320 had been reported for the following week.

For the week ending on 3 November, 17 cases were reported in the First U. S. Army, 1 in the Ninth U. S. Army, and 184 in the Seventh U. S. Army, the total number recorded for this week being 202.[11] Fifty percent of the cases in the Seventh U. S. Army were recurrences in men who had suffered from cold injury in Italy the previous year.

The total number of cases for the week ending on 10 November was 823 and for the following week 5,386. This was the peak of the epidemic, and for

[9] Reported in Annual Report, Medical Activities in the First U. S. Army, 1944.

[10] Memorandum, Maj. W. P. Killingsworth, MC, Office of the Surgeon, Third U. S. Army, for Colonel Hurley, Surgeon, Third U. S. Army, 12 Oct. 1944.

[11] Administrative and Logistical History of the Medical Service, Communications Zone, ETOUSA, vol. 14, ch 16. [Official record.]

the next several weeks there was a progressive decline in the number of cases.[12] The Third U. S. Army, which had had the largest number of cases, experienced the most precipitous decline. In the First U. S. Army, which had had the second largest number, the curve was also downward, but the decline was more gradual. In the Seventh and Ninth U. S. Armies, the pattern of the curves was similar to that of the other armies but was generally much lower. Early in December, the rates for the theater as a whole were only a fifth of the maximum rates, and it was thought that the situation was under control.[13]

When the Germans attacked in the middle of December, in what came to be known as the Battle of the Bulge, the number of cases of cold injury again increased sharply. The peak incidence, 3,213 cases, occurred in the week ending on 29 December 1944.[14] The maximum number of cases in the December outbreak occurred in the First and Third U. S. Armies, which were most heavily engaged. In the Seventh and Ninth U. S. Armies, the upward swings were less sharp.[15] Neither in this epidemic nor in the later outbreak in January did the number of cases per week approximate the 5,386 cases which occurred during the week ending on 17 November.

In contrast to the November outbreak of cold injury, which had taken the form of trenchfoot, in the December outbreak many cold injuries were in the form of frostbite. The cold was intense and the ground frozen, so that wetness was not a factor. This was a new and different experience, which the troops were not fitted to cope with. The men in all sectors of the battlefield had less time to care for themselves, and particular factors operated to increase the incidence in particular divisions and special smaller units. Even the best trained divisions had trouble during this period.

The decline in incidence which followed the epidemic in December 1944 was followed by another sharp upswing, beginning in the week ending on 12 January, when the weather again became extremely severe, with freezing temperatures and heavy falls of snow.[16] Again, many of the cold injuries took the form of frostbite. During this epidemic a new factor entered the situation; namely, the large number of raw and inexperienced replacements (p. 171) who had to be thrown into battle because of the manpower losses which had occurred during this critical period.

The incidence of cold injury continued high, with only minor variations, between the week ending on 12 January and the week ending on 9 February, though, after the thaw that began on 1 February, the character of the epidemic changed and trenchfoot again became predominant. At no time during this period were fewer than 3,000 cases reported each week.

[12] Coded Message CM-IN-E82072, Office of Chief Surgeon, Headquarters, Communications Zone, ETOUSA, to War Department (signed Eisenhower to Kirk from Lee). 3 Jan. 1945.

[13] (1) Diary, Preventive Medicine Division, Office of the Chief Surgeon, ETOUSA, 9 Dec. 1944, subject: Incidence of Trench Foot. (2) Coded Message, CM-IN, Headquarters, Communications Zone, ETOUSA, to War Department (signed Eisenhower to Surles for Houston from Lee), 18 Dec. 1944.

[14] See footnote 11, p. 138.

[15] Gordon, John E.: A History of Preventive Medicine in the European Theater of Operations, U. S. Army, 1941–45, vol. II, pt. 10, p. 46. [Official record.]

[16] See footnote 11, p. 138.

As the weather began to moderate and combat activity became lighter, the incidence of cold injury again began to decline. This time the decrease was permanent. There were 1,643 cases in the week ending 16 February but only 596 the following week. The peak incidence during March, 888 cases, was in the week ending on 9 March. In the week ending on 30 March, there were only 108 cases, and the total number of cases in April was only 230. Except under special, local circumstances, almost all of the cases which occurred after the middle of February 1945 were instances of trenchfoot.

What happened in the European theater during the winter of 1944–45 has been variously described. It is nowhere better summed up than in a comment in the annual report of the Surgeon, VII Corps, dated 26 January 1945. "Trench foot," he wrote, "appearing sporadically around the first of November, has become like a plague over the First Army front." His description was applicable to the entire frontline.

Variations in incidence.—Although cold injury was always almost exclusively a problem of armies in the field, there was considerable difference at all times during the winter in the incidences reported by armies, divisions, and smaller units. Generally speaking, the Third and First U. S. Armies, which had extremely heavy and difficult combat assignments, had the greatest amount of cold injury. On the other hand, combat activity did not tell the whole story. This was particularly evident when the records of smaller units were examined. Some divisions always had good records; this, however, does not necessarily mean that they were always free from cold injury. The 30th Infantry Division, First U. S. Army, for instance, was an old, seasoned unit, with a well-developed system of foot discipline, and its command had long appreciated the significance of the possible occurrence of cold injury in combat infantrymen.[17] Only when tactical circumstances were entirely beyond control did this division have an appreciable amount. Some divisions, in contrast, had records that were almost consistently bad, regardless of the degree of combat activity. Investigation of the situation in these divisions almost invariably brought to light conditions which could be improved. It was in this sort of investigation and counseling that trenchfoot-control teams (p. 177) had their greatest field of usefulness.

Variations between units were apparent when the trenchfoot incidence was low as well as when it was high. The Ninth U. S. Army, for instance, had relatively little cold injury because it was less actively engaged than the First and Third U. S. Armies, but its units nonetheless showed the same types of variations as were apparent in those armies.

Incidence according to services.—Because cold injury is so overwhelmingly a disease of frontline infantrymen, it is not always realized that it can also occur in other troops when conditions are favorable for its development. Col. John E. Gordon, MC, Chief, Preventive Medicine Service, Office of the Chief

[17] See footnote 15, p. 139.

Surgeon, ETOUSA, noted in his report of 22 November 1944 that the bulk of the cases reported up to that time (1,167) had occurred in the Infantry but that cases had occurred also in the Engineer, Field Artillery, Tank Corps, Quartermaster Corps, Cavalry Reconnaissance, Antiaircraft, Tank Destroyer, Ordnance, Antitank, Signal, and Military Police units. On 30 November, cold injury was reported in troops staging in rear areas, presumably because of their lack of overshoes and shoepacs.[18] In February 1945, there was an alarming number of cases at a large staging area in the Channel Base Section.[19] The outbreak was promptly halted by the provision of proper footgear and other equipment and by strict enforcement of preventive measures.

Cold injury among replacements (reinforcements) furnished a special problem, which is discussed later, under a separate heading (p. 171).

Impact of cold injury.—The impact of cold injury in a combat theater is discussed in detail elsewhere, but a few facts may profitably be repeated here because the details are, in many respects, even more overwhelming than the total incidence. The data have been gathered from correspondence, official diaries, and formal and informal memorandums of various kinds.

In November 1944, for instance, the 79th Infantry Division, Seventh U. S. Army, had 1,400 battle casualties and 210 casualties from trenchfoot. For the week ending 25 November, for every 100 battle casualties evacuated from the Third U. S. Army, 60 soldiers were evacuated for cold injury. The medical officer who conveyed this information to Lt. Gen. (later Gen.) George S. Patton, Commanding General, Third U. S. Army, noted that trenchfoot was doing quite as much damage to the Allied cause as was the enemy because of the duration of the disability and its tendency to recur when exposure was again experienced.

Losses of 10 and 15 percent, or more, of the strength of single units were not unusual. During the Lorraine campaign,[20] in November 1944, the 328th Infantry Regiment had to evacuate more than 500 men as casualties from trenchfoot and exposure during the first 4 days of one engagement; this number exceeded the number of battle casualties. During the drive into Metz, one company of the 11th Infantry Regiment had only 14 men available for duty chiefly because of losses from trenchfoot. During the 3-day battle to penetrate the Orscholz Line, the mounting toll of trenchfoot casualties, combined with battle casualties, made it impossible for the 358th Infantry Regiment to continue the attack. In all, it lost about 60 percent of its effective strength. The 357th Infantry Regiment was also so weakened from the same causes that it had to be withdrawn. At one time, the 1st Battalion was in such a precarious state that men whose feet were too swollen from trenchfoot to permit them to walk had to be carried by their comrades to forward foxholes.

[18] Essential Technical Medical Data, Headquarters, ETOUSA, for October 1944, p. 17.

[19] Semiannual Report, Channel Base Section, Communications Zone, ETOUSA, 1 Jan. 1945–1 July 1945.

[20] United States Army in World War II. The European Theater of Operations. The Lorraine Campaign. Washington: U. S. Government Printing Office, 1950.

During November and December 1944, the total number of cases of cold injury on the Western Front was more than 23,000. In terms of numbers, this was about an infantry division and a half. In terms of combat riflemen (4,000 to the division), the loss amounted to about 5½ divisions.

In his book, a Soldier's Story, Gen. Omar N. Bradley, Commanding General, 12th Army Group, presents the military interpretation of these losses. By the end of January 1945, he wrote, cold injury had seriously crippled the United States fighting strength in Europe. The malady had come upon the armies unawares, partly because the possibility of its occurrence had been ignored. By the time the troops had been disciplined in the care and treatment of wet feet, trenchfoot had the effect of a plague. Previous combat had shown that casualties from this cause occur chiefly in rifle platoons, the handful of troops who must advance under fire and who have less chance of survival than men in any other of the combat arms. Before the invasion, it had been estimated that the infantry would incur 70 percent of the combat losses. By August 1944, that estimate had been raised to 83 percent. Actually, because 3 of every 4 casualties occurred in rifle platoons, the rate of loss in them exceeded 90 percent. Trenchfoot, though listed as a nonbattle loss, exacted its heaviest toll among riflemen in the line, where every casualty sapped assault strength and thus weakened the offensive.

Medical officers had estimated, General Bradley added, that by far the greatest number of the thousands of soldiers with trenchfoot who were evacuated from the frontlines could never return to combat, and they had also predicted that some of these casualties would be incapacitated for life.

The impact of trenchfoot upon hospitals and hospitalization was also extremely serious. Between 10 October and 28 November 1944, 11,348 trenchfoot casualties were admitted to 6 general hospitals in the Paris area from the First, Third, Seventh, and Ninth U. S. Armies.[21] For the 4-week period ending 24 November, for every 100 battle casualties admitted to these hospitals the weekly number of trenchfoot admissions was, respectively, 5, 10, 55, and 54. These admissions represented, over the same period, 1.3 percent, 4 percent, 20 percent, and 24 percent, respectively, of the total hospital admissions. On one occasion, trenchfoot accounted for 602 (38 percent) of 1,581 medical admissions to the 23d General Hospital.[22] It is not necessary to point out what such figures mean in terms of bed occupancy, medical attention, and nursing and other care. The situation, in fact, was generally much worse than it seemed on the surface.

A certain proportion of hospital admissions for trenchfoot were incorrect, though ordinarily the diagnostic error was well under 10 percent. Psychogenic causes explained some cases, but malingering, although it sometimes occurred, was surprisingly infrequent.

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[21] Essential Technical Medical Data, Headquarters, ETOUSA, for December 1944.
[22] Essential Technical Medical Data, Headquarters, ETOUSA, for November 1944.

CLOTHING AND FOOTWEAR [23]

Aside from any other considerations, the protection of the extremities against cold and wet cold depends upon two practices. One of these is general, the use of warm clothing which will keep the entire body warm. The other is local, the use of proper footgear which will keep the feet warm, without constriction. Combat necessities require that all items of clothing and footgear be of such construction that they do not interfere with rapid, unhampered movement of the soldier who is wearing them. These statements concern such elementary principles of protection against cold and wet cold, and thus of protection against cold injury, that they need not be elaborated upon. In addition, these principles are so closely connected with the medical aspects of exposure that they indicate why no apology is needed for the inclusion of a rather detailed discussion of clothing and footgear in a chapter dealing with cold injury in the European Theater of Operations in World War II.

The general situation with respect to clothing and footgear in this theater during the winter of 1944–45 may be summarized about as follows:

1. The clothing which had been introduced into the Mediterranean theater after the trenchfoot experience there in the winter of 1943–44 had been fully combat tested at the Anzio beachhead early in 1944, and a detailed, favorable report on it was available in the European theater by the end of June 1944. Observers from the Office of the Quartermaster General had been in the European theater for several weeks before this time and had the clothing available for demonstration. Their advice that it be adopted for use in the theater, to replace standard types of winter clothing, was not accepted by the theater chief quartermaster (p. 145). Although a change of mind finally occurred, stocks of the new models did not reach the theater until January 1945, and distribution was not accomplished until long after the urgent necessity had passed.

2. Orders for standard types of winter clothing were entirely inadequate because the strength of the field armies had not been correctly anticipated (p. 146).

3. Requisitions on the Zone of Interior for winter clothing were placed too late. The first bulk requisition did not leave the European theater until 15 August 1944. Sufficient consideration was never given to the timelag between submission of requisitions and eventual delivery of articles. A timelag is always inevitable, even in peacetime when the supply and delivery systems can be conducted with the greatest efficiency. It is far more prolonged in wartime when both production and transportation difficulties exist. Transportation difficulties prevailed in 1944 and 1945 not only between the Zone

[23] Except as otherwise indicated, all data concerning clothing and footwear in the European Theater of Operations are derived from the following three sources: (1) United States Army in World War II. The Technical Services. The Quartermaster Corps: Operations in the War Against Germany. [In preparation.] (2) United States Army in World War II. The Technical Services. The Quartermaster Corps: Organization, Supply, and Services. Washington: U. S. Government Printing Office, 1953, vol. I. (3) United States Army in World War II. The European Theater of Operations. Logistical Support of the Armies, September 1944–May 1945, vol. II. [In preparation.]

of Interior and the European theater but also from area to area on the Continent. where for several months ammunition and gasoline had first priority.

4. The multiplicity of styles and sizes in American battlegear made for difficulties of supply (p. 149). In spite of its complexity, however, the tariff of sizes, which was based on World War I estimates, was inadequate, particularly in the large sizes, in stocks of shoes and overshoes.

5. The belief current in some quarters in the late summer of 1944 that the war would be over before a winter campaign was necessary undoubtedly played a part both in the delay in ordering adequate winter supplies and in the acceptance of the new types of clothing and footgear.

What all of this added up to was that United States soldiers were improperly clothed and shod during the fall and winter of 1944–45 and that the epidemics of cold injury which occurred must be attributed, at least in part, to those deficiencies. The "pipeline obstacles" were numerous, but the shortages themselves "were in large part the result of poor planning and wishful thinking in the ETO and production difficulties in the Zone of Interior."

Clothing

Planning.—The Quartermaster General, as was his routine, sent Capt. (later Lt. Col.) William F. Pounder, Jr., QMC, to the European theater in March 1944 as an observer. Captain Pounder had the additional function of presenting the new winter M–1943 clothing, with a view to its use in the European theater. This clothing had been developed the previous year and had been thoroughly tested in the Mediterranean theater. As already mentioned, the report on the testing of this clothing at the Anzio beachhead was in the hands of the Chief Quartermaster, ETOUSA, by 25 June 1944. This was just about the time active planning was beginning for the provision of winter clothing for troops in the theater.

At this time, the clothing planned for the winter months (exclusive of footgear, which is discussed under a separate heading) was to consist of heavy wool underwear, olive-drab wool trousers and shirt, high-neck sweater, and wool ETO jacket. Service troops in rear areas would be provided with overcoats. Combat troops would wear herringbone-tweed jacket and trousers over the wool uniform. Although this equipment was intended for fighting in France and the Low Countries—areas notably wet, cold, and muddy—it was conspicuously lacking in water-repellent items.[24]

The uniform and equipment which Captain Pounder proposed, in line with his instructions from the Quartermaster General, consisted of heavy wool undershirt and underdrawers, wool field trousers, cotton field trousers, olive-drab wool shirt, high-neck sweater, wool ETO jacket, M–1943 jacket, olive-drab cotton field cap with visor, gloves consisting of a leather shell with wool insert, synthetic-resin poncho, wool sleeping bag with water-repellent case, and shelter

[24] Letter, Capt. Wm. F. Pounder, Office of the Chief Quartermaster, ETOUSA, to Col. Georges F. Doriot, Military Planning Division, Office of the Quartermaster General, 30 June 1944.

half tent. In order to use up the large stocks then in the theater, it was recommended that wool overcoats be used if sufficient quantities of the M–1943 field jacket should not become available.

Theater personnel, in refusing these suggestions, stated that available stocks of herringbone trousers would take the place of the proposed cotton field trousers, which would be an additional rather than an essential item, and that the synthetic poncho would take the place of the M–1943 jacket, for which the supply situation was unfavorable. It was decided that the following items would be presented to Maj. Gen. Robert M. Littlejohn, Chief Quartermaster, ETOUSA, for his approval for continental winter operations: Heavy wool undershirt and underdrawers, high-neck wool sweater, ETO wool jacket or olive-drab field jacket, field cotton cap, gloves with leather shell and wool insert, wool sleeping bag with water-repellent case, and wool muffler. Items not then in stock in the theater were to be requisitioned. Combat troops would wear herringbone jacket and trousers over the wool uniform. Service troops in rear areas would be equipped with overcoat or mackinaw.

Captain Pounder's request for permission to go to France to make observations of clothing and footgear in actual use in combat was not granted by General Littlejohn, and Captain Pounder returned to the United States.

The Preventive Medicine Division, Office of the Chief Surgeon, ETOUSA, also concerned itself with the question of winter clothing.[25] In May 1944, at the suggestion of Colonel Gordon, a conference was held with the chief of the Research and Development Branch, Office of the Theater Chief Quartermaster, at which it was learned that the theater quartermaster considered that the problem of cold injury had been solved, as far as the feet were concerned, by the use of a combination of heavy socks and shoepacs. Both items were in production and would be ready in sufficient time to meet winter needs. The only additional item needed would be windbreaking clothing to wear over the regular winter clothing. The substance of this interview was reported to Colonel Gordon.

In July 1944, in a communication addressed to the theater chief quartermaster, Colonel Gordon pointed out the part which lack of proper winter clothing had played in the trenchfoot epidemic in Italy the previous winter.[26] Correct clothing and footgear, he stated, would provide for maximum conservation of natural body warmth; would protect against wetness, which influences the conservation of general and local warmth; and would be without constriction. Immediate action was urged to agree upon details of procurement of the new and superior clothing and footgear which had been developed by the Quartermaster General after the Italian experience and otherwise to get the program under way.

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[25] Memorandum for Record, Lt. Col. Paul Padget, MC, Preventive Medicine Division, Office of the Surgeon General, 26 Apr. 1945, subject: Early Interview Concerning Trench Foot Problem and Footwear—Contact With QM.

[26] Under date of 6 June 1944, Captain Pounder was informed by the Military Planning Branch, Office of the Quartermaster General, that the Mediterranean theater had already submitted requisitions for the new winter clothing to be used in operations the following winter.

The reply from the Office of the Chief Quartermaster on 10 August was to the effect that procurement had been initiated to provide clothing designed for maximum conservation of body warmth. There would be a general issue to all troops of the high-neck sweater and the olive-drab wool field jacket to be worn over it. Overcoats, raincoats, and the other usual items of clothing would be available, including wool sleeping bags with water-repellent cases for all personnel. For a typical field army, which then was estimated at 325,000 men, there would also be provided olive-drab cotton field trousers, a windproof and water-repellent garment to be worn outside the wool trousers, ponchos, mittens with inserts, and field caps.

Requisitions.—The first requisition from the European theater was sent to the New York Port of Embarkation on 15 August, the day southern France was invaded. The requirements for the initial issue and 90-day replacement were based on one field army and the attached troops. Half of the requisition was to be delivered in September and half in October. The Chief Quartermaster, ETOUSA, gave definite assurances that no further requirements would be made. On 21 August, the Office of the Quartermaster General questioned the low requirements which had been submitted and stated that, if they were correct, they would force immediate cutback in the production schedules of the supply program. On 5 September, the original requisitions were confirmed.

In Europe, meantime, there had been a growing appreciation of the possibility of cold injury during the forthcoming operations and of its possible consequences. Requests for winter clothing and complaints about deficiencies in supply were beginning to be received from armies in the field. The port of New York was advised of the increasing seriousness of the supply situation. The reply was that half of the 15 August requisition had been approved for immediate shipment but that the items could not be shipped for another 2 weeks, at least. The theater chief quartermaster was requested to review all woolen-clothing requirements, to make as many reductions as possible, and to support all further requirements by complete justification, the data to include lists of all stocks on hand. This request was based on the 1944 policy of the Army Service Forces, which was to cancel contracts for all items of which more than a 60-day supply was on hand.

To understand some of the clothing deficiencies which developed in ETOUSA, it is necessary to go back several months. When the strictly functional M–1943 sateen field jacket, which had been tested in the Mediterranean theater, was exhibited in the European theater, the chief quartermaster was not interested in it for a number of reasons. He doubted that a sufficient number could be produced in 1944. He was anxious to have all troops in the theater uniformly dressed, which would not be possible if his doubts about production were justified. Finally, all echelons in the theater, from high command down, had a strong preference for something like the British battle jacket, which was used for both field and dress purposes and which came to be known as the Eisenhower jacket. It was not the quartermaster's policy "to force these new items down the throat of troops."

The M–1943 field jacket was therefore accepted in the theater for paratroops only, in spite of the War Department's insistence that this jacket, with the high-neck wool sweater, had been devised to replace the "limited standard field" jacket. The Quartermaster General doubted that without the new M–1943 jacket the troops would be adequately protected against cold weather and supported his statement by a study showing the advantages of this jacket over the wool overcoat for field troops. The commanding generals of the 12th Army Group and the First U. S. Army considered, however, that the overcoat was necessary for adequate warmth and that the Eisenhower field jacket with sweater was preferable to the M–1943 jacket and sweater combination. This decision was concurred in at SHAEF (Supreme Headquarters, Allied Expeditionary Force).

On 17 March 1944, a requisition was cabled to the War Department for 4,259,000 wool field jackets of the Eisenhower type, to be delivered in the course of 1944. Arrangements were later made for the phased shipments of 2,600,000 in the last quarter of 1944. The theater chief quartermaster and the combat commanders in Europe were all so eager to have this battle jacket that they were reluctant to submit requisitions which would slow down its production. During the summer, they continued to accept substitutes for it, including the old Parsons style of field jacket and the wool-serge service blouse. Many difficulties, however, were encountered in the production of the Eisenhower jacket. Although 500,000 were supposed to leave New York in September, by 13 September only 116,000 had been shipped to the port, and only 14,000 had been dispatched to the European theater. The deficiency in the theater was estimated at more than a million jackets when cold weather began. Large supplies of the Eisenhower jacket eventually reached the theater in January and February 1945, but few of them were issued for combat use.

Even when shortages became apparent in the European theater, General Littlejohn did not, at first, include the M–1943 jacket in his requisitions for substitutes for the Eisenhower jacket. Final arrangements were not made to accept the M–1943 jacket until 10 November 1944, after it had become evident that the overcoat, which field commanders as well as the Office of the Chief Quartermaster had insisted was essential for combat troops, was not satisfactory. It was bulky, it was not water repellent, and troops in combat frequently discarded it in fast-moving situations. The M–1943 jackets which finally reached the theater arrived too late to be useful during the winter.

One reason for the slow pace of planning and requisitioning in the European theater was the belief in some quarters that the war would end before a combat uniform would be needed for winter operations. This feeling of optimism, although it was far from universal, began to develop even before the fall of Paris, and it increased during the late summer. The need, it was felt, would be for a dress uniform for the army of occupation. There seemed to be more concern with the appearance of the troops than with their protection from the weather. It was suggested that the troops of the First and Third U. S. Armies, which would occupy Germany, be outfitted first. Even after trenchfoot had

appeared on the Continent, instructions were issued by the Supply Division, Office of the Chief Quartermaster, ETOUSA, to store in the United Kingdom the cold-climate clothing which arrived before the end of the year and to use Le Havre for whatever arrived later. As late as 31 October 1944, instructions were to pack light and dark trousers separately, so that they would not be issued indiscriminately, and the million ETO jackets received in the theater by the end of 1944 were held in the United Kingdom because the trousers which matched them (shade 33) were not available.

The situation on the Continent.—The tactical situation during the early stages of the invasion required that troops should carry as little as possible on their persons when they were landed on the far shore; the missing items of personal equipment were to be supplied later. The supply system for clothing and accessory equipment which had been planned was promptly put into operation and operated efficiently, but, while the needs of the troops were met, no surpluses of any consequence could be accumulated. Although clothing and personal equipment had a class II priority, it was not long before, for a number of reasons, difficulties began to develop. Illustrative of such difficulties were the following:

1. Because of the rapidity of the advance, all the attention was originally concentrated on the pressing demands for food, gasoline, and ammunition. What General Bradley described as a calculated risk (p. 209) was therefore taken with respect to clothing and other winter equipment. It was not, in fact, until the swift pursuit of the Germans was halted and the weather began to change that demands were made for winterizing items. Earlier, class II priority requisitions had been filled only when they were accompanied by special authorizations.

2. The first requisitions from the theater were far too low. They were based on authorized allowances and replacement factors which proved entirely unrealistic, even though the Quartermaster General considered the later theater estimate—that replacement rates must be 2½ times those prescribed by the War Department—to be somewhat exaggerated. Unquestionably, however, nothing lasted as long as had been expected.

3. Shipping shortages played a large part in deficiencies of clothing and personal equipment. In August, only 29,000 tons of quartermaster supplies were received on the Continent, against an allocation of 55,000 tons. Port discharge deficiencies accounted for additional shortages. At the end of September, with only 14 berths available, 75 ships were offshore. At the end of October, with only 18 berths available, 80 ships were waiting to be unloaded.

4. An additional complication arose from the fact that the clothing was distributed over a number of ships, instead of having been loaded in single ships, as had been requested. Distribution was therefore impossible until balanced loads had been accumulated. During the interval, there was considerable loss from pilferage because warehouse facilities were inadequate, and there were also losses from damage by the elements. The picture, according

to one account, was "one of vessels lying at anchor and backlogged supplies piled on piers in quantities which could frustrate the best logistical plan."

5. The opening of the Channel ports and of the port of Antwerp improved the situation but did not solve the problem of moving supplies inland. Rail and truck transportation continued in short supply. On 7 September, for instance, one division of the Third U. S. Army was more than a third short in clothing, especially shoes, shirts, trousers, underwear, socks, and overcoats, which were still in duffle bags on the landing beaches.[27] It would have required 200 trucks to move these supplies, and the division could not provide the transportation. Up to 13 September, practically 80 percent of issues of clothing and equipment for the Third U. S. Army had been renovated salvage. The army quartermaster was warned by the army surgeon that if these shortages were not rapidly rectified, in view of the recent cold weather and continued rains, "a rapid and explosive increase" in the noneffective rate from trenchfoot and respiratory ailments could be expected.

Even after the port of Antwerp had been in operation for 2 months, the First U. S. Army had to send its own trucks to pick up winter clothing. Vehicles were in short supply, and 50 tons of supplies had to be left behind.

It was not until well into 1945 that these and similar difficulties were completely overcome. An attempt to solve the problem of supplies by airlift from the United Kingdom had not been effective. Of more than a thousand planeloads of emergency supplies brought to the Third U. S. Army airstrip at Briey during August and September 1944, only 44 carried clothing and personal equipment.

6. Still another difficulty had to do with sizing. The tariff provided for shoes in 90 sizes, the M–1943 field jacket in 25 sizes, trousers in 34 sizes, and shirts in 27 sizes. When the Army clothing was issued in November 1940 to the first selectees to be inducted, it was found that, in spite of the apparent liberality of the tariff, there were not enough items of the larger sizes to provide for the present generation of soldiers. The original tariff had been based on the World War I experience. Revisions in August 1941 and July 1942 improved the situation but did not fully correct it. In the fall and early winter of 1944, both high level reports and reports of individual units showed continuing shortages of certain popular sizes. This was particularly true of field jackets, olive-drab wool clothing, herringbone-tweed clothing, and footgear. These errors were not completely corrected until early in February 1945, too late, again, to influence the trenchfoot situation in the European theater.

7. Deficiencies in other cold-weather items paralleled the deficiencies in personal clothing. The authorized issue of four blankets per man, for instance, had been reduced to two, in the expectation that the improved sleeping bag would take the place of the other two. For this reason, no blankets were shipped from the Zone of Interior to the European theater in either August or September 1944. Two million sleeping bags had been expected in the

[27] (1) Memorandum, Maj. W. P. Killingsworth, MC, Office of the Surgeon, Third U. S. Army, for Colonel Hurley, Surgeon, Third U. S. Army, 7 Sept. 1944. (2) After Action Report, Third U. S. Army, ETOUSA, 1 Aug. 1944–9 May 1945.

theater by the end of September. By the middle of the month, only 57,721 had been delivered. On 17 September, when it became evident that requirements for sleeping bags could not be met, General Littlejohn called for every blanket in the United Kingdom to be sent to him by every available vehicle on the ground that he had 400,000 prisoners of war to supply, as well as field armies. In all, he requested 4,000,000 blankets in September. The New York Port of Embarkation resumed shipments in October, and in the last quarter of 1944 more than 2½ million blankets and 2,000,000 sleeping bags reached the European theater, though only after delays at every phase of the supply pipeline and again too late to prevent much of the cold injury which occurred.

The situation in respect to clothing in the European theater in 1944–45 can be summarized in a few sentences. Production snarls and transportation difficulties all along the line accounted for many shortages. The major responsibility, however, must be placed upon delays in planning for and requisitioning necessary items, underestimates of needs, and a refusal to accept new, efficient, field-tested items of winter clothing. If these items had been requisitioned in time, they could have been provided in sufficient quantities. The Quartermaster General repeatedly warned the theater that its requisitions were not adequate either in quantity or in the proper kind of wind-resistant, wet-resistant winter clothing. The mistaken belief that the war would end promptly and that winter clothing would be needed for an army of occupation and not for troops engaged in combat explained some shortages. As a result, when the new clothing became available in adequate quantities, the acute need for it had passed.

The only army in the European theater which was properly equipped for combat in the winter of 1944–45 was the Seventh U. S. Army, which fought in southern France and which had been equipped with the new uniform and with shoepacs through Mediterranean theater supply channels. This army had a great deal of cold injury, it is true, but a large part of it could be explained by recurrences in men who had suffered from cold injury the previous winter (p. 382).

Footgear

The course of events in regard to footgear during the winter of 1944–45 followed the pattern just described for clothing. Neither the combat boot nor the service shoe proved satisfactory. Shoepacs, which were recommended, were not accepted at all in the beginning and were ordered too late in the end. Overshoes (galoshes) were not provided in sufficient quantity nor in sufficiently large sizes and were not made on the proper lasts. Wool socks were not available in sufficient supply.

Boots and shoes.—Combat boots or service shoes were worn by almost all of the troops in the field, except the Seventh U. S. Army, until shoepacs became generally available late in January 1945. The Seventh U. S. Army, as already noted, had been equipped with them in the Mediterranean theater. The Quartermaster General's clothing representative in the European theater had

written to the chief of the Research and Development Branch, Office of the Quartermaster General, before D-day, of the general dissatisfaction with both the combat boot and the service shoe. It was decided, however, to make no changes until there had been more field experience with these items. In the meantime, action was to be directed toward improving the fitting of the footwear at staging areas in the Zone of Interior.

Among the complaints made about the service shoe, in connection with cold injury, were the following: [28]

1. It had to be worn with leggings and was therefore difficult to remove for foot care. In this respect, the combat boot, although it was open to many of the objections raised about the service shoe, was superior to it.

2. It was so constructed that even when it was fitted loosely, as it usually was not, there was very little room in the vamp. Because of the shape of the last, there was pressure across the top of the foot when heavy socks were worn, since there was no space between them and the overlying leather. The uppers were cut so scantily that even shoes which were fitted correctly could not be brought together by lacing without harmful constriction; this defect was exaggerated when extra socks were worn. General Hawley had examined patients with trenchfoot and had found marks of the shoelaces deep in the swollen tissues. This could not have happened with the British field boot, which was cut so generously that the uppers could be brought together from the time the shoe was first put on.

3. Both service shoes and combat boots were fitted too snugly, partly from the general desire to keep the feet trim in appearance, partly because only three widths were available, and partly because of carelessness in fitting. General Hawley remarked in this connection that in 30 years of Army service he had seldom seen shoes fitted with the care and expertness the function deserved.

4. Attempts to improve the situation were not very successful. Additional shoes were usually issued in the same size as the original pair, partly as a matter of routine and partly because of shortages of larger sizes. As with clothing, so with shoes, the tariffs were inadequate for the new generation of soldiers. By the middle of October, the First U. S. Army was complaining of a shortage of wide, large-sized combat boots. The committee appointed by the Chief Quartermaster, ETOUSA, to study the tariff reported that the existing War Department tariff should be revised to provide for more than twice as many E-width shoes and more than three times as many EE-width shoes as were then provided. These deficiencies occurred in spite of the fact that shoes were provided in 90 different size variants.

5. Shortages prevented replacement of shoes originally fitted, and repairs were slow. When the first trenchfoot outbreak occurred, many of the men had only a single pair of shoes, and some were still wearing the ones issued to them before D-day.

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[28] (1) Report, General Board, United States Forces, European theater, Medical Section Study No. 94, subject: Trench Foot. (2) Report, Col. A. G. Duncan, QMC, Office of Chief Quartermaster, ETOUSA, to Maj. Gen. Paul R. Hawley, Chief Surgeon, 16 Apr. 1945, subject: Footwear and Socks for Use in the European Theater of Operations.

6. The fact that shoes were originally fitted too snugly gave rise to a number of other consequences. The soldier's feet spread during combat training, and a shoe which had fitted him in civilian life no longer fitted him now. When the shoes became wet, the fit, because of shrinkage of the leather, was even snugger than it had been originally. No provision at the original fitting had been made for the wearing of extra socks or heavier socks during cold weather, and the shoes were therefore too tight when these socks were used. When the shoes were removed for foot care and to change the socks, the feet swelled and it was difficult to replace a shoe which had been fitted snugly to begin with. The practical consequence, in the European theater, was that men were unwilling to remove their shoes to care for their feet.

7. Neither the combat boot nor the service shoe was waterproof or water resistant. The welt sole leaked, there was leakage at the seams, and the leather was permeable.

8. Dubbing was no solution to the problem, although it was supplied in lavish quantities. It did not make boots and shoes waterproof, and the men complained that it made their feet perspire because it shut out air and therefore kept their feet cold.

When in February 1945 a special investigation of the whole footgear situation was undertaken in the theater, the observer, who was an official of one of the large shoe companies, made substantially the same criticisms as those just listed.

Socks.—The sock difficulties in the European theater took two chief forms: The socks which were provided did not contain enough wool, and they were not available in sufficient quantities for men in the frontlines to receive clean, dry socks daily, a requirement which implied provision for washing and drying soiled socks, as well as an efficient system of exchange.

In March 1944, Col. (later Brig. Gen.) Georges F. Doriot, QMC, Chief, Research and Development Branch, Office of the Quartermaster General, wrote his observer in the European theater that Table of Equipment 21 then authorized one less pair of woolen socks per man than the experience in the Mediterranean theater had shown to be necessary. Another warning about the type of socks provided for United States troops came in April 1944. The theater chief quartermaster was then notified by the Professional Services Division, Office of the Chief Surgeon, that the chief consultant in surgery for the Norwegian Army in the United Kingdom considered that the socks worn by United States Army troops were fitted too tightly and did not contain a sufficient quantity of wool.

It has been related elsewhere (p. 63) that when War Department Circular No. 312 was published in July 1944, there were several references to wool socks in it; the soldier was supposed to carry extra pairs on his person and to wear this type of sock in combat. Provision was to be made for a daily supply of clean, dry socks in each unit. It has also been noted (p. 65) that the Commanding General, Army Service Forces, at the request of the Quartermaster General, notified all commanding officers at ports of embarkation that this

circular was not to be construed as justification for an increase in the authorized allowances of wool socks. It is significant, in the light of the events of the following winter, that the European theater did not consider that the terms of the circular would have any effect upon the initial issue of this type of sock.

War Department Technical Bulletin (TB MED) 81 and the circular on foot care published in the European theater in October 1944 (p. 164) prescribed that heavy woolen socks be worn, that an extra pair be carried, and that others be made available by daily exchange when troops were on duty for more than a few days in wet, cold regions. Cotton socks were to be used only for garrison duty.

When the footwear representative of the War Production Board surveyed the situation in the theater in February 1945, he was even more specific in his recommendations.[29] He thought that neither light wool socks nor cotton socks should be issued at all to combat troops, though he granted that, until shortages of heavy wool socks could be overcome, the light wool socks, which were in oversupply, would have to be used, as a matter of expediency. He recommended that, as soon as it was possible, supplies be limited to heavy wool socks, cushion-sole wool socks, and ski socks. He also stressed the point, already discussed, that the wearing of two pairs of socks was useful only if the shoes were fitted with this in mind. Otherwise, the practice was actually harmful because of the constriction produced and the resulting embarrassment of the circulation in the lower extremity.

Early in October 1944, Colonel Gordon's office and preventive medicine officers who were with field armies began to work with the Quartermaster Corps to establish some system, similar to the British system, whereby clean socks could be supplied regularly to frontline troops.[30] The program could not be put into effect immediately because socks were not in sufficient supply and enough laundry units were not available. By the middle of November, these deficiencies had been at least partly corrected and a daily sock exchange had been instituted. It was found that the best plan in all armies was to bring the fresh socks forward with the daily rations (p. 182). Each man, when he received his rations and his dry socks, would turn in his wet, soiled socks for exchange. When the tactical situation or other circumstances interfered with the daily sock exchange, the men were instructed to remove their wet socks, wring them out, and dry them inside their shirts or sleeping bags while they were wearing the extra socks which they had been carrying on their persons.

Statistics from the 108th General Hospital, where a special investigation of trenchfoot was conducted, showed how the tactical situation could influence the supply of socks and, in turn, the incidence of trenchfoot. For the week ending 27 November 1944, 96 of each 100 men admitted with a diagnosis of

[29] Memorandum, Maj. Gen. Robert M. Littlejohn, Chief Quartermaster, ETOUSA, to Quartermaster General, War Department, 23 Mar. 1945, subject: Footwear and Socks for Use in the European Theater of Operations.

[30] Memorandum, Maj. W. P. Killingsworth, MC, Office of the Surgeon, Third U. S. Army, for Colonel Hurley, Surgeon, Third U. S. Army, 12 Oct. 1944.

trenchfoot had adequate supplies of socks (at least 3 pairs per man). For the week ending 21 December, at the beginning of the Battle of the Bulge, only 46 in each 100 men were adequately supplied. By the following week, the number of men adequately supplied in each 100 had fallen to 42.[31] These figures, of course, do not tell the whole story. In the stress of combat, many of the men who had dry socks were unable to put them on.

Early in the trenchfoot epidemic, it was found that many of the men seen in the aid stations with apparent cold injuries really needed nothing more than an opportunity to warm their feet and put on dry socks. It was eventually arranged to provide supplies of dry socks in all aid stations, and, as a result, many frontline soldiers who otherwise would have been evacuated and lost for combat duty could be returned directly to duty.

Overshoes (galoshes).—Even before the November epidemic of trenchfoot, there had been warnings by medical and other officers from various units that a high incidence of cold injury could be expected if adequate supplies of galoshes were not available. As early as July, the acting quartermaster of the Advanced Section Communications Zone, ETOUSA, asked that shipments to France from D-day plus 150 should be sufficient by 1 October to equip every soldier with an initial issue of various items of winter clothing and equipment, including arctic overshoes. Maj. Gen. Albert W. Kenner, Chief Medical Officer, SHAEF, after he had visited the 6th Army Group on 12 October 1944, included this matter in his memorandum on the subject to the Chief of Staff, SHAEF. In the report, Essential Technical Medical Data, ETOUSA, for October 1944, it was stated that, in view of the shortage of overshoes, which then affected 60 percent of the total troop strength, and the shortage of shoepacs, the situation was "viewed with apprehension."

In spite of these warnings, by the middle of November only the Seventh U. S. Army, which had been equipped through Mediterranean theater supply channels, was completely equipped with overshoes and shoepacs, and only three divisions from other armies were similarly equipped. At this time, the Third U. S. Army had only one pair for each four men.[32] In December, nine divisions were still only partly equipped, and in January seven divisions still did not have overshoes for all personnel.

Although there were a number of reasons for these shortages, the over-all explanation was the policy of taking overshoes away from soldiers at ports of embarkation in the Zone of Interior. The plan was that the men would be reequipped upon their arrival overseas. This was War Department policy, founded on the difficulties of effective distribution and the laudable objective of reducing the large amounts of equipment and clothing which the individual soldier necessarily had to carry with him. In practice, the plan of reequipment in the European theater proved thoroughly impractical.[33] It worked so badly,

[31] Report, Headquarters, 108th General Hospital, 1944, subject: A Progress Report on the Etiological Factors of Trench Foot.

[32] See footnote 30, p. 153.

[33] Essential Technical Medical Data, Headquarters, ETOUSA, for October 1944.

in fact, that some troops developed cold injuries while waiting for their galoshes in staging areas.[34]

The facts of the matter were repeatedly pointed out to authorities in the United States as follows:

1. Supplies of overshoes in the theater or on current requisition were adequate merely for maintenance of troops already in the theater.

2. The supply lines were by this time spread all over Europe, and the distribution of overshoes after they had been received took weeks because of transportation difficulties.[35]

3. Large sizes were in short supply.

4. There was a clear-cut relationship between the development of trenchfoot and the shortage of overshoes. On 15 November 1944, General Hawley wrote the theater chief quartermaster that hundreds of cases of trenchfoot had already occurred and thousands more could be expected "if something drastic is not done." The War Department was not impressed by any of these arguments, and the policy of sending troops overseas without overshoes continued unchanged until the end of the war.

Improper sizing played the same part in the overshoe situation as in the clothing and other situations. There was an undersupply of large sizes, so serious that at one time one corps was short 11,000 overshoes in the larger sizes (from size 10 up).[36] Although 90 sizes of boots and shoes were available, only 10 sizes of overshoes had been provided. Enough large sizes were not available until March 1945.[37]

Another reason why it was difficult to match up shoes and overshoes was that many of the overshoes available had been purchased in trade channels and the lasts on which they were made did not fit the lasts on which boots and shoes procured on military specifications had been made.[38]

To increase their mobility, troops were occasionally ordered to discard their overshoes before an attack. Armored infantry could have them brought forward later, in halftracks, but regular infantry had no such means of transportation, and their overshoes, once discarded, were usually irretrievably lost and had to be replaced. More often, the troops were not ordered to discard their overshoes. Instead, they simply threw them away because they were difficult or awkward to wear and a nuisance to carry.

When the footgear representative of the War Production Board surveyed the theater in February 1945, he recommended that thereafter (1) all overshoes be made of rubber; (2) all troops be equipped with overshoes except infantrymen, who would wear shoepacs, and troops on garrison duty, who would wear the regulation combat shoe; (3) sizes and lasts conform with sizes

[34] Technical Intelligence Report, Col. B. C. Jones, GSC, Chief, Intelligence and Security Division, Army Service Forces, 17 Feb. 1945, subject: Medical Corps Personnel and Trench Foot.

[35] Letter, Maj. Gen. Robert M. Littlejohn, Chief Quartermaster, Headquarters, Communications Zone, ETO, to Maj. Gen. R. L. Maxwell, G-4, War Department, 18 Nov. 1944.

[36] See footnote 9, p. 138.

[37] Report, Maj. Paul A. Siple, QMC, Technical Observer, for Commanding General, ETOUSA, 12 Apr. 1945.

[38] See footnote 29, p. 153.

and lasts of Army service shoes; and (4) all overshoes be plainly stamped with their size, to permit prompt reissue and to avoid the wastage which had occurred during the previous winter for lack of such identification.

Finally, overshoes originally available in the theater were often made with canvas tops because of the rubber shortage. These tops, which were not waterproof, tore readily, and the life of this type of galosh was short.

Supplies flown in from the United Kingdom Base helped to ease the shortage of overshoes in November 1944, when it first became apparent.[39] It was not then realized that overshoes should have been provided for the theater on a hundred-percent basis. Priorities were, properly, given to combat troops, but galoshes were also needed by service units, which often had to work continuously in rain and mud, and by such troops as Military Police and antiaircraft units, which had to stand immobile for long hours, regardless of weather and terrain.

The course of events left little doubt of the relationship between the incidence of trenchfoot and the lack of overshoes. During November, for instance, the 9th Infantry Division, 2,426 of whose strength was without overshoes, had 183 cases of trenchfoot. By the end of November, 99 percent of the 28th Infantry Division had secured overshoes, but in the meantime there had been 738 cases of trenchfoot. In the 3d Armored Division, there were 56 cases of trenchfoot in 450 troops without overshoes. In the Ninth U. S. Army, the highest trenchfoot rates in the November epidemic occurred in the 84th and 102d Infantry Divisions, only 35 percent of which had overshoes.[40] These divisions accounted for 62.25 percent of all the cases of trenchfoot in this army up to 22 November.

Statistics secured by questioning casualties with trenchfoot admitted to the 108th General Hospital supplied the following significant data about overshoes: [41]

For the week ending 27 November, 82 of 100 men with trenchfoot had lacked overshoes or had not received them in time to be effective, 52 had not received overshoes, 28 had received them after sustaining cold injuries, and 2 had discarded their overshoes before combat.

For the week ending 21 December (the first week of the Battle of the Bulge), 60 of 100 men had lacked overshoes for the reasons just stated. Of this group, 38 had not received overshoes at all, 10 had received them too late, and 12 had discarded them before combat.

For the week ending 28 December, the total number of men without overshoes was 55; of these, 36 men had not received them at all, 4 had received them too late to be useful, and 15 had discarded them before combat. The number of men who discarded their overshoes before combat, while too small to be of any statistical significance, was significant to medical and other officers familiar with the tactical situation and the character of United States troops.

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[39] Annual Report, Preventive Medicine Division, Office of Chief Surgeon, ETOUSA, 1944.
[40] Annual Report, Surgeon, Ninth U. S. Army, ETOUSA, 1944.
[41] See footnote 31, p. 154.

The troops generally felt that overshoes hampered their mobility in active combat, and the fighting in the last 2 of the 3 weeks included in this survey, during the Battle of the Bulge, was very heavy indeed.

There are, of course, other facts behind these figures. During each of these 3 weeks, a number of men who had been provided with overshoes had wet feet most of the time. The canvas tops, already commented on, leaked and tore. Rain or snow also destroyed the effectiveness of sound protective footgear, or water came over the tops when rivers had to be crossed. Sometimes, all of these causes were effective. Actually, only 18 of the 100 men surveyed the first week had been able to keep their feet dry, only 2 in the second week, and only 11 in the third week. The figures, again, reflect the tactical situation.

Shoepacs.—As already mentioned (p. 145), in May 1944, a representative of Colonel Gordon's office was informed by a representative of the theater chief quartermaster that the cold-weather problem in regard to the feet would be solved by a combination of heavy socks and shoepacs and that both items would be in production in time to meet the winter needs. Shoepacs were also discussed at the meeting on winter clothing held in the theater in June 1944 (p. 144), at which Captain Pounder had stated the objections of the Quartermaster General to the items of winter clothing proposed. The footgear planned for winter combat was to include service shoes, overshoes, leggings, and light wool socks. Captain Pounder pointed out that this combination of footgear would not be satisfactory in a country which was particularly cold, wet, and muddy in winter. He proposed, instead, that winter footgear consist of shoepacs, with 2 pairs of felt insoles and 4 pairs of ski socks per man. Although it was agreed that, in order to use up stocks presently in the theater, the combination of service shoes, leggings, and overshoes might be issued as a substitute for shoepacs, it was agreed also that shoepacs with felt insoles and ski socks should be included in the list of items recommended to the theater chief quartermaster for use during winter operations on the Continent.

On 10 August 1944, in response to an inquiry made on 23 July concerning footgear (p. 145), General Hawley's Preventive Medicine Division was informed by the Supply Branch, Office of the Chief Quartermaster, ETOUSA, that among items of footgear for troops expected to fight in wet-cold conditions on the Continent would be a new type of shoepac, made in three widths, with correct orthopedic support. These shoepacs were to be fitted over a cushion sole or over heavy British woolen socks and ski socks. Allowances would be made for extra socks for each soldier. If this footgear was used correctly, adequate foot protection would thus be provided in the minimum temperatures expected in northern France and southern Germany—10° F. (−12.2° C.)—during the winter.

The Seventh U. S. Army, as already mentioned, had been equipped with shoepacs through Mediterranean theater supply channels. The first requisition for shoepacs from the European theater, on 15 August 1944, was for 446,000 pairs. This was a small number, and the timing was late, in view of the limited shipping available and the low priority for clothing and footgear.

War Department Circular No. 312 listed criteria for winter footgear but did not specifically mention shoepacs. TB MED 81 stated that shoepacs best met the requirements of insulation and ventilation except on rough, mountainous terrain. When it was distributed in the theater as a circular letter, in place of the circular letter originally planned (p. 164), and in the theater medical bulletin (p. 164), all mention of shoepacs had been eliminated at the request of General Littlejohn's office, since it was then known that shoepacs would be available only for a limited number of personnel in the theater.

On 8 December, when it had become evident that the footgear provided in the theater (the service shoe and the combat boot) would not furnish adequate protection against trenchfoot, a request was cabled from the theater for 500,000 additional pairs of shoepacs, over and above the 446,000 already shipped and the 90,000 pairs issued to the Seventh U. S. Army. The theater was informed on 16 December that this requirement could not possibly be met because of limitations of production which could not be overcome for 3 or 4 months. An attempt to fill the requisition would disrupt the shoe and wool production of the whole country. It was noted in this reply that the issue of shoepacs, about which the troops themselves had many reservations, would not solve the primary problem, which was strict compliance with the provisions of War Department Circular No. 312 and TB MED 81. In the light of these facts, it was requested that the requisition be reconsidered. On 23 December, the theater repeated the original request, using as justification the fact that extraordinary cold and wet conditions were being encountered at the time. None of the shoepacs requisitioned arrived in the European theater until after the middle of January 1945, and those which were received were not distributed in sufficient numbers until it was too late for them to exert any significant influence on the incidence of cold injury.

Unfortunately, the shoepacs originally issued to the Seventh U. S. Army in Italy and those which went to the European theater were of the old type and were open to many objections. Because of the lack of ventilation, the feet, even in the coldest weather, perspired when the men were active. Later, the felt innersoles froze, and the feet became excessively cold. In warmer weather, excessive perspiration caused maceration of the skin. A cycle was often set up of perspiration, maceration, the development of so-called shoepac foot, hospitalization for 10 to 15 days, return to duty, and a repetition of the cycle.[42]

The shoepacs issued in the European theater were the 6-inch type, too low to offer much protection in deep mud, swampy ground, and flooded foxholes. They offered no protection at all when streams had to be crossed. They lacked arch supports and heels. The soft rubber soles wore out quickly. It was for these reasons that the theater chief quartermaster had rejected the recommendation of the Quartermaster General that they be substituted for the combat boot (p. 157).

The shoepacs supplied were also, for the most part, too large. This made them unsatisfactory for marching, and men had to be evacuated for blisters

[42] Essential Technical Medical Data, ETOUSA, for December 1944.

on their heels. No provision had been made for the wearing of additional socks with them.[43]

Finally, shoepacs cannot be worn efficiently unless their use is understood. The supply for the European theater had to be distributed almost literally in the midst of battle, and instructions for their use were often given after they had been worn. As a result, shoepacs in the European theater were seldom as efficient as they should have been.

In spite of these and other objections, men who learned to wear shoepacs correctly came to prefer them to service shoes and combat boots. At the end of the cold season, it was generally agreed that in spite of their deficiencies the shoepacs were the most satisfactory footgear for fighting in cold, wet weather. This was the opinion of the conference on clothing held in March 1945 and the footgear representative of the War Production Board (p. 155). It was also the opinion expressed by the General Board, United States Forces, European Theater of Operations, in its report on trenchfoot (p. 208) and of Maj. (later Lt. Col.) Paul A. Siple, QMC, an observer from the Office of the Quartermaster General, who had been in the Antarctic with Admiral Byrd and who studied the whole clothing and footgear situation in the theater in the late winter of 1945.

Improvisations.—When the shortage of adequate footgear first became acute, many units resorted to improvisations to secure additional protection from rain and snow. Some units wore the white plastic powder bags provided with 155-mm. projectiles inside or outside of their shoes. These bags were extremely effective, but they were in short supply. Some units made boots of four thicknesses of blanket and wore them inside their overshoes, without shoes. Some troops which fought in Holland wore felt slippers and overshoes with two pairs of socks. The incidence of trenchfoot was reduced in all the units which used these and similar improvisations, one reason probably being the free movement of the toes and feet possible when constricting footgear was omitted.

Summary

A more detailed account of the clothing and footgear used in the European theater in the winter of 1944–45 does not properly belong in this volume. Enough has been related to show the important role which inadequate clothing and footgear played in the causation of trenchfoot. The items issued were basically unsatisfactory because of deficiencies in insulation or ventilation, or in other respects. The clothing was not windproof or water repellent. The footgear did not protect against cold and wetness and had other defects. Even these unsatisfactory items were in short supply. More efficient clothing and footgear, which had been tested both in and out of combat, were available, but the theater chose not to accept the new models, in spite of repeated warnings from the Quartermaster General and his observer in the theater that the troops would not be properly protected in combat operations during the

[43] See footnote 37, p. 155.

winter. The director of the Research and Development Branch of the Office of the Quartermaster General had predicted that if the European theater persisted in using a uniform already shown to be inadequate, the Italian experience with cold injury would be repeated. His prediction, unfortunately, was only too correct.

When supplies of the improved clothing and footgear were finally ordered, cold injury was already widely prevalent, and the supplies were not received until it was too late to alter the course of events.

Finally, neither the old nor the new models were correctly worn because the troops had not been trained in their use. The United States soldier, as Major Siple stated after he had surveyed the situation in February 1945 (p. 431), was better trained in the care and use of fighting equipment than in the care and use of his clothing.

These conclusions were, in substance, the conclusions of the General Board, United States Forces, European theater, set up later in 1945 to study the whole cold injury situation in the theater.

DEVELOPMENT OF THE TRENCHFOOT-CONTROL PROGRAM

Activities in 1942–43

The first recorded mention of cold injury in the European theater was apparently made in a letter dated 5 August 1942, in which the Chief Surgeon, on the request of the Office of the Surgeon General, transmitted information on the management of frostbite as recommended by the British Medical Research Council, together with some observations on immersion foot.

The first theater publication dealing with cold injury concerned immersion foot. It was Circular Letter No. 12, Office of the Chief Surgeon, 20 January 1943. It was stated in this letter, "A condition which closely resembles the trench foot of the last war may affect the extremities exposed to cold without immersion provided the degree of cold is insufficient to cause frostbite."

Medical Bulletin No. 1, Office of the Chief Surgeon, 18 March 1943, reproduced the contents of Medical News Letter No. 1, Office of the Surgeon General, which was published 1 January 1943. The material on which this letter was based was assembled under the auspices of the Committee on Information, Division of Medical Sciences, National Research Council, with the cooperation of the American Medical Association and the Surgeons General of the Army and the Navy. The letter also reproduced the substance of the article on frostbite by Raymond Greene, which had appeared in *Practitioner* in January 1942, and the substance of an article on immersion foot published by Webster, Woolhouse, and Johnson in the *Journal of Bone and Joint Surgery* for October 1942.

Activities Before the Outbreak of Cold Injury in 1944

In analyzing the cold injury epidemics in ETOUSA in World War II, it must be borne in mind that there was little official information in the theater concerning the serious losses from this cause in the Mediterranean theater in the winter of 1943–44 and there was no continuous official medical liaison between the two theaters. As one instance of the lack of liaison, the official report on trenchfoot in the Mediterranean theater, which was submitted to the Surgeon, MTOUSA (Mediterranean Theater of Operations, United States Army), in January 1944, did not reach the European theater until a year later, when the urgent need for the data in it was practically over. It seems to have arrived then only because Colonel Cutler requested it directly from the Surgeon of the Mediterranean theater.

There was, of course, considerable informal correspondence between medical officers in the two theaters, though none specifically for the purpose of studying cold injury. Curiously, it was a dermatologist who was most impressed by the potentialities of this condition. On 10 November 1943, Lt. Col. (later Col.) Donald M. Pillsbury, MC, Senior Consultant in Dermatology, Office of the Chief Surgeon, ETOUSA, reported to General Hawley concerning his tour of medical installations in the North African theater. He described the epidemic of what he termed immersion foot in Italy and recounted his discussions of the problem with medical officers in the North African theater, including Maj. Fiorindo A. Simeone, MC, who was then making a special study of this condition (p. 101). Colonel Pillsbury stated that the treatment to date was unsatisfactory, but that several approaches toward prevention were practical. It was his opinion that the problem was great enough to warrant the use of every facility of General Hawley's office in its solution and that the Surgeon, MTOUSA, should be informed promptly of the results obtained. Colonel Pillsbury's recommendations concerning dermatologic conditions and venereal disease were duly initialed by the theater venereal disease control officer and the chief of the Professional Services Division, Office of the Chief Surgeon, but no action seems to have been taken on his recommendations concerning an energetic program for the prevention of cold injury.

Colonel Cutler, when he visited Italy in November and December 1943, observed a number of cases of trenchfoot. He was not then impressed with them because of his experience in World War I, in which cold injury took the form of "terrible swollen feet with ulcers and blue color." Major Simeone did not believe that more than a quarter of the men affected would be able to return to duty, but Colonel Cutler was then of the opinion that these soldiers were utilizing the pain very hard as a way out of fighting.

On his return to England, Colonel Cutler discussed cold injury with the chief consultant in surgery to the Norwegian forces in the United Kingdom. This officer, who had also just returned from Italy, had participated in the Russo-Finnish War, and in Colonel Cutler's opinion had had as wide an ex-

perience in cold wet feet as any medical officer living. As a result of these discussions and after reflection upon his own observations in Italy, Colonel Cutler transmitted the following (summarized) remarks to the theater chief quartermaster, through channels, 9 April 1944:

1. The socks furnished United States Army troops did not have sufficient wool content.

2. Rigid discipline must be enforced within combat companies, so that socks would be changed daily, even if this meant nothing more than wringing them out and putting them on again.

3. United States Army soldiers were invariably fitted with shoes that were too small.

Colonel Cutler added his own impressions of the enormous loss of manpower caused by cold injury in Italy and the importance of its prevention, since no effective method of treatment had been discovered.

This memorandum was forwarded to the theater chief quartermaster from General Hawley's office 11 April 1944, with a notation that his office had in preparation a proposed circular on the proper care of the feet. On the same date, this information was sent to the Chief Surgeon's Professional Services Division, with the request that a draft of the proposed directive be prepared with the least practical delay.

The requested draft, entitled "Prevention of trench foot (immersion foot)," was forwarded to the executive officer of the Office of the Chief Surgeon, 25 April 1944. It emphasized the incapacitating character of the injury, the lack of specific therapy for it, the possibility of prevention, and the preventive measures which could be employed. These measures included keeping the feet warm and dry, wearing properly fitted shoes and two pairs of all-wool socks, removing shoes and socks daily, rubbing the feet lightly with lanolin or petrolatum after they were dried, and making every effort to encourage movement and maintain mobility.

No further action was apparently taken on this proposed circular at this time, other than referring it to the Preventive Medicine Division of the Chief Surgeon's Office.

Preparations for the invasion of the Continent.—Cognizance was taken of the danger of cold injury in the preparations for Operation OVERLORD, the invasion of the Continent. In Standing Operating Procedure 15, Medical Service on the Continent, which was drawn up in March 1944, as part of Policies and Procedures for Mounting the Invasion, and which was published 29 July 1944, paragraph 53 read as follows:

> Trench foot (Immersion foot). Emphasis will be given to the care of the feet and to the provision of proper clothing and footwear. Special attention will be given to these details for combat troops operating under wet, cold conditions.

Annex No. 8, which was the medical plan for mounting the invasion, did not mention cold injury. Annex No. 9 to the Operations Plan, Communica-

tions Zone, for NEPTUNE, the assault phase of OVERLORD, contained the following paragraph:

> Section VIII, 40. "Trench Foot"—("Immersion Foot").—The cold wet weather prevailing during the winter season in the area will predispose combat troops to this affection. Supplying seasonal changes of clothing opportunely, giving particular attention to the furnishing of proper footwear, are important measures for preventing casualties due to trench foot.

The Manual of Therapy, issued by the Chief Surgeon, ETOUSA, on 5 May 1944, contained a section on foot hygiene, which emphasized the importance of (1) cleanliness, (2) keeping the feet dry, (3) using foot powder, (4) changing the socks frequently, (5) wearing properly fitted shoes and socks, (6) avoiding trauma, (7) caring for the feet after long marches, and (8) caring for the shoes and socks. It was again advised, as in other publications, that the shoes be laced tightly.

Section XIV, paragraph 7, of the Manual of Therapy read as follows:

> The importance of a foot bath with soap and water cleansing, vigorous massage (20 Min.), dry socks, and a change of shoes in the prophylaxis of foot disability resulting from exposure to cold and moisture cannot be overemphasized.

The manual contained a rather extensive description of fungous infections of the feet, but there was no further mention of cold injury.

Preceding letters on the subject of cold injury were rescinded on 10 June 1944,[44] and attention was directed to the Manual of Therapy, which, it was stated, contained the principles of therapy to be followed in the theater.

Postinvasion Activities

On 22 June 1944, Colonel Gordon's office recommended publication of a command directive entitled "Care of the Feet" for distribution to army groups, armies, air forces, base sections, and analogous commands. This directive included principles of fitting, care, and use of shoes; the choice and use of socks; and general instructions on foot hygiene. It emphasized that company commanders were responsible for the correct fitting of shoes and that instructions to fit them over light wool socks should be modified, if necessary, to permit them to be fitted over heavy wool socks or two pairs of light wool socks. Instructions were given for the breaking in of new shoes, and tight lacing (contrary to previous advice) was warned against. Specific instructions were given how to lace shoes when the uppers fitted too snugly. Instructions were given for changing of socks regularly and for drying socks by improvised methods if a fresh pair was not available. Finally, instructions were given for the care of the feet, including cleanliness, conditioning, care of the nails, care of blisters and abrasions, avoidance of excessive sweating, and prompt report of infections or other disabilities to the medical officer.

[44] Circular Letter No. 80, Office of the Chief Surgeon, Headquarters, ETOUSA, 10 June 1944. subject: Policies and Procedures Governing Care of Patients in the European Theater of Operations.

Paragraph (4) read as follows:

External Conditions. The feet are subject to all of the common injuries due to external causes, but there is one type to which they are particularly prone. Slightly different forms of this injury are known as Immersion Foot, Trench Foot, Shelter Foot, etc., but all are fundamentally the same. The condition results from long exposure to a combination of wetting, cold (which need not be extreme) and stagnation of circulation due to inactivity or constricting clothing or boots. Prevention depends upon avoidance of wetting and chilling if possible and where these are unavoidable the preservation of circulation by exercise, relief of constricting clothing and as a last resort general manipulation. After the condition is well established, with numbness, swelling and change of color of the feet, walking and even massage are to be avoided.

This publication was disapproved by the Adjutant General, ETOUSA, on the ground that existing manuals covered the subject and that the problem was the responsibility of subordinate commands. Colonel Gordon thereupon forwarded the content of the proposed publication informally to the surgeons of major commands.

In September 1944, Colonel Gordon's office began work on a circular letter dealing with the care of the feet and intended for publication to all commanding officers, including those of smaller units. After the proposed letter had been concurred in by other divisions of the Chief Surgeon's Office, it was sent to the Adjutant General, ETOUSA, 11 October, with the statement that publication was urgent and should be expedited because of the possibility of trenchfoot in the theater. When it appeared on 24 November as Circular No. 108, Headquarters, ETOUSA (appendix E, p. 525), heavy losses from cold injury had already been sustained.

Meantime, as already noted, other publications had become available. War Department Circular No. 312, dated 22 July 1944 (p. 63), was distributed in the theater on 2 September 1944. TB MED 81, dated 4 August 1944 (p. 65), was received in the theater later that month. When it arrived, a circular letter containing substantially the same material was in process of preparation. TB MED 81 was substituted for the material in preparation and was published 18 October 1944, as Circular Letter No. 126, Office of the Chief Surgeon, ETOUSA. As already mentioned (p. 158), a statement in this bulletin dealing with shoepacs was deleted at the request of the Chief Quartermaster, ETOUSA, because it was now evident that they could be supplied only to a very limited number of personnel in the theater.

In order to give additional and faster circulation to the information contained in TB MED 81, this bulletin was reproduced in the theater medical bulletin for 1 November 1944. It was preceded by a statement by General Hawley to the effect that the Italian experience had shown that cold injury could disable men as suddenly and with as little warning as a severe wound, that many of those affected would remain permanently unfit for duty under conditions of cold and moisture, and that all medical personnel should familiarize themselves with the contents of TB MED 81 because it indicated the possible extent and severity of cold injury and the paramount importance of preventive measures.

Meantime, there had been numerous informal warnings of the possibilities and potentialities of cold injury. On 4 October 1944, Colonel Cutler informed Col. James K. Kimbrough, MC, Chief, Professional Services Division, Office of the Chief Surgeon, ETOUSA, that Lt. Col. (later Col.) Joseph A. Crisler, Jr., MC, Consultant in Surgery, Office of the Surgeon, First U. S. Army, had sent word to him that he was fearful of trouble with trenchfoot in the coming weeks and months and that he (Colonel Cutler) shared these apprehensions.[45] All experience, the memorandum continued, justified the statement that there is no sound treatment for trenchfoot and that prevention is all important. It further stated that the Medical Department should insist that woolen socks be worn and that shoes be properly fitted, since all Americans wear their shoes too small. Unless these warnings were heeded, Colonel Cutler concluded, "there will be disaster." The memorandum also called attention to the habit of Norwegians, especially Laplanders, of putting straw in their big shoes during the winter, thus providing both ventilation and insulation, and to the Russian custom of changing from leather to felt shoes and binding the feet instead of wearing socks in cold weather. Neither Russians nor Norwegians suffered from cold injury.

In a report, Health of the Command, 12th Army Group, for August 1944, the possible increase of respiratory diseases during cold weather was mentioned, but the report contained no mention of cold injury. In the report for September 1944, dated 11 October, respiratory diseases were again mentioned, and a paragraph was devoted to trenchfoot:

> b. Trench Foot. Attention is also directed to the great loss of time and the non-effectiveness of personnel experienced in the Italian Campaign last winter and spring from "trench foot," "immersion foot," and similar injuries due to cold and wetness. Not only should emphasis be placed upon the early issue of winter foot-gear, but also upon fitting of shoes and socks, cleanliness of the feet, and early treatment of foot conditions. The command function of educating and training combat troops in this problem if diligently carried out, will go far toward reducing non-effectiveness from these causes.

This report, which was intended for the 12th Army Group commander, as well as for subordinate commanders, recommended (1) that winter clothing be issued at the earliest practicable date and (2) that commanding officers of all echelons take the necessary steps to insure that all men in their commands were properly instructed in the care of their feet under winter combat conditions and were adequately supplied with properly fitting socks and shoes.

Army publications.—On the army level, the first directive concerning cold injury (Professional Memorandum No. 5, Trench Foot), which was issued before the outbreak, appeared on 1 October 1944, from the Office of the Surgeon, First U. S. Army. All commanding officers and all medical officers assigned or attached to corps, division, and separate medical units were warned of the possibility of cold injury, especially in wet and damp weather and even when the temperature was above freezing. Causes of trenchfoot and meas-

[45] Informal Routing Slip, Chief Consultant in Surgery, to Chief, Professional Services Division, 4 Oct. 1944, subject: Trench Foot, Immersion Foot.

ures of prevention were outlined, and the importance of teaching troops to protect themselves as individuals was stressed. It was pointed out that the First U. S. Army was then operating in terrain ideal for the development of trenchfoot and in weather that was also ideal for its occurrence.

When Colonel Cutler received this memorandum, he commented that it was an excellent summary of Circular Letter No. 126 (p. 164) but that he regarded it as unfortunate that two separate memorandums should be issued on this important subject. He hoped proper authorities would advise the First U. S. Army to use Circular Letter No. 126 instead of their own publication. Colonel Kimbrough added a note to this comment to the effect that, since the Chief Surgeon's circular letter was entirely adequate, it would be unfortunate if each army were to put out a separate circular on the subject. In effect, that is what each army did and what many lower units also did. Many of these circulars were unduly long, and some of them combined matters, such as how to prevent trenchfoot and how to wash wool socks without shrinkage (p. 167), which might better have been handled separately.

On 8 October 1944, the Ninth U. S. Army headquarters issued Memorandum No. 68, entitled "Medical Instructions." In it, the possibility of trenchfoot in the climatic conditions then present and the areas then occupied was stressed, and attention was directed to War Department Circular No. 312. On 3 December, after trenchfoot had already caused thousands of casualties in this and other armies, a second communication was issued by the Ninth U. S. Army in which the effective methods of prevention used by the British were summarized.

In the Seventh U. S. Army, Circular No. 20 was issued as a command directive on 9 October 1944. In it, attention was called to the losses suffered the previous winter in Italy. The causes, symptoms, and treatment of trenchfoot were outlined, and methods of prevention in combat as well as in reserve were described. It was emphasized that cold injury is a preventable condition and that its prevention is the function and responsibility of command. This circular also pointed out that commanders must learn how to prevent cold injury and must see that their orders were carried out. The Seventh U. S. Army originally consisted of divisions which had fought in the Mediterranean theater the previous winter. Many of the troops had suffered from cold injury then, and there were numerous recurrences as soon as the weather in France became cold (p. 382).

The warning that commanding officers must inform themselves concerning cold injury was very necessary. It was repeatedly found in all armies during the coming weeks that commissioned officers, like noncommissioned officers and enlisted men, did not understand the real nature of cold injury.[46] Some of them, in fact, believed that the condition was similar to severe athlete's foot.

The Third U. S. Army issued its first directive on the subject of trenchfoot

[46] Letter, Headquarters, Third U. S. Army, Office of the Surgeon, to Commanding General, Third U. S. Army, 19 Apr. 1945, subject: Activities of Third U. S. Army Trench Foot Control Team.

(Circular No. 76) on 9 November 1944. During the weeks prior to the issuance of this circular, numerous informal discussions between medical and other personnel at army headquarters and in subordinate echelons were held. Although trenchfoot was a serious problem in the army when Circular No. 76 was issued, the directive merely stated officially and in writing, policies and plans which were already in effect.

In this circular, troop commanders were directed to familiarize themselves with War Department Circular No. 312 and to comply with its directions. Commanders were given the direct responsibility of preventing cold injury. The following unequivocal statement was made: "The excessive development of trenchfoot in an organization will be considered as indicative of inadequate supervision and control." This circular also contained numerous details concerning the cause and prevention of cold injury and included a detailed set of instructions for laundering socks and instituting a sock exchange.

Measures Taken During the Epidemics of Cold Injury

On 17 November 1944, by which time thousands of cases of trenchfoot had already occurred, General Kenner addressed a memorandum on the subject to the Chief of Staff, SHAEF. In it, he discussed the incidence of trenchfoot and the causes, with particular emphasis upon cold weather, wet feet, and constriction about the feet. He also outlined the action being taken to check the epidemic. The control of cold injury, he stated, had been placed in command channels, since foot discipline was a command responsibility. He emphasized proper footgear, including overshoes, and the use of dubbing. He reported that definitive action had already been taken on his recommendations that the unit issue of heavy wool socks be increased, that high priority be given to forward movement of socks, and that a concise brochure on trenchfoot, for universal distribution, be prepared and published by the Chief Surgeon, ETOUSA.

General Kenner's memorandum was approved at SHAEF and forwarded to the Commanding General, Communications Zone, ETOUSA, for his information and guidance.

On November 17, a field directive on the subject of trenchfoot was prepared by the chief of the Preventive Medicine Section, Office of the Surgeon, 12th Army Group, and was hand carried by Col. Alvin L. Gorby, MC, Surgeon, 12th Army Group, to the commanding general. In this memorandum, the whole situation in the field was surveyed.

General Bradley immediately ordered the material issued as a command directive (Circular No. 19). In addition, he sent personal letters to the commanding generals of all field armies in the 12th Army Group. In these letters, he pointed out the heavy loss of manpower caused by cold injury, the permanence of many of these injuries, the particularly heavy losses in the infantry, the fact that cold injury was largely preventable by the proper assumption of responsibility by command, and the apparent absence of all assumption of

responsibility by command at that time. General Bradley also noted that in many units galoshes had been left behind by direction, spare socks had not been required, and in some instances men had not removed their shoes for 5 to 10 days. He requested that all army commanders give these matters their immediate personal attention.

Immediately upon the receipt of these letters, the commanding generals of the First, Third, and Ninth U. S. Armies prepared and distributed to corps and division commanders letters embodying the information contained in General Bradley's letter and ordering immediate measures to control the trenchfoot epidemic.

The letter from General Patton, dated 21 November 1944 (appendix F, p. 529), is typical of the substance of all these letters. In it, attention was called to the gravity of the situation. The causes of cold injury were outlined. Specific control measures were listed, including the use of overshoes, the proper fitting of shoes, the use of dubbing, the provision of extra socks, and daily foot care. It was stated unequivocally that control was a function of command, and a distinction was made between control measures for which the individual soldier was responsible and the support which command could provide. The letter began with the blunt statement, "The most serious menace confronting us today is not the German Army, which we have practically destroyed, but the weather which, if we do not exert ourselves, may well destroy us through the incidence of trench foot." [47]

On 23 November 1944, General Hawley sent identical letters to the surgeons of the 12th Army Group, First U. S. Army, Third U. S. Army, and Ninth U. S. Army, pointing out to them that, if ideal methods of prevention of trenchfoot could not be accomplished, simple measures to keep the circulation active in the feet would result in the disappearance of most cases. He recommended removal of the shoes and socks once a day and massage of the feet until the circulation was completely reestablished. He also pointed out that, while dry socks were desirable, wringing water out of wet socks and then replacing them was preferable to leaving the shoes and socks on continuously. The letter concluded:

> 3. The ratio of trench foot to battle casualties is so high that, by failing to solve this problem, we are doing practically as much damage to our own troops as the enemy—and, by "we," I do not mean the Medical Department. This is a disciplinary problem, particularly one of leadership in small units.

In spite of his recognition that the prevention of trenchfoot was a command problem, General Hawley was not entirely satisfied with the activities of the

[47] On 19 November, Col. Charles B. Odom, MC, surgical consultant to the Surgeon, Third U. S. Army, had addressed a memorandum to General Patton in which he outlined the seriousness of casualties from cold injury among United States troops, the far better situation among German troops, and the inadequacies of the footgear supplied to United States soldiers. The shoes, he said, were badly fitted and the quality of the socks was poor. After analyzing the major factors in the causation of trenchfoot and the discouraging outlook for the man who sustained it, the memorandum concluded: "It is apparent from talks with our soldiers that they do not realize the importance of caring for their feet, nor are they properly instructed and disciplined in this regard."

Medical Department. On 25 November 1944, he wrote to Colonel Gorby, as follows:

> * * * I am not sure that the Medical Department has been aggressive enough in this situation. We have published long dissertations on the prevention of trench foot which are too long for anyone to read. Furthermore, they lay down so many requirements that, unless the soldier can fulfill all of them, he does nothing. Apparently no one has ever told the small unit commander that the very essence of prevention of trench foot is the prevention of stagnation of circulation for periods greater than 24 hours.

General Hawley concluded his letter by again laying down his own concept of prevention. He stated that he thought that if the shoes were removed once every 24 hours, if the feet were massaged briskly, preferably while they were higher than the hips, and if the water was wrung out of wet socks before they were replaced, cold injury could be prevented in 75 percent of all cases.

High command also made it clear, though somewhat belatedly, that control was the responsibility of command and that prevention was both feasible and practical. A letter, dated 24 January 1945,[48] stated:

> While appreciative of the adverse climatic factors existing in combat areas, he [General Eisenhower] desires to emphasize that this condition [cold injury] may be controlled by the proper exercise of Command, particularly by officers of company grade. It is desired, therefore, that higher unit commanders impress upon all ranks the necessity for unremitting attention to this command responsibility.

There was a similar acceptance of responsibility, though frequently equally belated, in most individual units. The annual report of medical activities in the XIII Corps, Ninth U. S. Army, dated 31 January 1945, read, in part, as follows:

> It [trench foot] was the most important and most prevalent condition that could have been prevented * * *. There are several reasons for a high incidence of this disease. First * * * neither the line officer nor the medical officer is sufficiently aware of the condition prior to the time the troops are exposed to the hazards of unfavorable weather and terrain conditions. Second, neither the line officer nor the medical officer stresses sufficiently proper care of the feet. Third, the footgear and clothing issued by the U. S. Army is not adequate for wear under conditions apt to result in trench foot. Fourth, commanding officers often fail to relieve their front-line units sufficiently frequently. Fifth, commanding officers fail to provide facilities for the drying of shoes, socks and clothing; fail to give adequate instructions to their men; * * * fail to realize that the care of the feet of their troops is a command responsibility. All of the above reasons, except the third, could be eliminated by adequate instruction and indoctrination of officers and noncommissioned officers in the training phases.

Individual Instruction and Indoctrination

One of the major problems in the control of trenchfoot in the European theater was the necessity for instructing the individual soldier how to take care of his feet. Almost none of these troops had had any previous training in foot hygiene in cold wet weather. All personnel had to be instructed; line officers, as has already been mentioned several times, knew no more of the matter, for

[48] Letter, SHAEF, to Commanding Generals, 12th Army Group, 6th Army Group, First Allied Airborne Army, and Communications Zone, European theater, 24 Jan. 1945, subject: Control of Trench Foot.

the most part, than the men for whose well-being they were responsible. The instruction had to be given in highly unfavorable circumstances, in combat, when the soldiers were concerned with other matters that seemed of much more importance than taking care of their feet. One of them was saving their lives. Yet, in some manner, they had to be impressed with the urgent necessity of taking care of their feet. Although they should have been taught these things earlier, it is nonetheless fair to say that the effort, even if made late, was extremely effective.

Formal instruction was obviously impractical under the circumstances, and the facts of the trenchfoot situation and methods of preventing it, particularly in the individual soldier, were conveyed to the men in a variety of ways.

Before the invasion, it had been planned that trenchfoot would be one of the subjects to be considered in a series of articles on health to be published in Stars and Stripes, in which it would be discussed in the article on footgear.

After the first general epidemic of trenchfoot, in November 1944, publicity was intensive. News articles, editorials, and feature notes appeared in Stars and Stripes, including news summaries on 10 November and 29 November and editorials on 6 December 1944 and 19 January 1945. Articles appeared in Ears on 4 and 5 December and in War Week on 9 December. A short article appeared in Combat Tips for 2 December and a 4-page spread (half of the issue) in the 16 December issue. Material was placed in division publications, such as the Invader of the 28th Infantry Division. In these publications, the language of authority was translated into the language of the GI:

1. Keep your feet as dry as possible. With all the mud, this is easier said than done but you gotta do it anyway.
2. Elevate your feet at intervals, every two or three hours, whenever your feet get cold and wet. Just flop on your derrière and do push-ups with your legs.
3. Modernize your slit trench, if possible, by putting in flooring. Pine boughs make a nice GI color scheme * * * but don't use any floor wax.
4. Wear overshoes. That is, if you have them.

Radio publicity was employed intensively. Mobile broadcasting facilities made it possible for the messages on trenchfoot to reach frontline troops in areas in which printed matter was not practical.

Posters in preparation in the United States (p. 72) were not ready in time to be useful in the European theater, but a poster was prepared in the theater for general distribution, and the use of posters prepared in individual units was encouraged. Some of them were very effective.

In his memorandum (p. 167) to the Chief of Staff, SHAEF, on 17 November 1944, General Kenner had recommended that the Chief Surgeon, ETOUSA, publish a concise brochure on trenchfoot for distribution to the troops. Colonel Gordon set this project in motion, although his own experience indicated that articles for newspapers, magazines, and periodicals, which could be repeated, were more purposeful.

With the cooperation of the Public Relations Division, ETOUSA, the preparation of a brochure was expedited, and distribution was begun the second

week in January 1945. Two and a half million copies were printed, so that each soldier in the theater could receive one. Those used in the United Kingdom were printed in London and those used on the Continent were printed in Paris, where distribution was delayed because of a strike of printers. When the copy was sent to the Assistant Chief of Staff, G–3 (operations and training), ETOUSA, 6 December, it had been noted that early printing was more important than an elaborate effort delayed beyond the present period of urgent need.

When an inquiry to The Surgeon General produced the information that the film on trenchfoot being prepared in that office was not yet ready, an educational film on the subject was prepared in the First U. S. Army. Clinical material was obtained at First U. S. Army medical installations, medical supervision was supplied by an officer of that army, and the technical work was done by a photographic section from SHAEF. The official film on trenchfoot (FB180, p. 73) did not reach the theater from the Zone of Interior until 24 February 1945.

The clinical pictures of trenchfoot made by the 2d Medical Arts Detachment at the 108th General Hospital were used for instructional purposes, although only after some debate about their value for nonmedical personnel. Still photographs were also made to illustrate preventive measures as practiced by men in the field.

Training of Reinforcements [49]

The problem of trenchfoot in reinforcements assumed three forms in the European theater:

1. It occasionally occurred in the Ground Force Reinforcement Command, while the men were still undergoing training. When this happened, it could usually be accounted for by special circumstances, such as the lack of overshoes. In February 1945, 22 of 449 reinforcements received by the 47th Infantry Regiment were found, on inspection by a representative of the G–3 Section, Headquarters, ETOUSA, to be suffering from trenchfoot.[50] The explanation was that they had stood in the wet for hours at a time during training.

2. Most of the cold injury which occurred while troops were in the Reinforcement Command was secondary, in the form of recurrences in troops recently released from the hospital after treatment for primary cold injury. In November 1944, there were almost no cases in the Ground Force Reinforcement Command, but in December, for the reason just stated, there was an appreciable number.

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[49] The name of the Ground Force Replacement Command was changed on 28 December 1944 to Ground Force Reinforcement Command, the reason being that some officers believed that the British term "reinforcement" was more suitable, because of the morale factor, than the original term "replacement." The implementing letter instructed all concerned to inform new men that they were combat reserves or reinforcements, not replacements for men who had been killed or wounded. As a matter of convenience, the term "reinforcements" is used uniformly throughout this section, regardless of date.

[50] Letter, Lt. Col. Richard P. Fisk, AGD, Headquarters, ETOUSA, to Commanding General, Ground Force Reinforcement Command, 23 Feb. 1945, subject: Trench Foot Among Reinforcements.

3. Most of the cases of cold injury in reinforcements occurred in troops sent into the field without proper training in its prevention. The plan in the European theater provided for a 2- to 3-week period of training for all replacements arriving from the United States before they were assigned to combat units. Military exigencies did not permit the uniform application of this plan. The training period frequently had to be cut short because of the urgent need for manpower in the frontlines. During the Battle of the Bulge, for instance, very little time intervened between the arrival of troops in the theater and their assignment to units in combat.

The program of training in the Reinforcement Command included a course in first aid and field sanitation, in the preparation of which the Surgeon General's Office had participated.[51] Foot hygiene was a part of this course. Greater emphasis was placed upon this subject after the distribution of War Department Circular No. 312 and TB MED 81. When the original program proved inadequate and recently arrived reinforcements were found to be suffering heavy casualties from trenchfoot, the program of indoctrination was further intensified, action being initiated both inside and outside the Reinforcement Command.

Colonel Gorby wrote General Hawley on 1 December 1944 that he had asked all army surgeons to take the necessary steps to see that reinforcements were properly indoctrinated in the facts of cold injury before their assignment to combat units. On 7 December, General Patton recommended to the Commanding General, ETOUSA, that before their release from the Ground Force Reinforcement Command each officer and each enlisted man be given intensive individual instruction in measures to prevent cold injury, including the correct fitting of shoes, combat boots, and overshoes. It was also recommended that command responsibility for cold injury be emphasized to officers and that the importance of rotation be particularly stressed. These recommendations were designed to decrease "the probability that they [officers and enlisted men] will become casualties soon after arrival in combat areas." [52]

Two circulars on the subject of cold injury were issued by the Ground Force Reinforcement Command, No. 55, dated 13 December 1944, and No. 3, dated 10 January 1945. Later, all depots were instructed that no reinforcements were to be reassigned until they had received the proper instruction in cold injury and until that fact had been duly noted on each man's WD AGO Form 20.

As the dates indicate, in this as in other commands, the action taken to prevent cold injury was correct, but it was taken too late to influence the epidemics which occurred in the European theater in the winter of 1944–45.

Training and Schools

It was midsummer of 1944 before the prevention of cold injury came to be regarded as one of the essential considerations in the infantry training

[51] Annual Report, Surgeon, Ground Force Reinforcement Command, European theater, dated 30 Sept. 1945.

[52] Letter, Headquarters, 12th Army Group, to Commanding General, ETOUSA, 7 Dec. 1944, subject: Training of Replacements in Prevention of Trench Foot and Care of the Feet.

program in the Zone of Interior (p. 74). By the time the program had been fully implemented and the troops trained under it had reached the European theater, the trenchfoot epidemics were practically ended. In other words, except for the divisions of the Seventh U. S. Army which had been trained in the Mediterranean theater, the troops which fought in Europe through the winter of 1944–45 had had only the most casual training in the prevention of cold injury, if, indeed, they had had any at all. This lack of knowledge and training was not limited to enlisted men. With few exceptions, line commanders had equally little understanding and appreciation of the risks of cold injury and of methods of preventing it.

Finally, and again with few exceptions, medical officers were almost equally ignorant and untrained, since cold injury is an entirely unknown condition in most parts of the United States. Even in the coldest portions it is observed only occasionally, practically always in the form of frostbite. Although numerous opportunities existed for instruction of medical officers in the European theater, a study of the record does not indicate that they received any special training in the subject before cold injury began to occur.

The Medical Field Service School was established at Shrivenham, England, as part of the American School Center operated by the Services of Supply, on 27 February 1943 (Circular No. 22) for training medical officers in aspects of military practice not ordinarily encountered in civilian practice. Before it discontinued operations on 15 October 1944, about 900 officers had been trained in 21 classes. The field of instruction was wide, but the curriculum apparently did not include cold injury, at least as a special subject; it may have been mentioned incidentally. Cold injury also does not seem to have been included in the instruction in Medical Department training methods provided by a demonstration platoon at the school. Between courses, this platoon toured base sections, putting on demonstrations for the hospitals.

Courses in such subjects as plaster technique, laboratory technique, anesthesia, oxygen therapy, and the making of artificial eyes were given for officers and enlisted technicians at various station and general hospitals in the theater, and selected medical officers attended courses at British hospitals and schools. In all of these courses, as at Shrivenham, the range of interest was wide, but cold injury was apparently not covered in any of them.

OTHER CONSIDERATIONS OF PREVENTION AND CONTROL

Rotation

During the cold injury season in the European theater, fighting was always too desperate and combat manpower was always in too short supply to permit unit rotation to any considerable degree. This was a war of movement, and troops were almost always continuously engaged. Because of the tactical

situation and the limited manpower available, therefore, major commanders seldom found that any large-scale rotation of troops was possible.

Absence of regular rotation practices was one of the major handicaps of the control program. In spite of the serious difficulties connected with it, however, rotation might still have been accomplished if there had been any stated theater policies concerning it. There were none,[53] and, until the end of combat, such unit rotation as was practiced was according to the orders of individual subordinate commanders. This was not a desirable state of affairs.

Individual rotation was difficult and was not practiced uniformly, though it was employed irregularly and to some extent almost everywhere along the front. Since experience has shown that trenchfoot does not, as a rule, develop until after more than 24 to 48 hours of relative immobility, rotation, when it was correctly practiced, had the objective of taking small groups, of squad size or larger, out of the lines for a few hours within these periods.

Many times, conditions in the rear were almost as severe as in forward areas, but usually a tent, a dugout, a ruined building, or some similar protection was available. Here, soldiers could care for their feet, change their socks, and have warm food and drinks. Drying facilities were provided whenever possible.

In spite of the irregular practice of rotation, units which employed it to the limits of the possibilities found it an extremely useful method of preventing trenchfoot. The possibilities, of course, frequently depended, more than anything else, upon the will and resourcefulness of the unit commander.

Tentage and Shelter

In April 1944, when planning for the invasion of the Continent was under way, an elaborate program was outlined (Standing Operating Procedure No. 5, ETOUSA) for the shelter of the invading troops.[54] The idea was that all camps and depots should be changed over, in phases, first from canvas coverage to wood and metal huts and then to buildings.

The theater chief quartermaster was not optimistic about the use of existing buildings, because of heavy bombings, and did not regard new construction as practical. It was his idea that tentage should be provided for 2,500,000 troops, about 90 percent of the total number then envisaged, and for their supporting personnel. This planning ran counter to the experience in North Africa, a barren area, where heavy tentage for 50 percent of the troops had proved adequate. No allowances were made in the European theater for barracks and hospital buildings, which would have provided—and later did provide—for a certain proportion of the shelter needed.

The requisitions for tentage made in the summer of 1944 were not filled. Indeed, the requisitions were never more than halfway met, and when the

[53] Report, Office of Chief Surgeon, ETOUSA, to The Surgeon General, 16 May 1945, subject: Trench Foot—Revised Report No. 9.

[54] See footnote 23 (1), p. 143.

field forces called for tentage it was unavailable. At first, the troops did not fully explore the possibilities of houses, barns, and other structures, as European armies had always done, and this omission resulted in a certain amount of unnecessary exposure. Later, as their experience increased, the men began to protect themselves in existing buildings and eventually found them better than tents.

Salves and Ointments

In World War I, British medical officers at first laid much stress upon the use of salves and ointments in the prevention of trenchfoot (p. 202). In 1917, this practice was discarded in favor of the use of foot powder, and it was not reverted to in World War II. Salves and ointments were part of the preventive routine used by American troops in World War I (p. 48), and they were also used by some of the troops who participated in the Attu campaign (p. 310).

During the summer of 1944, a number of inquiries concerning the use of salves and ointments were made of the Professional Services Division, Office of the Surgeon General, as well as of the Professional Services Division, Office of the Chief Surgeon, ETOUSA. The substance of the replies, which stated the official policy concerning these agents, was as follows:[55]

1. Tests by both ground and air forces had shown salves and ointments to be of no value.

2. The National Research Council had arrived at the same conclusion after studies of work that had been done in Canada. The only exception to this opinion was that oil-impregnated socks might be of some value in the prevention of immersion foot.

3. The use of oils and salves might engender a false sense of security and lead to carelessness in the strict application of such essential preventive measures as cleanliness, frequent changes of socks, and general foot discipline.

4. The application of grease to the feet before the shoes were put on might cause so much sweating, especially in men with a tendency to hyperhydrosis, that a state of chronic local immersion might be produced with vasodilatation and perhaps the formation of small vesicles.

5. The Russians, who had conducted extensive tests with various salves and oils, had also concluded that this was not a useful form of prophylaxis.

The epidemic of trenchfoot in November led to a number of inquiries concerning the preventive value of this practice, but the Professional Services Division, Office of the Chief Surgeon, ETOUSA, invariably replied that the use of these agents had been carefully considered and was not recommended.

Although this was official policy, a number of units in the theater used various agents to massage the feet, some in the hope that the lubricants might have some preventive effect, others frankly for the psychologic effect and to

[55] (1) Memorandum, Lt. Col. A. L. Ahnfeldt, MC, Director, Sanitation and Hygiene Division, Preventive Medicine Service, Office of the Surgeon General, to Major Walker, Preventive Medicine Service, 4 May 1944, subject: Use of Oil as a Preventive in Frostbite, Freezing, and Trench Foot. (2) Informal Routing Slip, Professional Services Division, to Preventive Medicine Division, 4 Aug. 1944, subject: Trench Foot.

insure massage of the feet. One unit used shaving cream. One division surgeon ran tests on the relative value of massage alone, massage with lanolin, and massage with petrolatum. In another division, aidmen carried a mixture of mineral oil, cod liver oil, and oil of peppermint, which they gave the men to use on their feet. One medical officer had the supply officer make up anhydrous lanolin with 10 percent beeswax for this purpose. So far as is known, none of these practices proved effective and all of them were quietly dropped, though not before a number of men suffered maceration of the feet from the collection of excessive perspiration under the oils and greases which they had used.

EPIDEMIOLOGIC SURVEY AND CONTROL

Even before cold injury had become a serious problem in the European theater, officers representing General Hawley and Colonel Gordon had visited major commands of the 12th Army Group. Their surveys began in October. As a result, they were able to observe the November outbreak of trenchfoot at first hand and to evaluate the efficacy of the various measures taken to control it. On their return to 12th Army Group headquarters at the end of November, they were able to corroborate, from firsthand observation, what experienced observers already knew; that is, that the major means of prevention of cold injury is proper command control. They could also emphasize, from their personal experience, that, even when the tactical situation is most difficult and terrain and environmental conditions most unfavorable, units in which foot care is a correctly supervised command responsibility could maintain reasonably low rates.

The field surveys undertaken in October and November had not been specifically directed toward cold injury. In December, a formal survey of the cold injury situation was undertaken. The observers, all experienced officers who had seen cold injury in the Mediterranean and European theaters, were accompanied by medical inspectors of the various armies. They surveyed the field armies, division by division, collecting accurate data on the incidence and prevalence of trenchfoot in each unit; unit combat experience; weather conditions; terrain; status of clothing supplies; rotation policies and practices; the quality of unit and foot discipline; and whatever other host and environmental factors were known, or were presumed, to influence the development of cold trauma. Conferences were also held with army, corps, and division surgeons and with as many senior commanders as possible. The wealth of material secured in this survey is discussed in detail under the heading of epidemiology (p. 363), and only the main points need be summarized here:

1. The winter of 1944–45 was the worst Europe had experienced in years.

2. The terrain which was fought over was chiefly open country, easily flooded, and crossed by many rivers in flood because of heavy precipitation.

3. Clothing and footgear suitable for the environmental situation and the

terrain were in short supply and were still inadequate at the end of December 1944.

4. The tactical situation could take no account of the unfavorable weather, terrain, and supply situations. The November offensive by United States ground forces and the German counteroffensive in December placed very heavy demands upon combat troops. It was necessary that they expose themselves in the performance of essential duties, and the isolated position of many units, as a result of enemy action, greatly increased the risks of exposure.

5. In spite of these adverse circumstances, a considerable degree of command control was perfectly practical, the proof being that in many units it had been accomplished. Efforts at general indoctrination of troops and at preventive measures by command were increasing and were becoming increasingly effective.

Trenchfoot-Control Teams

The recommendation of the Paris Conference on Trench Foot, that trenchfoot-control teams be established at army level (p. 183), was implemented by the directive published on 30 January 1945 (appendix G, p. 531). Each control team consisted of a line officer and an officer of the Quartermaster Corps. The function of these teams was to visit corps, division, and regimental headquarters for two chief purposes: (1) To assess the past and present cold injury situation and (2) to teach unit trenchfoot-control officers practical measures for preventing outbreaks of cold injury and for controlling them if they occurred. It was the duty of these unit control officers, in their turn, to train trenchfoot-control officers and noncommissioned officers in battalions, companies, and platoons. The functions of control personnel in the smaller units were to check on individual foot discipline in their units; to encourage obedience to instructions and better performance by means of personal instruction and force of example; to determine shortages of clothing and equipment; and to institute programs of discussions and demonstrations among small groups, so that all personnel would be familiar with the need for, and the details of, the special measures necessary to prevent cold injury.

Trenchfoot-control teams were set up too late to exert any substantial influence on the incidence of cold injury in the European theater during the winter of 1944–45. By the time they had become fully operational, weather conditions were improving, German resistance was deteriorating, and the Allied forces were moving swiftly and victoriously forward toward the Inner Reich.

In spite of the late institution of the program, it was nonetheless the consensus of those who watched the program in operation that it provided an extremely effective means of combating cold injury. This was the opinion of the personnel of the teams from all five armies which met at the Office of the Chief Surgeon on 21 April 1945, together with medical inspectors of the various United States field armies and representatives of Headquarters, 12th Army Group.[56]

[56] Report, Medical Section, 12th Army Group, to the Adjutant General, 12th Army Group, 7 May 1945, subject Monthly Summary of Medical Section Activities.

The general feeling was (1) that this was the best method of bringing preventive measures to units of company grade and (2) that squad leaders were essential components of the control program, since they were in close contact, day and night, with their squadmates and could encourage and guide individual foot care and discipline.

It was also the unanimous feeling of those present at this meeting that, should operations be required during the next winter, these control teams should be reorganized and reactivated before the trenchfoot season began. Finally, it was decided that trenchfoot-control officers or teams could profitably be established on divisional as well as army levels.

The full potentialities of the trenchfoot-control program are discussed in the chapter on prevention (p. 484).

CONFERENCES

Regular conferences were held by General Hawley with base section surgeons. The agenda covered a wide range of subjects of both administrative and clinical significance. Other conferences were held with senior consultants, and still others with his division chiefs. Inter-Allied conferences on war medicine were also held during 1942, 1943, 1944, and 1945. Cold injury, however, was scarcely mentioned at any of these conferences until after it had become a serious problem in the theater.

At a conference held in London on 21 July 1944, attended by various professional and administrative personnel, General Hawley stated that The Surgeon General was greatly concerned about the possibility of cold injury during the coming winter. He emphasized that the causes were well known and that prevention was the important consideration. The Surgeon General, General Hawley continued, thought that a sock with a high wool content would prevent cold injury, and Colonel Gordon's division, with assistance from the Professional Services Division, would at once take up the matter with the theater chief quartermaster. Three million pairs of pure-wool socks were on hand in the theater, but the troops did not like them. The alternative might be to request the Quartermaster General to develop an 80-percent-wool sock. At this conference, Colonel Gordon stated that material on the subject of cold injury had been put together and was ready to be published. General Hawley observed that it would not be of much value if the necessary socks were not available.

At a meeting of his division chiefs on 4 October 1944, General Hawley stated that he could not himself think that the end of the war was in sight and that he thought that plans should be made for all eventualities before they developed. Cold injury was not specifically mentioned as one of the eventualities he had in mind.

On 6 October, at another meeting of his division chiefs, General Hawley

stated that in recent visits to various evacuation hospitals of field armies he had found nurses living in cold tents surrounded by water and mud and that respiratory disease rates were increasing. At the meeting of division chiefs held on 26 October, Col. William S. Middleton, MC, Chief Consultant in Medicine, Office of the Chief Surgeon, ETOUSA, also reported an upward trend in respiratory disease in the First and Third U. S. Armies.

A conference held in Paris from 14 to 16 October was attended by professional consultants to the British, Canadian, and United States Army forces on the Continent. Although cold injury was beginning to be evident by this time, the agenda did not include any mention of it. Other conferences were also held on the Continent, but later, after trenchfoot had already become a serious problem.

At the 10 November meeting of General Hawley and members of his staff, trenchfoot was mentioned for the first time since the 21 July meeting in London. It was now becoming a problem. The shortage of overshoes and the quality of the socks being issued to the troops were discussed. It was brought out that the theater quartermaster had said that the supply of socks was more than ample.

At the 30 December meeting of the Chief Surgeon's consultants committee, in Paris, trenchfoot occupied much of the agenda. The discussion covered both the clinical manifestations of cold injury and its management, with special emphasis on the value of prompt exercise. The idea then prevailed that 50 percent of casualties from this cause could be returned to duty and that anywhere from 5 to 35 percent of the patients hospitalized in the Communications Zone could be returned to duty. The experience in the Mediterranean theater had already shown that the optimism indicated by the figure of 35 percent was unwarranted. Colonel Middleton remarked that the lack of clinical coordination was shown by the fact that every new unit which encountered cold injury had to go over the same therapeutic trials and errors that had already been explored by units farther forward.

The February 1945 Inter-Allied Conference was devoted to cold injury. Papers on the subject were presented by Maj. Leiv Kreyberg, Royal Norwegian Medical Corps, Professor of Pathology, University of Oslo; Col. C. S. Ryles, Professor of Hygiene, Royal Army Medical College; and Raymond Greene, physician, Emergency Medical Service. Cold injury does not seem to have been discussed at any of the earlier meetings of this group.

The other conferences held on cold injury and on cold-weather clothing were not convoked until the problem had become extremely serious.

Conferences on Trenchfoot

In January 1945, just as the epidemiologic survey of trenchfoot in the European theater was nearing completion, cold injury again began to increase in frequency. The disappointing increase, the large numbers of hospital beds

already occupied by casualties suffering from trenchfoot, and the findings of the epidemiologic survey pointed to the need for a pooling of experiences and a general review of the situation. The Chief Surgeon therefore authorized a conference on trenchfoot, which was held in Paris on 24 January 1945. It was participated in by representatives of the Medical Department, Quartermaster Corps, and G–1 (personnel and administration), ETOUSA, the preventive medicine officers of the several field armies, the officers who had conducted the epidemiologic survey (p. 176), and the medical and surgical consultants in the theater. Combat commanders were represented by Col. (later Brig. Gen.) Sterling A. Wood, commanding officer of the 313th Infantry Regiment, 79th Infantry Division, who had shown a particular interest in, and comprehension of, the trenchfoot problem.

The discussions and conclusions of this conference in regard to the pathologic process, clinical manifestations, therapy, and prognosis of trenchfoot are presented elsewhere in this volume, under the appropriate headings. The opening presentation by Colonel Gordon was a comprehensive analysis of the situation from the standpoint of control. The substance of his remarks was as follows:

Epidemic cold injury may be compared with a waterborne epidemic of typhoid fever. In such an epidemic, general measures would first be taken, including the chlorination of water and the institution of a general control program. Then specific measures would be instituted. Focal points of local outbreaks would be sought for and would be eliminated by the application of the general epidemiologic principles of focal attack. This procedure had been followed in the attack on cold injury. Commanding officers in all echelons had made an energetic effort to educate troops and perfect their discipline. The chief quartermaster had invoked all the resources of his office to provide and distribute winter clothing. Finally, the Medical Department had conducted an intensive campaign of instruction in preventive measures for both units and individuals. In this presentation, the epidemiologic similarities between the trenchfoot situation in Europe and the malaria situation in the Southwest Pacific were also pointed out.

The analysis of the epidemic of cold injury had revealed decided variations from unit to unit, whether the unit was an army or a battalion. These variations made it clear that future steps in prevention must be directed toward the smaller units. The small unit did not necessarily require additional general education and indoctrination. It did not even require a more assiduous application of general measures of control. The essential point was that every company, and even lesser units, must understand the special conditions which were producing cold injury within their own ranks. These conditions were not necessarily the same in all units. Frequently, in fact, they were quite different. If the individuality of the special causative factors were realized, rotation, for instance, would not be overemphasized in a unit in which the cause of cold injury was the lack of proper clothing or failure to enforce foot discipline.

Special experiences.—Of a number of special experiences described in the course of the discussion, the following are of special interest:

1. When it was found in the Seventh U. S. Army that reinforcements coming into one division through regular channels or from hospitals were not acquainted with the facts of cold injury, it was decided, about 1 November 1944, that the convalescent hospital and the replacement depot were good spots in which to initiate preventive training. At this particular time, it was the custom in replacement centers to give the troops a 30-minute lecture on their general health, only 10 minutes of which was devoted to the care of the feet. Trenchfoot was either not mentioned at all or was discussed within 2 minutes. The lecture period was lengthened to 60 minutes, and at least 30 minutes of the time was devoted to cold injury.

The educational program instituted at the convalescent hospital consisted of short, informal discussions; radio programs; and the use of articles on the subject in Stars and Stripes. A representative of the Quartermaster Corps was assigned to the hospital to teach methods of utilizing winter equipment. Among other things, he demonstrated how easy it was to get out of the sleeping bag, once the trick was known. This officer, together with Medical Corps officers, worked down to battalions, companies, and smaller units. As a result of these efforts, the Seventh U. S. Army had become extremely foot conscious.

The same speaker (Lieutenant Colonel Gowan) who reported this effort in the Seventh U. S. Army also reported the value of individual efforts at instruction. When he visited the 36th Infantry Division, he found that a medical aidman, who was later killed, while serving in a lost battalion, had made the men remove their shoes at intervals, wring out their socks, exercise their feet and toes, and employ other simple measures to prevent trenchfoot. His work paid large dividends. Although the tactical and environmental circumstances were highly favorable for the development of a large number of cases of trenchfoot, the number which occurred was very small.

2. The second experience was related by Colonel Wood. In his notes on the conference, Colonel Cutler stated that this officer's remarks were "more effective than any of the professional discussion." Later, General Hawley passed on to the surgeons of the field armies Colonel Wood's suggestion that every regimental commander could profitably be taken on a tour of hospitals caring for trenchfoot casualties, so that they would comprehend the real seriousness of the injury.

Colonel Wood knew nothing of trenchfoot until he observed it, as a patient with another condition, in the 40th General Hospital. There he saw enough of it to make him very much aware of it. Before he returned to his own regiment, he was able to have conferences on the subject with the Chief Surgeon and Colonel Cutler.

His remarks concerning his actions thereafter deserve extended quotation:

> I went in and asked my division surgeon, "What are you doing about trench foot? * * * He said, "On the 22nd of November we got up a circular." I said, "Let's get it out and see what it is." * * * It had come to my regiment when we were in the middle of fighting

a battle. There was one copy to the regiment and there had been no follow-up on the part of the higher command to see what had happened to it. The regimental commanders did not know about the dangers of trench foot. * * * I worked * * * to have them [the posters] issued and displayed in every conspicuous place around the area. * * * I had ten basic factors about trench foot printed up and required that every single individual have one and have the company commanders check to see that they have them personally. Then I talked to the division commander and he sent me * * * to tell all the other regiments in the command all that I had seen. At that time we had no trench foot. We did not know what we were going to get into. We were fortunate in that we had the shoepac. [In another connection the speaker said that his own men preferred the shoepac to the combat shoe and could march 18 to 20 miles in it.] We had ski socks, so that we did have basic equipment. There was one thing we immediately found. * * * we had never been trained in this type of foot discipline over here. Colonel Gordon was talking about the original training and education. We never had any training about trench foot. * * * Command control and discipline were also mentioned. Now the difficulty as I see it is that of command control. * * * peaks [of trench foot] are going to happen because during a month's time in our organization the noncommissioned officers and officers are casualties and going back. [They are] the people that will normally handle the supervision to see that the man does what he should do * * *.

I think the commanding officers have to receive some definite orders, not suggestions. One of my objections to all these medical bulletins is that you use too long words and that we don't know what you are talking about, and that they are too lengthy. They should be just as brief as possible. We should get them in quantities, so that we can give them to the man who has to carry them into effect.

Because of the high rate of replacements, in actual practice it means you have to start to educate people all over again. None of the early training we had even two months ago will ensure that the individual man does what he is expected to do. We have broken it down to the noncommissioned officers. Actually I have a more stable rate of noncommissioned officers in my regiment than commissioned officers; often the company commander is a second lieutenant who has recently come in. Each man carries one of the papers and he is checked. They are erased for consideration for a Paris pass if they are caught without one. Then if you can get those leaders to force the men to change their socks, you are doing a great deal in the right direction. That is command responsibility, but in the way we are scattered up there, the company commander is busy planning what he is going to do next. It has to be broken down. The regimental commander has to ask the battalion commander for a report of what he is doing on trench foot, which is exactly the same as he must ask if the men are being fed and supplied. Then he has to insist that the battalion commanders do the same thing with company commanders, but the men who actually made the men put on the dry socks have to see them put on * * *.

One thing we require is that as soon as a man gets into any shelter at all, he is to lie down on his back, elevate his feet and remain there just as long as he can, and wiggle his feet as much as he can. We have tried to convince them that if for a period of thirty minutes time during a twenty-four hour interval, blood can be made to pump into the toes, we can eliminate a great deal of trench foot * * *.

We have drawn extra duffle bags * * * for every company. All the socks are in the duffle bags. It doesn't make much difference in size. * * * All our requisitions are for size twelve socks. The ration detail comes up at night and takes back with it the duffle bags of wet wool socks. They come up then with one dry pair of socks for every man in the company. * * * After a forty-eight hour period we are getting duffle bags and dry socks for every man in the company. That is the rotation system and we are able to use it most of the time. If you can get food to the men, you can also get socks to the men. It can be done if it is ordered, and the same thing applies about wearing socks. When we are ordered to do something, we do it without any question, but if the division surgeon comes up and says, "I think it would be a good idea to get dry socks every day," it just doesn't get done, and I

would like to recommend that the recommendations from here go down through command channels. By that way the line officer does what he is told automatically without thinking whether it can be done; if we leave it to him, it won't be done. I think it would be much simpler just to tell him to do it.

In reply to questions, the speaker stated that one man, preferably the mess sergeant, should be made responsible for the dry socks. He also recommended that education on trenchfoot be given in the reenforcement depot, to make company officers conscious of the problem before they went forward. Second lieutenants were often company commanders within a few days after they had joined the regiment, and, if they had not been previously instructed concerning cold injury, it was necessary to wait for a break before the matter could be taken up with them.

Conclusions and recommendations.—The general responsibility for trenchfoot was particularly emphasized in the discussions at the conference. It was distributed among (1) the individual soldiers, who had to take care of their own feet; (2) command, which had the responsibility of training the soldiers and seeing that they did what they were told to do; (3) the Quartermaster Corps, which had the responsibility of providing clothing and footgear suitable for winter combat; and (4) the Medical Corps, which had to keep the various command and quartermaster echelons informed about cold injuries, without at the same time letting the individual soldier believe that he was going to lose his legs from this cause.

The most universal fault, the conference concluded, was poor foot discipline, and the time had arrived for firm and definitive action within units in which this deficiency was evident. The similarities between the trenchfoot situation in Europe and the malaria situation in the Southwest Pacific suggested that improvement could be accomplished in Europe by the same approach that had been effective in the Pacific; that is, the use of control teams for individual inspection, education, and discipline.

A recommendation embodying the concept of control teams was supported, and the necessary steps were taken later to form such a team in each of the field armies (p. 177 and appendix G).

After the trenchfoot teams had been appointed in accordance with the directive authorizing their establishment, Col. Tom F. Whayne, MC, preventive medicine officer of the 12th Army Group, suggested that it would be profitable for members of the teams from the various armies to meet with preventive medicine officers from the armies as well as representatives of the theater and the army groups, in order to discuss the functions of the teams and methods of procedure. This conference was held in Paris on 16 February 1945.

Quite properly, because of the command and training implications of the cold injury problem, the conference was opened with a general discussion of the whole problem by a representative of G–3, ETOUSA. The medical aspects of the problem were then discussed by General Hawley. A résumé of causative factors, the present status of the cold injury situation, and the principles of the control program were presented by Colonel Gordon. This (morning) session

was concluded by a roundtable discussion in which members of the trenchfoot-control teams and others participated. Many practical aspects of the problem were covered. The afternoon session, which was entirely clinical, was held at the 108th General Hospital, at which a special study of patients with trenchfoot was in progress. After an opening clinical lecture on the nature of cold injury, patients were presented and methods of treatment were demonstrated and discussed.

The over-all effectiveness of the trenchfoot-control program could not be evaluated in the European theater because, at about the time the control teams went into action, the weather ameliorated and, with the thaw that occurred, cold injury began to decrease. It was, however, the consensus of all who had participated in the first conference that a second conference, attended by essentially the same personnel, should be called to review the activities of the teams and of the officers and noncommissioned officers who had been responsible for the implementation of the program. It was hoped that enough information could be brought out to permit some sort of evaluation of the operations of the control teams. This conference was held in Paris on 21 April 1945.

The program of the second conference, after the opening remarks by Colonel Gordon, was devoted to discussions of foot discipline, weather, clothing and equipment, operational conditions, and similar matters. The experience of certain divisions of the Seventh U. S. Army which had previously been exposed to cold injury was compared with that of other divisions which had had no previous experience in winter combat. It was the consensus of those present (1) that the plan of using control teams provided an effective and profitable means for the control of cold injury; (2) that it greatly enhanced the training of the individual soldier and the small unit in their own responsibilities in the matter; and (3) that it also utilized the elements of command, supply, and medical personnel in a well-coordinated and interlocking combination.

It is highly significant that the majority of the members of this second conference (13 of 15), all of whom had observed trenchfoot under combat conditions, concluded that, in the control of trenchfoot, the most important of all considerations was individual foot care, followed, in order of importance, by adequate clothing and equipment and sound rotation policies. Bad weather, although it is the fundamental cause of all cold injury, was given the place of least importance by all the officers voting.

Conferences on Winter Clothing

The conference on winter clothing which the chief quartermaster had planned to call for late December 1944 was necessarily postponed because of the German breakthrough in the Ardennes which occurred at that time. The conference was eventually held in Paris on 29 January 1945, and a followup conference was held in the same city, with much the same personnel in attendance on 17 March.

A detailed record of these conferences is not the proper concern of this volume, but certain general facts may be stated.[57] It had been the hope of the chief quartermaster that the conference would recommend a simple, basic uniform, suitable for all branches of the Army and planned in accordance with limitations of transportation and production. As he pointed out, the United States Army had 70 items of basic winter clothing, against 11 basic items for the British Army. The British Army had made its plans for a simple uniform at the beginning of the war and did not change them; as a result, it did not experience the shortages and inadequacies of various items which constantly plagued the United States Army.

The two conferences did not accomplish the goal which the chief quartermaster had set for them, but they did improve matters by reducing the 70 basic items of clothing by 21, the number of sizes by 29, and the number of fabrics required in the manufacture of the uniform from 10 to 4.

As to clothing, it has been correctly said that the items finally decided upon represented a weighing of preferences rather than a meeting of minds. This was because the clothing recommended by the Quartermaster General had been thoroughly tested only in the Fifth and Seventh U. S. Armies, which had used it with satisfaction for two winters. The 12th Army Group, which expressed a preference for the obsolete armored force uniform, had scarcely tested the new items which it was voting against. On the whole, the conclusions finally arrived at were much the same as those arrived at by members of the trenchfoot-control teams who had observed cold injury at first hand in the field. On one point, at least, there was unanimity, that the shoepac was the most acceptable footgear for frontline troops to wear in winter.

CLINICAL INVESTIGATIONS

Mention has already been made of the study of cold injury in Air Force personnel undertaken in 1943 at the 2d General Hospital in the United Kingdom (p. 134). A number of other studies were undertaken when cold injury became prevalent among ground troops in the European theater in November 1944, but most of them were informal and concerned only small series of cases. One of them was a study of therapeutic methods at the 110th Station Hospital. Another was a study of negative pressure therapy at the 7th General Hospital. Still another was an investigation at the 92d Medical Gas Treatment Battalion, Third U. S. Army, to determine what type of casualty could be retained in the army area for treatment with the expectation of return to combat duty. Incidentally, several hundred men were returned to duty under this plan.

In view of the excellent results obtained by the formal study of influenza and empyema undertaken in World War I, it is unfortunate that trained investigators were not sent from the Zone of Interior to the European theater to

[57] Letter, Maj. Gen. Robert M. Littlejohn, Chief Quartermaster, ETOUSA, to the Quartermaster General, 9 May 1945, subject: Winter Uniform.

set up similar studies for cold injury. Not a great deal could be done by personnel in the European theater. All facilities were heavily involved in the care of patients. The clinical material, paradoxical though it may seem, was much too abundant to permit extensive, properly controlled studies to be set up generally.

Early in October 1944, Colonel Crisler of the First U. S. Army had suggested to Colonel Cutler that hospitals for specialized care of trenchfoot should be set up in each army and should be staffed by medical officers experienced in this special field. Colonel Cutler transmitted the suggestion to Colonel Kimbrough, but events, unfortunately, moved too fast for this excellent plan to be carried out. The exchange of information at the trenchfoot conference in Paris in January 1945 (p. 179) permitted the evaluation of various diagnostic and therapeutic techniques, but it was then too late to institute formal investigations.

The single formal study of trenchfoot in the European theater was made at the 108th General Hospital, under the direction of Capt. (later Maj.) Octa C. Leigh, Jr., MC. Consultants on the project included Col. Johan C. Holst, consultant in surgery to the Norwegian Army in the United Kingdom, and Major Kreyberg. The specific objectives of the study were to provide a simple, workable classification for rapid triage; to study various methods of therapy; and to accumulate as much practical data as possible concerning the duration of exposure, the duration of immobilization, the kind of footwear worn at the time of injury, and similar matters. The details of this investigation are cited in appropriate places throughout this volume. The investigation, unfortunately, was not as complete as it might have been because the special equipment required, including skin temperature thermocouples and capillary microscopes, was received too late to be entirely useful.

Plans for a study of anticoagulant therapy (heparin) in cold injury were proposed by the Medical and the Surgical Consultants Division, Office of the Surgeon General, but for a variety of reasons this project could not be carried out. The rationale of this type of therapy is discussed elsewhere (p. 326).

REPORTING AND NOMENCLATURE

War Department Technical Bulletin (TB MED) 92, issued 15 September 1944, provided that War Department MD Form 86ab, though intended for use in reporting communicable diseases, should also be used to report trenchfoot, immersion foot, and frostbite under a special heading. The reason for the use of this form was that reports made on MD Form 52 would be too late to accomplish one of the most important purposes of the Statistical Health Report; namely, to furnish current information on the incidence of communicable diseases.

When trenchfoot became epidemic in the European theater, it was found that Form 86ab was not providing statistical data quickly enough to be useful, and Form 323 was substituted for it.

Form 323 was a daily report prepared by all medical units in the theater primarily for use by the Office of the Chief Surgeon; it permitted the reporting of epidemic conditions without loss of time. Reports made on this form, however, were less exact than reports made on Form 86ab. For this reason and as a result of different methods of reporting, the first statistics secured for cold injury contained some inaccuracies, chiefly in the form of overreporting. The errors, which were sometimes substantial, were finally all corrected.

Because of necessary wartime classification of medical casualty reports, higher headquarters at times encountered some difficulty in associating the casualties from trenchfoot with the exact unit in which they occurred and the location of the unit on the battlefront. From the standpoint of Colonel Gordon's office in Paris, the secrecy with which military operations were being carried on delayed the evaluation of the reports of trenchfoot as they were submitted, first weekly and then daily. The condition appeared suddenly, and the number of casualties increased rapidly. Colonel Gordon apparently had difficulty, from the reports which he received at first, in determining the exact units which were most affected and their location. Division, corps, and army surgeons, who were closer to the trouble, of course did not have this difficulty.

Other problems, however, were not settled during the entire war. The first was the category in which cold injury belonged in statistical reports. The second was the nomenclature to be employed for it. The third, which arose out of the confusion in the nomenclature, was the award of the Purple Heart for cold injury (p. 189).

Because of lack of clarity in directives, trenchfoot and immersion foot were at one time or another included in medical statistical reports both as nonbattle injuries and as diseases, while frostbite was variously considered as both a battle and a nonbattle injury, depending upon the interpretation of the individual command. As long as cold injury was not a major problem in the theater, the confusion did not make too much difference. In November 1944, with the outbreak of what proved to be a true epidemic, the confusion became serious. It resulted in both underreporting and overreporting, and it added further to the administrative difficulties which arose in connection with the award of the Purple Heart.

As pointed out elsewhere, the terms "high-altitude frostbite," "immersion foot," "trench foot," and "frostbite" were developed as matters of expediency, when the now generally accepted concept of cold injury, that all of these conditions represent varying degrees of the same fundamental pathologic process, did not exist. The distinction between these conditions is not of major importance and is often artificial. In World War II, in fact, trench-

foot was often, in effect, immersion foot, and the distinction between trenchfoot and frostbite was usually made according to the environmental temperature at the time the injury was sustained. If the temperature was above 32° F. (0° C.), the diagnosis was trenchfoot; if the temperature was below this level, the diagnosis was frostbite. When weather records were lacking or incomplete in any area, as they frequently were, this entirely artificial distinction broke down, and the diagnosis rested with the individual medical officer.

The principal source of the confusion was administrative. Circular Letter No. 156, Office of the Chief Surgeon, ETOUSA, dated 20 October 1943, directed that cold injury be designated as (1) high-altitude type, (2) ground type, and (3) immersion foot. When TB MED 81 arrived in the theater the following year, it left the theater Chief Surgeon and The Surgeon General at variance over the nomenclature of cold injury. The opinion was rather freely expressed that the term "trenchfoot" would persist, which it did, although formal recognition was not given to the popular nomenclature until 18 November 1944, when Circular Letter No. 156 was rescinded with the issuance of Circular Letter No. 134, Office of the Chief Surgeon, ETOUSA. Nothing seems to have come of the sensible suggestion of the senior consultant in orthopedic surgery, Col. Mather Cleveland, MC, that the term "foxhole foot" would be better than "trenchfoot," since this type of cold injury seldom occurs in large, roomy trenches, in which men can move about, but does develop in foxholes, where they are very often almost completely immobilized.

Circular Letter No. 94, Office of the Chief Surgeon, ETOUSA, 31 August 1944, directed that patients admitted for cold injury and retained more than 24 hours (that is, for more than food and rest) should be classified as battle casualties. This regulation was frequently violated, with the result that hospital registrars were confused, and statistical reporting was becoming inaccurate. On 30 November 1944, Col. David E. Liston, MC, Deputy Surgeon, ETOUSA, directed that for the time being all cases of trenchfoot should be classified as nonbattle injuries. Shortly before, Colonel Kimbrough had recommended to General Hawley's executive officer that the relevant portions of Circular Letter No. 94 be altered and that disabilities due to exposure be listed as diseases.

Because of the mounting confusion, General Hawley's office requested a War Department ruling on the classification of trenchfoot, immersion foot, and frostbite incurred in combat areas. The reply, dated 3 December 1944, directed that these injuries should not be classified as battle casualties. This ruling was reaffirmed in April 1945.

The reports indicate that trenchfoot and frostbite were both reported as trenchfoot up to the end of 1944. Thereafter, they were reported separately, although the distinction, as already mentioned, was artificial in the extreme. Many medical officers experienced in this type of trauma always thought that the three categories (immersion foot, trenchfoot, and frostbite) would better have been considered under the generic heading of cold injury, if only because

a more correct concept of the etiologic factors and pathologic process would thus have been obtained. The terms of the award of the Purple Heart, however, made it necessary to continue the separate classifications.

AWARD OF THE PURPLE HEART

One of the byproducts of cold injury, which arose principally in the European theater, was the troublesome, entirely administrative, problem created by the award of the Purple Heart. At least part of the difficulty arose from the confusion in the nomenclature of cold injury, which has just been summarized.

This award, which had been established by Gen. George Washington at Newburgh on 7 August 1782, during the War of the Revolution, and which had lapsed shortly afterward, was revived on 22 February 1932, on the 200th anniversary of his birth, "out of respect to his memory and military achievements," in War Department General Orders No. 3. The award was to be given to members of the United States Armed Forces wounded either in action against an enemy of the United States or as a direct result of an enemy act, provided that the wound thus incurred required treatment by a medical officer. For purposes of the award, a wound was defined as "an injury to any part of the body from an outside force, element or agent sustained as the result of a hostile act of the enemy or while in action in the face of the enemy." The word "element," it was specified, "refers to weather and permits award to personnel severely frostbitten while actually engaged in combat." It was stated, equally specifically and entirely illogically, that trenchfoot did not merit the award.

Army Air Forces.—The question of awarding the Purple Heart for cold injury first arose in World War II in connection with cold injury in flying personnel. In September 1943, the Preventive Medicine Division, Office of the Chief Surgeon, ETOUSA, concurred in the opinion that this type of cold injury justified the award. A few weeks later, however, the inconsistencies of this policy were pointed out to G–1, ETOUSA, by General Hawley in a line of argument to be repeatedly advanced in connection with this award. The Purple Heart, the Chief Surgeon pointed out, was a command, not a medical, problem. Frostbite was a disability produced by the hardships of service, not by enemy action, and it was usually preventable. While it could result from defects in equipment, it was more likely to result from individual carelessness. Protective clothing might be damaged by enemy action, but, if the principle upon which the Purple Heart was being given for cold injury in flying personnel were applied consistently, it was hard to see where the line was to be drawn; the award might as reasonably be made for pneumonia, tonsillitis, and a cold in the head, all of which might develop after exposure. Furthermore, if men in the Eighth Air Force were given awards for frostbite, every soldier on the ground who had sustained a cold injury also deserved it. Awards were not

given for cold injury in the Royal Air Force. On the contrary, each injury was investigated, to determine whether damage to protective clothing had occurred by enemy action or by negligence.

In May 1944, when changes were made in Army Regulations (AR) 600-45 (Changes No. 4) concerning the terms of the award, reference to cold injury in flying personnel was deleted and the term "element" was defined, without restriction, as referring to the weather. It was again specified that, while severe frostbite sustained in combat justified the award of the Purple Heart, trenchfoot did not.

Residua of the Aleutians campaign.—The Purple Heart was apparently never a serious administrative problem in the Mediterranean theater either in the winter of 1943–44 or in the following winter. Questions concerning it next arose in June 1944, in connection with the residua of cold injury in the Aleutians campaign. Immersion foot, as cold injury incurred in that area was called, was not mentioned in the regulations for the award, and the commanding general of the 7th Infantry Division, whose troops had suffered heavily from cold injury during that campaign, recommended that the Purple Heart be given for immersion foot.

When the correspondence on the subject was referred to the Surgical Consultants Division, Office of the Surgeon General, the reply sent on 15 September 1944 agreed that the current regulations were unfair for a number of reasons:

1. Many soldiers incur trenchfoot while actually in combat and are more seriously injured than some who incur frostbite, even if it is severe.
2. They may lose one or both lower extremities as a result of their injury.
3. Although immersion foot, trenchfoot, and frostbite develop under different circumstances, the basic pathologic process and the clinical manifestations are similar, the difference being in degree, not in kind.

In view of these facts, it was recommended that, since all three types of injury might be incurred in actual combat, the disputed paragraph (16A) in AR 600-45 should be altered to read: "In connection with the definition of the 'wound' above, the word 'element' refers to weather and permits award to personnel severely Frostbitten or incurring Immersion Foot or Trench Foot while actually engaged in combat."

In subsequent weeks these arguments were reiterated and expanded in the Surgeon General's Office. On 5 October 1944, the Surgeon General's executive officer wrote to the Decorations and Awards Branch, Office of the Adjutant General, that specifications as to the severity of cold injury were not regarded as practical, partly because injuries without loss of structure might be graver than those in which tissue is not lost.

On 3 October 1944, Brig. Gen. (later Maj. Gen.) Russell B. Reynolds, GSC, Director, Military Personnel Division, Headquarters, Army Service Forces, recommended to G–1, War Department, that the regulations be altered to permit the award to personnel who had incurred trenchfoot or immersion foot as well as frostbite if they were actually engaged in combat, if they required amputation of a part, or if the injury required hospitalization. The changes

proposed were not made, but, on 21 October 1944, the deputy chief of staff settled the question which had arisen in connection with cold injury in the Aleutians campaign by authorizing the 7th Infantry Division commander, who had raised the question, to make the award to members of his division who had sustained immersion foot during the Attu operation if the injury had been incurred in actual combat and if it had resulted in amputation of a part or in other permanent injury.

European theater.—Meantime, the matter was again coming to a head in the European theater, this time in connection with the ground type of cold injury. As the weather became colder and wetter, and as cold injuries increased in numbers, the situation became more and more confused and unsatisfactory, especially from the administrative standpoint.

On 25 November 1944, Colonel Gorby, the 12th Army Group surgeon and an experienced field medical officer, pointed out to G–3 of the army group that it was not at all fair to limit the award to amputees since more lasting incapacity might be incurred without any loss of tissue. His own opinion, however, was that the award should not be given for any type of cold injury. Trenchfoot was preventable. It was the responsibility of the individual soldier and of his commanding officer to prevent it. Its occurrence usually indicated poor training, poor command, and poor soldiering. The medical officer was in no position to determine whether it was or was not preventable in any given case, and it would be more logical to award it for diseases which could not be prevented. If word got about that the Purple Heart was to be awarded for cold injury, an immediate increase in hospital admissions could be expected; it would be a good way out for potential S. I. W. (self-inflicted wounds). The Russians, although they were fighting in an environment productive of cold injury, had very little of it because in every instance, no matter what the circumstances, disciplinary action was taken against the injured man and his commanding officer. In Colonel Gorby's opinion, disciplinary action rather than awards would reduce the personnel losses due to cold injury. No definitive action resulted from these sound arguments.

Still other complications were arising. Line officers, out of consideration for their men, naturally wanted a liberalization of the regulations, to permit the Purple Heart to be awarded for trenchfoot. On the other hand, just at this time, the concept of command responsibility for cold injury was beginning to be comprehended, and those charged with the prevention of the injury objected, with logic, to making nominations for an award to be presented for the very condition which they were ordered to prevent. The conflict of interests, centering around the criteria for awarding the Purple Heart and complicated by the confusion of nomenclature just described, actually tended to affect the Adjutant General's accounting of battle casualties.

The Purple Heart came in for considerable discussion at the conference on trenchfoot held in Paris in January 1945 (p. 179). It was pointed out that in view of the terms of the award, which required a distinction between frostbite and trenchfoot, the nomination of the man for the award really

rested with the medical officer who first saw the patient, since he was aware of weather conditions and duty status. It was therefore an error, which should not be permitted to continue, to change the diagnosis in evacuation hospitals in any case of cold injury unless there was sound clinical evidence of diagnostic error. If this plan were followed, the award would at least be made consistently, for the diagnosis would be consistently right or consistently wrong. General Hawley said that, over his opposition, the award had been extended to such absurd lengths that it might as well be issued with rations.

No change in Army Regulations was made during the epidemic phase of cold injury in the European theater. The award continued to be a matter of administrative controversy, with the Medical Department, because of its exclusive power to determine diagnoses, squarely in the center. On 4 February 1945, General Hawley wrote The Surgeon General that the wording of the regulation (severely frostbitten) could be interpreted to apply only when the lesion was so extensive that cells were killed and there was an actual loss of a part, or a slough through the whole thickness of the corium. He said that, as a practical matter, it was not possible to distinguish between frostbite and other forms of cold injury. The hospital wards, he said, were full of embittered infantrymen who had sustained trenchfoot, often of a serious degree, but who were not entitled to the Purple Heart. The Medical Department was being required to administer a policy which it had not set up and which it could not administer fairly. Forward units were conferring the Purple Heart and were not being too strict about it, under pressure from frontline commanders who demanded liberality in the award to keep their troops reasonably mollified. As the situation now stood, General Hawley added, men with simple blisters caused by frostbite were receiving the Purple Heart while men with incapacitating lesions from trenchfoot were not getting it.

On 26 February, General Hawley pointed out to the surgeons of the other armies in the European theater that the Third U. S. Army did not authorize the award because of the difficulty of determining the degree of severity of the injury within the period established for holding these casualties in the theater. He felt that the same step could well be taken in other armies in the theater.

The last War Department message on the subject received in the European theater did nothing to resolve the difficulties connected with the award. In April 1945, in response to a second inquiry from the theater concerning the classification of cold injuries, the Adjutant General's Office replied that trenchfoot, immersion foot, frostbite, and injuries similar to them would not be reported for statistical purposes as battle casualties but that the award of the Purple Heart to personnel severely frostbitten while actually engaged in combat would not be affected by this ruling. This meant, in effect, that although cold injuries were not to be classified as battle casualties the Purple Heart, which is an award for an injury sustained in battle, would continue to be given for one type of cold injury but not for the other two.

The General Board, United States Forces, European theater, trenchfoot (cold injury, ground type).—The General Board which investigated, among other matters, the subject of trenchfoot in the European theater later in 1945 (p. 208) stated that a just and equitable award of the Purple Heart for cold injury was possible only if it was authorized for all casualties who sustained cold injuries while actually engaged in combat, and only if the injuries were of sufficient severity to require treatment by a medical officer. The Board recommended that the current policies be reviewed and that the award either be granted for both trenchfoot and frostbite or not be granted for either. Before the award was recommended in any instance, consideration should be given to such factors as combat and weather. It should also be determined whether or not the injury was due to negligence or to deliberate intent or was avoidable and to what degree it was attributable to enemy action.

Action in the Zone of Interior.—When casualties from overseas began to be returned to the United States, the problem of the award of the Purple Heart for cold injuries came to the fore in this country. For example, in February 1945, the commanding officer of the United States Army General Hospital, Camp Carson, Colo., which was a trenchfoot center, wrote to The Adjutant General [58] that the great majority of the patients under his command had received their cold injuries while fighting for their lives, under very unfavorable conditions of combat. Many had been pinned down for days in water-filled foxholes, continuously raked by machinegun fire and periodically subjected to tank assaults. Some had been kept for days on outposts and patrols and could not possibly remove their shoes. Some had been in combat for as long as 30 days without extra socks. There could be no question of personal neglect in such cases. Moreover, many of these casualties were likely to have serious sequelae, ranging from severe paresthesias and hyperhidrosis to gangrene, possibly with amputation of half the foot.

In fairness to these casualties, as well as in the interests of uniformity, the letter proposed that a policy be established whereby the Purple Heart would be given for trenchfoot on two criteria: (1) That the disability be acquired in combat and (2) that it be sufficiently disabling to require evacuation to the Zone of Interior. It was further proposed that the award be accomplished in Zone of Interior hospitals, after thorough investigation of the records in each case. These proposals were concurred in by the commanding general of the Seventh Service Command.

When this communication was referred to The Surgeon General by The Adjutant General for comment and recommendations, The Surgeon General expressed complete accord with the views of the basic communication and reiterated the recommendations made by his office on 5 October 1944 (p. 190). It was specified again that if a soldier was to receive the award, his injury must have been incurred during actual combat and that its severity must have been

[58] Letter, Col. T. E. Harwood, MC, Commanding Officer, U. S. Army General Hospital, Camp Carson, Colo., to The Adjutant General, 12 Feb. 1945, subject: Award of Purple Heart.

sufficient to require hospitalization. Evaluation of the severity of the injury was considered impractical. It was pointed out again that injuries without loss of tissue might prove to be graver than those in which tissue was lost.

In a memorandum dated 7 April 1945, addressed to Maj. Gen. George F. Lull, Deputy Surgeon General, Lt. Col. Roy H. Turner, MC, acting director of the Medical Consultants Division, Office of the Surgeon General, pointed out that Army Regulations 600–45, Changes No. 5, dated 11 November 1944, permitted the award of the Purple Heart for severe frostbite, while trenchfoot was not considered to merit the award.

At the time this change was made, Colonel Turner pointed out, frostbite was limited almost entirely to flying personnel. In April 1945, however, a large number of patients at the United States Army General Hospital, Camp Butner, N. C., were suffering from trenchfoot, and the clinical picture in these cases could not be differentiated from that of patients in the hospital suffering from frostbite. Existing regulations about the award of the Purple Heart were a cause of impaired morale and unfavorable criticism of the Medical Department, and it was suggested that consideration be given to a change in the regulations, so that severe trenchfoot would also merit award of the Purple Heart.

In the third endorsement of the basic communication, dated 14 April 1945, Maj. Gen. Norman T. Kirk, The Surgeon General, recommended to Gen. Brehon B. Somervell, Commanding General, Army Service Forces, that AR 600–45, paragraph 16a (2), be either amended to include immersion foot and trenchfoot or rescinded insofar as it authorized the award of the Purple Heart for frostbite. In doing so, General Kirk also mentioned the memorandum submitted by his office on 5 October 1944 to The Adjutant General (p. 190).

In a memorandum addressed to the Professional Administrative Service of the Surgeon General's Office on 18 May 1945, Brig. Gen. Fred W. Rankin proposed that the regulations governing the award of the Purple Heart be changed either to exclude the award altogether for cold injury or to authorize the award for all nonpreventable cold injuries actually sustained in combat if the injury necessitated hospitalization while in service. It was noted that the unfair regulation differentiating between frostbite, for which the award was authorized, and trenchfoot, for which it was not, had just been perpetuated in Changes No. 6, AR 600–45, dated 2 May 1945.

When the War Department G–1 concurred in this suggested change with the proviso that the award be made only if the cold injury resulted in amputation or partial amputation of a member, the action reopened the question which had already been so warmly debated. The Surgeon General's Office took exception, on the ground that amputation was not a suitable criterion of injury. A soldier severely frostbitten on the cheek, chin, or forehead would not receive the award by this criterion; neither would a casualty with serious and perhaps permanent impairment of the local vascular tree, though he would be left with a major disability. Furthermore, the great emphasis placed by

the Army upon the preventable nature of cold injury had to be taken into consideration, even while it was remembered that circumstances beyond individual control might be responsible for any gradation of the injury. It was therefore recommended that if the Purple Heart were to be given at all for cold injury, three criteria must be met:

1. The injury must be severe.
2. It must require hospitalization.
3. It must be ascertained that the circumstances of the injury were not preventable and were beyond human control.

The president of the War Department Decorations Board did not look with favor upon a proposal that the whole matter be dropped on the ground that there would probably be few instances of cold injury in the future. He took the position that since the question had been raised it should be settled. He suggested that the criteria of award should include a proviso that the injury had not been incurred as the result of the soldier's own negligence or misconduct. To some extent, this would take care of possible malingerers and would put the responsibility on medical officers. A little later, G–1 of the War Department concurred with the suggested changes, on the ground that if the award was made for one injury it should be made for all.

In July 1945, the Adjutant General, Army Ground Forces, recommended that the award should not be given for frostbite. He wished a wound to be defined as "* * * a physical injury to any part of the body from an outside force, or from a noxious agent used as a weapon, sustained as a result of a hostile act of the enemy or while in action in the face of the enemy." He considered that any substantial departure from this definition was confusing and detracted from the prestige of the Purple Heart, which should be maintained. This letter also repeated the arguments that the award was no more logical for cold injury than for pneumonia, malaria, and other medical conditions; that there was no point at which to stop if any single type of nonbattle casualty were to be considered a basis for the award; and that the problem was complicated by the fact that cold injury might or might not be preventable.

While this correspondence was in progress, Changes No. 7, AR 600–45, was issued on 14 July 1945, with the disputed paragraph as it had appeared on 3 May 1944 (Changes No. 4), before the most recent argument about it had arisen. This meant that personnel severely frostbitten while actually engaged in combat might continue to be awarded the Purple Heart, but that the award would be withheld from soldiers who acquired trenchfoot under precisely the same circumstances.[59]

[59] The paragraph in question remained unchanged until May 1951, when the recommendation was revived that the Purple Heart should not be awarded for frostbite. In the notation from G–1 for the Chief of Staff, United States Army, it was pointed out that the Air Force and Navy had eliminated the award for cold injury, and that the Army, to provide for more uniform standards of awards, should also eliminate it. This recommendation was concurred in on all levels, and the Chief of Staff on 23 August 1951 approved the elimination of frostbite and trenchfoot as reasons for the award of the Purple Heart (Changes No. 4, AR 600-45). The award was therefore not made again during the remainder of the war in Korea.

PUBLIC AND CONGRESSIONAL REACTIONS TO THE TRENCHFOOT SITUATION IN EUROPE

During the entire period in which trenchfoot was epidemic in the European theater there was intense public interest in the situation in the United States. Full cooperation was given to newsmen working in the theater; they were supplied with as much information as military security permitted. Numerous stories appeared in the lay press. Much of the material was accurate and was fairly presented. Much of it, however, was not, and even the most accurate accounts usually failed to make clear that the trenchfoot problem was a complex one and that it was not possible to simplify it by incriminating any single factor or any single set of circumstances.

How completely the situation could be misunderstood is apparent from the following extracts from a letter which was received by Senator Robert A. Taft from one of his constituents.[60] After noting published reports of the widespread incidence of trenchfoot and "frozen feet," the writer continued:

> I have also noted the statement attributed by Gen. Lear that the cause was more a question of discipline rather than adequate foot wear. Knowing Gen. Lear's passion for discipline, I suppose he would say the soldiers could fight in their shirt tails as long as they were properly disciplined.
>
> That may be all right on a sunny golf course in the South but would hardly apply to the fighting front during an European winter. Inadequate foot wear may be the reason but a reason is not an excuse for the proper army authorities failure to provide proper foot gear. With the benefit of the knowledge obtained by the experience of our Allies both British and Russian, there appears to be no excuse for overlooking this important matter. Why not hand out a little discipline to the disciplinarian who failed?

Senator Taft sent the letter to General Kirk. In his reply, General Kirk pointed out that trenchfoot was a many-sided problem, with many causative factors, one of which was discipline. The Senator's correspondent had apparently misinterpreted the meaning of the word discipline, which in connection with trenchfoot meant the enforcement of foot care and other measures designed to prevent the soldier from contracting trenchfoot through carelessness. Combat troops were correctly trained in these precautions, but, unless the regulations were rigidly enforced, they would not prevent cold injury.

On 5 March 1945, the Mead Committee, formally known as the Special Committee for the Investigation of the National Defense Program, requested the commanding general of the Army Service Forces to make an inquiry into all phases of trenchfoot in Europe, with special reference to medical reports and the performance of procurement and supply agencies charged with furnishing proper equipment. After several conferences, and the submission on 15 March 1945 of a written report on the activities of the Surgeon General's Office in connection with cold injury,[61] it became evident that to secure all the material

[60] Letter, H. J. Hamlin, to Sen. Robert A. Taft, 3 Feb. 1945.

[61] Memorandum, The Surgeon General, for Mr. Julius H. Amberg, Special Assistant for Secretary of War. 15 Mar. 1945, subject: Trench Foot Control—Medical Department Action.

which the committee had requested would require an on-the-ground investigation in the European theater itself.

The investigation was carried out by Lt. Col. (later Col.) Mason Ladd, JAGD, director of the Legal Division, Office of the Surgeon General. His formal report, which was submitted to The Surgeon General on 9 June 1945,[62] covered the following subjects: (1) Action of the Chief Surgeon and surgeons of army groups and armies, European theater, to prevent the development of trenchfoot; (2) factors causing trenchfoot; (3) observations of the British experience with trenchfoot; (4) trenchfoot as a fixed hazard in fighting of the type experienced in the winter of 1944–45; and (5) miscellaneous comments.

The report contained copies of the circular letters and other material issued on the subject of trenchfoot, interviews with various observers in the European theater, extracts from official diaries, statistical data, data on amputations for trenchfoot; and reports of conferences with The Surgeon General and officers of the British Army.

The conclusions arrived at by Colonel Ladd as a result of this investigation were as follows:

1. Efforts in the prevention of trench foot in the Office of the Chief Surgeon, ETO, and in the medical service in this theater, are considered to represent an efficient and thorough dealing with the problem. The work was commenced timely, but became effective only after the initial outbreak of cold weather injuries. When the problem became appreciated generally as a serious threat to military operations, complete cooperation was given by the entire theater command. Although training in foot discipline had been carried on in the ZI and in this theater, its significance in the prosecution of the war on the Continent was not fully appreciated by the troops until the incidence arose. An army-wide education program on the control of trench foot was initiated and successfully carried out.

2. The reduction of trench foot is believed to involve the following controllable factors in order of significance as listed below:

a. Discipline in care of feet.

b. Footgear and clothing.

c. Rotation of troops (short and long term).

3. Among those contacted * * * the shoepac with ski socks, one or two pairs, was regarded as the most suitable footwear for cold, wet weather in combat operations, although the necessity of discipline in its use, and the need for proper fitting were emphasized. For ordinary use, an improved, water-proofed combat boot with the smooth surface of the leather on the exterior was believed desirable. A system by which exchange of types of shoes according to weather conditions, as practiced in some units of the army last winter, was also favored.

4. The subject of supply of winter footwear and winter clothing is a matter pertaining to the Office of the Chief Quartermaster, and is not covered in this report. Based upon opinions expressed by Medical Officers, the matter would appear academic for this theater, as the ordinary winter clothing of the type issued generally during last fall should be fully adequate for ordinary winter conditions and action of the Army of Occupation. The production of new supplies will undoubtedly include improvements realized out of the winter's experiences. The later types of cold weather clothing used in the ETO are regarded as of utmost importance for Pacific operations where many of the wet and cold hazards encountered in combat action in the ETO may be reasonably anticipated to reappear.

[62] Report, Lt. Col. Mason Ladd, JAGD, Director, Legal Division, Office of the Surgeon General, dated 9 June 1945, subject: Report of Study of Records and of Investigation Relative to Incidence of Trench Foot, With Special Reference to its Course and the Activities of Army Medical Service Within ETO in Preventive Measures.

5. In attempting to evaluate the various factors giving rise to the incidence of trench foot in the ETO during the winter of 1944–45, it was the unanimous opinion of all persons contacted, or groups of persons, that any one cause cannot be designated as the single cause, but that all factors were interrelated, and each of a different force under the varying circumstances under which it operated. It is a practical impossibility to single out any one cause. There is no magic cure or prevention—trench foot control involves a combination of all relevant factors. Under the type of warfare, during the conditions experienced last winter in the ETO by the American Armies, trench foot in a substantial amount is believed to have been an unavoidable hazard of war. The incidence may be reduced but not eliminated under the adverse conditions faced in Europe last winter. Under less severe conditions where fighting is less active, it may be possible, with careful discipline, rotation and suitable supplies, to reduce trench foot to the point of almost complete elimination.

Colonel Ladd's report was presented to General Kirk on 9 June 1945. On 6 August 1945, two copies were delivered to Brig. Gen. Kenneth C. Royall, Special Assistant to the Secretary of War, in accordance with a request from his office that the report be delivered to him directly rather than through channels.[63] The understanding was that one of these copies was to be forwarded to the Mead Committee for use in its consideration of the trenchfoot problem in the European theater.

This report, while an excellent summary of the cold injury situation in the European theater, contained little material not already available in the Zone of Interior. When it was presented to General Kirk, the war in Europe had been over for a month. The war in the Pacific ended a week after it was delivered to General Royall, for transmission to the Mead Committee.

The investigation inspired by the Mead Committee unquestionably helped to focus attention upon the whole trenchfoot problem. Any Congressional investigation would demand respect and attention from the agency which was being investigated. On the other hand, by the time the investigation was requested (5 March 1945), cold injury had almost ceased to occur in Europe, and the severity of the epidemics had been so great that the attention of all responsible agencies of the War Department was already focused upon the problem. The dates of the delivery of the report to The Surgeon General and to General Royall for the Mead Committee explain why the investigation exerted no influence upon the planning in the Pacific and had no special impact elsewhere.

EXPERIENCES OF OTHER ARMIES

British Armies

The British and Canadian troops fighting in Europe in the winter of 1944-45 had an extremely low incidence of cold injury, 206 cases as compared with the

[63] Memorandum, The Surgeon General, for Brig. Gen. Kenneth C. Royall, Special Assistant to Secretary of War, 6 Aug. 1945, subject: Report of Study of Records and of Investigation Relative to Incidence of Trench Foot.

United States Army experience of approximately 46,000 cases.[64] The discrepancy was in line with the discrepancy observed between British and United States troops in Italy during the winter of 1943–44 (p. 103). On the surface, the circumstances under which British and United States Armies fought on the Western Front seem substantially the same. A closer investigation shows that in a number of respects they were quite different. These facts are best analyzed by presenting summaries of three separate reports made by Maj. William L. Hawley, MC, Major Siple, and Colonel Ladd.

Major Hawley, the epidemiologist from the Preventive Medicine Division of General Hawley's office who observed conditions in the British 21st Army Group, reported that factors responsible for the superior British record were, in order of importance, as follows:

1. The smaller number of divisional combat days engaged in by British and Canadian troops.

2. The tactical handling of troops. On an advancing front, provision was always made in the British and Canadian Armies for periods of alternating activity and reserve. During periods of extreme cold, all elements of forward units were withdrawn from the line every day for rest and warming.

3. Weather, in the sense that the American troops did a greater amount of fighting in the snow than British troops.

4. Clothing and footgear. The British battle dress was warmer, the sock had more insulation when it was wet, and the shoe had slightly more insulation and fitted the foot much more loosely than similar United States footgear.

5. The daily consumption of hot food and drink in forward areas. British and Canadian troops were issued hexamine cookers for use in the frontline and thus were able to indulge their national tea-drinking habits no matter where they were.

6. Discipline and morale. The average British soldier was more likely than the United States soldier to do exactly what he was told to do. If, therefore, he was directed to carry a certain number of extra pairs of socks on his person, he carried them. Similarly, he took care of his feet as directed. The United States soldier was frequently careless in such matters. Under direct fire, neither United States nor British troops displayed much interest in their feet.

The most important of the factors just listed, in Major Hawley's opinion, were the smaller number of combat days engaged in by British and Canadian troops and the more favorable climatic conditions under which they fought. On the other hand, the preventive measures practiced in these armies were undeniably better and were better enforced than the United States Army practices, especially in the early fall and winter of 1944–45. When combat situations were parallel, as they were in at least four instances in which United

[64] As has been explained elsewhere, the figure of 46,000 for cold injury in the European theater was later raised to 71,000 when all reports were available and when the cases in which cold injury was not the primary cause of the casualty were included. The figure of 46,000 is retained in this connection because it is the one used in the earlier reports from which much of the discussion in this chapter is taken.

States and British or Canadian troops occupied adjoining areas in battle, the British and Canadian records were better. "It cannot be denied," said the report, "that where comparisons seem valid the incidence in British-Canadian troops is much less than in the Americans."

Major Siple, who was sent from the Office of the Quartermaster General to the European theater in April 1945 to study various phases of cold injury, arrived at the following conclusions concerning the low incidence of cold injury in British and Canadian troops: [65]

1. The constant wet-cold conditions in the British Isles during the winter months, combined with the heavy losses sustained by the British from cold injury during the first winter of World War I (p. 43), made the British Army extremely foot conscious. The immediate cessation of losses from this cause in World War I when the proper control measures were instituted showed clearly that cold injury is preventable. The lessons of the earlier experience were therefore incorporated into the training of British soldiers on the Western Front in World War II, just as they had been incorporated into the training of those who fought in Italy. Foot discipline in the British Army was the responsibility of the unit commander; if he failed to carry out the foot inspections and other preventive measures required, he could be subjected to court-martial. The situation in the United States Army was, of course, essentially the same, but American officers did not assume their full responsibility and authority in this matter and did not exercise their full powers of discipline.

2. The British and Canadian Armies fought a holding campaign during most of the winter months and therefore had much less exposure in combat than American troops, who were pushing forward actively during the same period.

3. The areas of Holland and northern Belgium, where the British and Canadian Armies did most of their fighting during the winter of 1944–45, have a good deal of sandy soil, in which drainage is rapid. As a result, these troops did not spend so much time in mud and standing water as did American troops. Furthermore, these areas are somewhat warmer and drier than the more mountainous areas where American troops fought during the winter of 1944–45.

4. When British and Canadian troops were found to be wearing leather boots not adequate for the cold-wet conditions they were encountering, they were provided with completely waterproof boots.

5. The British militia boot had certain advantages over the American combat boot. The range of sizes was greater, and the higher toe and deeper forequarter permitted the use of additional socks during extremely cold weather. It was impossible to lace the boot tightly because the uppers already met when it was first fitted. The British boot was also somewhat more waterproof than the American boot because of the construction of the sole.

6. Throughout the winter fighting, it was British and Canadian policy not to keep any man in the frontlines more than 48 hours at a time if it was at all

[65] See footnote 37, p. 155.

possible to relieve him. The few cases of trenchfoot which appeared in these armies occurred when this precaution could not be carried out.

7. During the periods British and Canadian troops were out of the line during the winter, they could usually be billeted in buildings, where they were able to dry their clothing and footgear and otherwise care for themselves.

Colonel Ladd, during his investigation of trenchfoot in Europe in the spring of 1945 (p. 197), held conferences with the Director General, British Army Medical Services, and certain key officers on his staff. While the emphasis placed upon the importance of various causative factors naturally varied somewhat from officer to officer, the substance of these conferences with British medical officers was as follows:

1. The answer to trenchfoot could be summed up in a single word, "discipline." Assuming that troops had reasonably good equipment and encountered ordinary cold-wet conditions, they would not contract trenchfoot if they took care of their feet. The medical services of the British Army advised upon foot care and discipline, but execution of the advice was the function of line officers, whose personal responsibility it was to see that the men gave their feet proper care.

2. Troops should have a month or more of training, with the care of the feet an important part of the program.

3. All-leather boots and heavy wool socks provided for British troops were important in the program of prevention. Soldiers seldom liked the boots when they first began to wear them, but, by the end of the month of training, they were usually well satisfied with them. Some British officers regarded the British boot as the most important single factor in preventing trenchfoot. It fitted more loosely than the American boot, was made of heavier leather, and could not be laced tightly, since it was so cut that the uppers came together when the soldier first put it on. Its loose fit made movement of the feet possible even when the boot was soaked through, and the circulation of the lower extremities could therefore be maintained.

4. Every British soldier who fought in cold weather was provided with a long, loose, sleeveless leather jerkin, which he wore constantly. In general, British clothing was warmer than American clothing and was more loosely fitted.

5. British soldiers also kept themselves warm by their habit of drinking hot tea. They carried their own equipment and brewed tea many times during the day, even during brief halts in marches.

6. The differences in temperament between British and United States soldiers accounted for the fact that British troops did what they were told to do, without asking questions. Habits of obedience were not deeply ingrained in United States soldiers.

7. All British frontline troops were frequently rotated as individuals. They were given brief rest periods, in places provided behind the lines, where they could take care of their physical needs and care for their feet. This

practice, while it depended upon the resourcefulness of the individual unit commanders, was almost universally carried out.

8. British and United States troops fought over different terrain, with the differences in favor of the British. Weather and combat activity were also in favor of British troops.

9. United States troops had moved fast and aggressively, and trenchfoot was one of the prices paid for their victory.

At the Inter-Allied Conference on War Medicine held in February 1945, Col. C. S. Ryles, Professor of Hygiene, Royal Army Medical College, said that the magic that had practically eliminated trenchfoot in the British armies in World War I was contained in the General Routine Orders issued 28 November 1915. These orders provided (1) that every man must carry a second pair of socks on his person; (2) that arrangements must be made for drying the socks and reissuing them during tours in the trenches; and (3) that the boots and socks must be taken off in the trenches from time to time, as circumstances permitted, to dry the feet and rub them well, and to put on dry socks.

The only difference between the orders issued in 1915 and those issued in 1917 was that, in the second orders, greases and lubricants were discarded in favor of foot powder. The orders under which the British armies operated in World War II were essentially the same as those issued in 1915 and 1917.

Lt. Col. (later Col.) Theodore L. Badger, MC, Chief Medical Consultant, Normandy Base Section, thought that there was a fundamental difference between British and United States soldiers in regard to their feet. Americans, he said, for the most part walk only when they cannot ride. The British, on the contrary, walk constantly, not only about their business but for recreation. They spend their weekends and vacations on hikes. As a result, they are foot conscious. They take care of their feet. They are careful about the fit of their shoes. These civilian habits were carried over into military life. As a result, British troops understood the necessity for caring for their feet in service, learned promptly from training and experience, and practiced what they already knew about foot care even before they were told what to do.

French Army

Troops of the First French Army fought in the same general territory as the Seventh U. S. Army, engaged in much the same operations, and were exposed to much the same environmental conditions. The bulk of the forces operated in the Vosges Mountains, where rain and snowfall were heavy. Each man had been issued 2 pairs of service shoes, but the allotment of 150,000 pairs of galoshes was not sufficient for the issue of 1 pair per man.[66] The program of education was good; it was based on that of the Seventh U. S. Army, and the principle of command responsibility for the care of the feet was the same as the United States Army principle.

[66] Coded Message, Communications Zone, European Theater of Operations, to War Department, signed Eisenhower from Lee to Kirk, 15 Jan. 1945.

During the week ending 12 October 1944, there were 110 cases of trenchfoot reported in the First French Army. Between that week and the week ending 28 December, cold injury was epidemic; 662 cases were reported for the week ending 16 November, and 907 cases for the following week. After a brief period of improvement, there was a second outbreak, in which 574 cases were reported for the week ending 21 December and 582 for the following week. The highest weekly rates per 1,000 men for this period were 3.039 for the week ending 16 November, 4.223 for the following week, 2.648 for the weeks ending 14 December and 21 December, and 2.717 for the week ending 28 December. The smallest number of cases during this period, 105, was reported for the week ending 9 November, and the lowest rate, 0.573, was reported for the week ending 2 November.

German Armies

German troops fought under the same circumstances and in the same areas as United States troops during the winter of 1944–45, and a comparison of their experiences is therefore of some value. The best information concerning the incidence of cold injury among them was derived from the direct testimony of prisoners of war, whose physical condition usually furnished concrete proof of their statements. A great deal of the prisoners' evidence was contradictory, but this could easily be explained by variations in the circumstances of weather and combat. The material is best presented according to the sources from which it was derived, with no further attempt to explain the contradictions.

Records of German units opposing the Third U. S. Army contain no references to trenchfoot, which was apparently no problem among the enemy troops at a time when it was a serious problem in United States troops.[67] For this, there were apparently two reasons. The first was that many of the troops facing the Third U. S. Army were seasoned veterans of the previous campaigns on the Eastern Front. German troops had suffered severely from cold injury during the winter of 1941–42, and they had learned their lessons well. The second reason was that German soldiers in late 1944 lacked the mechanized transport (and the freedom to use it when it was available) which characterized the Allied armies. They were, therefore, necessarily inured to long marches on foot and were physically prepared to withstand cold injury.

Up to 15 December 1944, the number of cases of cold injury observed in all German troops was apparently limited. Thereafter, the numbers were larger. Most German noncommissioned officers reported seeing only occasional cases, but a few reported that up to 10 percent of the strength of their units, or more, had been affected in varying degrees. A corporal who had been captured on 14 January 1945 and who had been with a paratroop regiment in the field since 1 January, reported that all 34 men in his platoon suffered from frozen feet, as the Germans called trenchfoot. A battalion surgeon captured on 13

[67] See footnote 20, p. 141.

January by the Third U. S. Army had seen no trenchfoot in his unit before 1 November 1944; since that time, about 2 percent of the men had contracted it. In the infirmary in the prisoner-of-war enclosure, 150 German soldiers had to be hospitalized because of severe trenchfoot and frostbite; gangrene was sometimes present when they were captured. Lack of bed space did not permit hospitalization of prisoners with milder cold injuries.

A United States medical officer in charge of the dispensary in another prisoner-of-war enclosure in the First U. S. Army area said that, between 4 January and 11 January 1945, 5,061 prisoners had passed through this cage; of the 437 who reported on sick call, at least half were treated for trenchfoot or frozen feet. Of the 44 who were hospitalized for this cause, 21 had serious injuries. Thirty of the 76 prisoners hospitalized between 11 January and 17 January also had cold injuries.

Colonel Cleveland noted in his official diary for the week ending 21 February 1945 that, in a tour of 11 hospitals, he had observed about a thousand German prisoners with frostbite, about a third of it serious because of gangrene of the toes, the forepart of the foot, or the entire foot. He thought that practically all of these men would eventually require amputation of some portion of the foot.

At the 196th General Hospital, Colonel Cleveland saw 127 prisoners, about 20 percent of the prisoner-of-war admissions, with frostbite of various degrees. At the 180th General Hospital, there were 100 cases, many severe, among 622 German prisoners. At least one man was likely to lose the whole foot. At the 168th General Hospital, which was serving as the parent organization of a large prisoner-of-war hospital to be staffed by prisoner-of-war personnel, admissions for cold injury totaled 665; 222 cases were mild, 167 moderately severe, and 276 severe. It was believed that several of the patients in this hospital would probably require amputation of the entire foot.

At the 189th General Hospital, there were 146 cases of cold injury on the medical service, 76 mild and the remainder moderately severe. On the surgical service, 16 prisoners had mild cold injuries, 63 moderately severe injuries with superficial gangrene, and 120 severe injuries, with deep gangrene of the toes or of a portion of the foot. Twenty-seven amputations had already been performed, 6 of the forepart of the foot and 13 of the entire foot.

In all of the other hospitals mentioned, Colonel Cleveland observed German prisoners with cold injuries who had already undergone amputation in forward hospitals. The general practice in the fixed hospitals was to delay amputation until mummification had occurred unless infection required it more promptly, as it did in many instances. At this time (February 1945), it was thought that the frequency of moist gangrene was increasing in prisoners of war.

The prisoners themselves stated that cold injuries had been far more prevalent in the winter of 1943–44 than they were during the winter of 1944–45. Some men who had fought on the Russian front in previous winters had already had one or more of their toes amputated.

The German medical officers, as well as the United States Medical Corps

officers who interrogated them, commented on the greater susceptibility to cold of men who had suffered previous cold injuries. A German officer captured in October 1944 thought that cold injury was less likely to occur in younger men, who were well fed. A United States medical officer thought that, on the contrary, it was more likely to occur in younger men because they had not learned to take care of their feet. Some German medical officers emphasized the factor of poor circulation. One regarded the constitutional makeup of the parasympathetic and sympathetic system as a possible predisposing factor. One thought that men who were pale and who tired quickly were more likely to suffer from cold injury. He also thought that heavy smokers were more susceptible.

Interrogation of German medical officers and corpsmen produced fairly consistent statements concerning equipment and discipline. It was apparently not the practice to issue special equipment before the onset of cold weather, though some men reported receiving extra socks, shoes two sizes larger than those worn during the summer, and rags for their feet. A few said that they had received chemical pocket heaters.

German clothing was, on the whole, very good. Every captured prisoner wore an overcoat. The German field boot (fig. 33), which had years of development behind it, seemed a very satisfactory item. It was made of excellent quality cowhide and was loosely fitted, without lacings. It extended to just above the calf (just below the head of the fibula). It had no pressure points.

U. S. Army photo

FIGURE 33.—Winter footgear used by German troops captured during fighting in Ardennes.

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The leather was thoroughly impregnated with a waxy substance, applied after the use of oil, and was practically water resistant. This was partly because one of the first duties of a German recruit was to spend an hour or more daily in rubbing and polishing his boots. Few of the soldiers had overshoes, but with this type of boot they did not need them.

German socks were of heavy wool. Men who did not wear two pairs were given flannel or other cloths which they wrapped around their feet outside of their socks. The socks were loosely fitted, sometimes so loosely that the toe could be doubled back under the foot.

The preventive program practiced by German troops was similar to that employed in the United States Army, except for the great emphasis placed upon the daily application of salve to the feet. Presumably, the massage implicit in the application was responsible for the apparent good results. Men who had received basic training in the care of the feet stated that the routine was to keep the feet clean, with warm water followed by cold water; to use foot powder regularly; to cut the nails square; to exercise the feet as much as possible; to remove the shoes and rub salve into the feet whenever possible; to take care of calluses; to rub shoe cream into the shoes every day; to carry a pair of dry socks in the pocket; and to dry wet socks inside the shirt.

Men who had received special, additional instructions against cold said that they had been advised to wear American overshoes; to wrap the feet in blankets if the night had to be spent in the open; to select dry foxholes, or to fill wet foxholes with straw or wood, so that it would not be necessary to stand directly in water or mud; to put straw in the shoes, or to wrap paper around the feet inside the shoes; and never to let the metal part of the shoe touch the foot. Men who had served on the Russian front were well aware of the importance of these precautions.

The majority of the prisoners stated that no provisions had been made during the extremely cold, wet weather for issuing dry socks or for rotating personnel to places where heat was available and their clothes could be dried while they rested. Smoking was restricted during cold weather because of its depressant effect on the temperature of the extremities. Alcohol was advocated for its vasodilating effect.

No single person in a unit was responsible for foot discipline. It was only occasionally reported that medical corpsmen examined the soldiers' feet and made suggestions for their care. There was no evidence of any sort of control organization. The individual soldier understood, however, that he was responsible for the condition of his feet and that he must report any trouble with them to the corpsman at once. The soldier who contracted trenchfoot was not punished unless it could be proved that he had deliberately exposed himself, to escape service. Then punishment was severe; a court-martial could mete out prison sentences of 2 or 3 years, or, occasionally, a death sentence. A document, taken from a German prisoner during interrogation and dated 28 December 1944, confirmed these statements. It had been prepared by a battalion

medical officer, to be read to all members of the unit. Note was taken of two cases of frostbite, the occurrence of which made it necessary to remind the personnel that anyone suffering from this condition could be charged with self-mutilation, an offense subject to court-martial and punishable with imprisonment or the death sentence.

Russian Armies

Russian armies did no fighting on the Western Front at any time during World War II, and their experiences are therefore not comparable to United States Army experiences. Their armies have always operated in regions of extreme cold, and they have long known how to combat these conditions. Furthermore, since the Russian Army is a conscript army, with long and intensive training, they are acclimatized and are trained for combat in cold weather.

Russian clothing during World War II was loose, warm, and efficient. Russian soldiers usually wore fur gloves. Their footgear was usually a very loose-fitting felt boot (the valenki) without a heel and with a single seam. Each man had a pair of felt boots and another pair of leather boots, which were also very soft and pliable and which were to be worn while the felt boots were drying. Both felt and leather boots were free from constriction at any point.

Soviet troops did not wear socks. Instead, they were supplied with linen or woolen cloths, 36 centimeters long and from 16 to 20 centimeters wide, which they wrapped around their feet in a prescribed fashion. When this bandage was properly applied, it was without seams or wrinkles. Each man had 2 or 3 of these cloths; boots were issued in only 3 sizes, and differences in sizing were compensated for by differences in the thickness of the wrappings. If the bandage became wet, it was removed and reversed, the dry portion originally about the leg now being used for the foot. Newspapers were sometimes wrapped around the feet to furnish additional insulation.

The platoon commander routinely inspected the feet at the end of each march. The soldier was not permitted to go to sleep until his feet and footgear had been inspected. In effect, this meant that, unless the combat situation absolutely prevented it, the boots were taken off daily, the wrappings around the feet were reversed, and the feet were dried and rubbed.

The chief reason why the incidence of cold injury was so low in Soviet troops was that it was regarded as a preventable condition, the responsibility for which lay with the individual soldier, the small-unit commander, and the medical officer. The soldier was held accountable for the occurrence of disability, and punishment was meted out according to the neglect presumed to have caused the injury. In severe cases, the offense was looked upon as sabotage, since it deprived the army of man-hours which should have been spent on essential duties, including combat duty.

STATEMENT BY THE GENERAL BOARD

The definitive statement on trenchfoot in the European Theater of Operations is contained in the report of the General Board, United States Forces, European theater, [68] set up by General Orders No. 128, issued on 17 June 1945, to prepare a factual analysis of the strategy, tactics, and administration employed by the United States Armed Forces in this theater.[69] The following points were covered:

1. Between October 1944 and April 1945, 46,107 cases of cold injuries of all types required hospitalization. This loss of manpower amounted to more than three combat divisions and comprised 9.25 percent of the total hospital admissions for all causes during the entire campaign in western Europe.

2. The causes of cold injury were listed as wet and cold, immobility, lack of shelter, lack of regular warm food and drink, and wet footgear. Contributory factors were listed as impaired peripheral circulation caused by inactivity and constriction, general body cooling from inadequate clothing and exposure to the elements, and lowering of the metabolic rate due to fatigue and lack of warm food and drink.

3. The pathologic process was described.

4. The practical considerations and administrative difficulties of the award of the Purple Heart were discussed (p. 189).

5. The specific causes of trenchfoot in the European theater included extended supply lines and inadequate stocks of proper types of winter clothing and footgear, combined with the onset of wet, cold weather; the footgear worn by the troops, which was unsatisfactory in many respects and which was not waterproof or water resistant; the lack of galoshes for a large proportion of the troops when protection for the feet was most needed; the lack of shoepacs when they were most needed; the lack of proper socks in adequate supply.

6. Operational conditions were regarded as second in importance to inadequacy of clothing and footgear. Weather and terrain were also listed as possible etiologic factors. Infantrymen had been particularly affected, but cold injury had also occurred in reinforcements packed into trucks and railroad cars going forward to combat areas and in military police who had stood for long periods at traffic intersections.

7. A program of prevention had been employed, beginning with the issuance of Circular No. 312 on 22 July 1944 and the measures of education and prevention which followed. At the onset of the outbreak of cold injury, many men had only a vague idea of its possible seriousness, and practical

[68] This study was prepared by Col. L. Holmes Ginn, Jr., MC, Chief, Medical Section, Chairman; Lt. Col. Edward J. Whiteley, MC, Deputy Chairman; and Col. W. E. Wilkinson, MC. The principal consultants were Col. Horace McP. Woodward, Jr., Commanding Officer, Field Forces Port Detachment; Col. Samuel G. Conley, Commanding Officer, 274th Infantry Regiment, 70 Infantry Division; Lt. Col. John I. Ladd, Assistant G-1, Headquarters, 12th Army Group, and Maj. George T. Aitken, medical member of the trenchfoot control team, Headquarters, Fifteenth U. S. Army.

[69] See footnote 28 (1), p. 151.

methods of preventing it were not understood. After the epidemic had reached serious proportions, a more intensive program was instituted. The various phases of this program included indoctrination, command responsibility, provision of clothing and footgear suitable for intensely cold, wet weather, sock exchange, rotation individually and by units, and the establishment of trenchfoot control teams.

8. The European experience showed that an effective program to combat and control cold injury must be instituted in the War Department and must be based on the premises that a soldier must be provided with clothing and footgear suitable for fighting in cold, wet weather; must be given regular warm meals and hot drinks; and must have opportunities provided to warm and dry himself at least once daily. Supplies must be available when they are needed. Commanders in all echelons must be aware of the seriousness of cold injury and must take the necessary steps to insure the timely application of appropriate preventive measures. Unit surgeons must be thoroughly trained in triage and treatment. Indoctrination and training in preventive measures must be instituted in the Zone of Interior.

There was no doubt of the effectiveness of the control program that was finally instituted, even though the results could not be completely evaluated because the weather moderated just as the program became fully operative. Units which had employed vigorous preventive programs before the institution of the general program had consistently lower rates than units which had not instituted such programs, even when conditions were unfavorable.

9. The incidence of cold injuries in French, British, German, and Russian Armies was summarized.

10. It was recommended that a more effective combat boot be developed; that more adequate socks be developed and that they be provided in sufficient numbers; that the award of the Purple Heart be reviewed and a more consistent policy be developed; and that officers of the Medical Corps be given the same training in trenchfoot as they received in burns.

11. It was concluded by the General Board (1) that cold injury is largely preventable; and (2) that the relatively high incidence of cold injury in the European theater (9.25 percent of all casualties) was the result of inadequacy of clothing and footgear suitable for winter operations, unfavorable operational conditions, and the delay of many units in instituting a program with emphasis on, and close supervision of, measures that must be taken by the individual soldier to protect himself.

THE CALCULATED RISK

A thoughtful reader of this chapter on cold injury in the European Theater of Operations in World War II cannot fail to emerge from it with a number of impressions, such as the following:

1. There was a very heavy loss of manpower from this cause.

2. The losses chiefly affected the most critically needed of all troops, the combat infantrymen, at the very time in the fighting when their services were most necessary and reinforcements were in shortest supply.

3. The fundamental cause of the epidemics of cold injury was, of course, the wet, cold weather, which could not be altered and which had to be endured.

4. Combat was heavy and could not be postponed or altered.

5. The terrain over which the fighting occurred also could not be altered.

Against this array of facts must be set a number of other factors, including human factors, which could have been controlled and the control of which would have materially modified the factors which could not be altered per se:

1. Clothing was inadequate and improperly selected.

2. Footgear was inadequate and improperly selected.

3. Troops had not been trained to care for their feet and to protect themselves against cold, wet weather.

4. Planning for all of these contingencies came too late.

5. An effective program was finally put into operation, but when it became fully operative losses from trenchfoot had begun to decline and within a matter of weeks had become insignificant.

Unquestionably, one of the reasons for failure to prepare more adequately for the prevention of cold injury in the European theater was the expectation, at least in certain high quarters, that Germany would fall before winter fighting became necessary. This belief developed after the breakthrough in Normandy in July 1944, and it continued for a number of weeks thereafter, during the rapid advance of the First and Third U. S. Armies across France. This belief proved entirely erroneous. What happened with respect to cold injury was therefore, at least in part, the unhappy result of a calculated risk.

General Bradley wrote after the war: [70]

> When the rains first came in November with a blast of wintry cold, our troops were ill-prepared for winter-time campaigning. This was traceable in part to the September crisis in supply for, during our race to the Rhine, I had deliberately by-passed shipments of winter clothing in favor of ammunition and gasoline. As a consequence, we now found ourselves caught short, particularly in bad-weather footgear. We had gambled in our choice and now were paying for the bad guess.

[70] Bradley, Omar N.: A Soldier's Story. New York: Henry Holt and Co., 1951.

U. S. Army photo

FIGURE 34.—Tropical environment favorable to numerous skin diseases, including disability of the feet. A. Infantrymen from 7th Infantry Division wading across Maraby River, Leyte, October 1944. It was this sort of exposure in a tropical climate which produced so-called tropical immersion foot. B. Infantrymen of 43d Infantry Division moving along muddy road on Luzon, May 1945.

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CHAPTER VIII

The Pacific

Part I. Cold Injury in the Tropics

Although trenchfoot was recognized as one of the probable risks of combat in the Pacific in World War II, this condition, as it is ordinarily envisaged, did not occur among United States troops in these areas. The war ended before fighting was necessary under circumstances which would produce the classical type of wet-cold injury. However, in addition to the numerous skin diseases, including diseases of the feet, which developed in a tropical environment highly favorable for them, there was a brief experience in the Philippine Islands, chiefly on Leyte, with a disability of the feet caused by long exposure to wet terrain under combat conditions (fig. 34). This disability, for lack of a better term, was originally described as tropical immersion foot.[1] It can more logically be described as a type of cold injury low on the gradient (p. 20).

Lack of complete information on all details of this experience makes it somewhat difficult to analyze it. Precise climatic records are not available for October, November, and December 1944, the period in which the disability appeared. Records for the preceding 2 years showed that during these months temperatures on Leyte had ranged from 74° to 88° F. (23.3° to 31.1° C.). It is not known whether they were lower than this in the fall of 1944, especially at night. Furthermore, it is still not known at what temperature level cold injury can occur when it is associated with long exposure, fatigue, insufficient food, and combat stress.

Information about rainfall in the fall of 1944 is somewhat more adequate. During the preceding 3 years, it had ranged between 8.5 and 14.2 inches per month in three areas on Leyte (Tacloban, Palo, and Dulag) during the period in question. Weather records showed that, as a rule, rain fell on 20 days per month during the October–January period, against 10 days per month during the remainder of the year. Readings available for 1944 show a rainfall greatly in excess of what might have been expected in the light of these data. Engineers, who worked around the clock, recorded that 69 percent of the time lost on construction between 11 November and 18 November 1944 was caused by heavy rains, against only 11 percent lost because of air raids. Between 19 November and 2 December, the measured rainfall in three separate areas on

[1] (1) Letter, Maj. Frank Glenn, MC, Surgical Consultant, Office of the Surgeon, Headquarters, Sixth U. S. Army, to the Surgeon, Sixth U. S. Army, 27 Nov. 1944, subject: Trench Foot. (2) Letter, Brig. Gen. J. I. Martin, Chief Surgeon, United States Army Forces, Western Pacific, to Director, Army Institute of Pathology, 19 Oct. 1945, subject: Immersion Foot.

Leyte (Tacloban, Palo, and Dulag) varied between 11.08 and 14.8 inches. Between 10 December and 14 December, 16.62 inches was recorded at Buwi Drome; 7.6 inches fell in a single day. There seems no doubt, therefore, in spite of the lack of complete information, that constant wetness played a decided role in the intensification of heat loss, especially through the feet, in this experience.

From the time that fighting began in the jungles of New Guinea in the summer of 1942, large numbers of soldiers suffered from excoriations of the feet and from some degree of infection, which was often superimposed on a previous epidermophytosis. These lesions were, however, quite distinct from the variety of cold injury observed during the Leyte campaign (a total of 167 cases), and observed later, in scattered cases (55 in all), on the Visayan Islands during the first 6 months of 1945. The second outbreak was much milder than the first.

The incidence of this type of cold injury was comparatively low. Prompt recovery occurred in all but a few of the most severe cases when once the men were able to stay clean and dry. There was no similar experience on Luzon, because the dry season had commenced when combat operations were undertaken there (p. 221).

CLINICAL ASPECTS

On 23 November 1944, two evacuation hospitals on Leyte received some 120 soldiers with swollen, painful feet, all of which had been injured under the same circumstances. These men had been in combat on the frontline for periods ranging from 9 to 17 days. During this time, rains and typhoons had been almost continuous. Combat troops lived in foxholes or crawled through the jungles. Many were completely isolated. They had no dry socks or footwear, and there would have been no opportunities to change them if they had been provided with them.

Maj. (later Lt. Col.) Frank Glenn, MC, Surgical Consultant, Office of the Surgeon, Headquarters, Sixth U. S. Army, observed and examined these patients within 12 hours after they had been hospitalized. Their stories were all substantially the same, and their physical findings differed only in degree. Most of them reported that, after 4 to 7 days of existence under the conditions described, they began to experience burning sensations in their feet, first on the dorsum, later on the soles and over the toes. Movement at first gave some relief. Later, walking was progressively more painful. When rescue finally came, the men had to be carried by litter through swamps and over difficult terrain, which they all agreed they could not possibly have traversed by themselves. In some units, as much as 50 percent of the personnel was affected.

When they first removed their shoes, the men said, their feet appeared pale and swollen. Shortly afterward, the skin of the feet became flushed and warm. The burning sensations increased, and tingling and pain were soon experienced. Elevation of the feet gave some relief. Within 30 minutes after

the shoes had been removed, it was impossible to replace them because the feet were so intensely swollen. Some soldiers volunteered the information that these symptoms and signs did not appear until after it became impractical to remove the shoes every night. When the tactical situation prevented this, the disability described quickly followed.

At first, the feet were not ulcerated and there was no loss of skin. As time passed, however, pain and swelling increased, and ulcerations appeared, first on the dorsum, and then about the toes. Cracks on the soles were frequent, but ulceration in this area was uncommon.

When the men were first observed in the evacuation hospitals, it was striking to note that, although all of them were obviously fatigued, only an occasional patient seemed to be resting. Some sat with their feet elevated. Some let them dangle over the edge of the cot. Some clasped their ankles and lower legs. Most of them changed position frequently. Those who attempted to stand seemed helpless and distressed and were obviously in pain. When they walked, they moved with "hesitant deliberation," putting the weight of the body on the feet only after the feet were put down, like "a cat walking on flypaper." The most frequent complaint was a burning sensation, associated with "deep" aching of the dorsum and sole of the foot. Neither socks nor dressings could be endured.

Examination of the feet usually revealed a uniform erythema, which was frequently intense. The skin of the dorsum was tense and shining, and the soles were so swollen that they seemed to bulge. Blebs and ulcerations from which weeping serum exuded were often observed at the margins of, and between, the toes. In the most serious cases, there were scattered areas of ecchymosis, and the distal portions of the toes were blue, white, mottled and cold, in contrast to the swollen, erythematous aspect of the other portions of the feet. After the feet had been cleaned and dried, a line of demarcation was usually evident at shoe-top level. Only occasionally did edema extend above this level.

Ulcerating lesions were most numerous on the toes and over the dorsum of the foot. These lesions were blotchy, and their appearance suggested that they had been produced by pressure and abrasions. They varied in degree from patient to patient. Some were only superficial. In others, the destructive process extended down to, or through, the true skin. Some lesions were well demarcated, with a zone of necrotic tissue along the margin, as in decubitus ulcers or a gangrenous process. The skin between the lesions, especially over the dorsum of the foot, was pale, cold and inert. Secondary infection was strikingly infrequent.

Lymphangitis was present in a few cases, in all of which there was a previous history of troublesome epidermophytoses. When the men were directly questioned, about 15 percent admitted to some discomfort in the groin; all of this group were found to have enlarged and sensitive regional lymph nodes. There was no correlation, however, between the presence of lymphadenopathy and the degree of pain and swelling in the feet.

Pressure over the affected areas caused pain. Erythematous areas blanched slowly, and the return flush was delayed. In no instance were pulsations absent, nor in any instance were variations in the pulsations beyond the range of normal. Sensory changes were not clear cut. Areas of numbness and tingling could be demonstrated by light touch and pinprick. Areas of diminished sensation seemed to be increased when the feet were elevated. Attempts to outline areas of paresthesia and anesthesia were not satisfactory, perhaps because the patients were all uncomfortable and fatigued.

Temperature and pulse were invariably within normal range. Fatigue and inability to sleep were the only systemic reactions.

Treatment was based on keeping the patients off their feet as much as was possible in a crowded forward hospital. If the shoes had not already been discarded, they were cut off. Most of the patients had long since discarded them, and no pictorial or other record, unfortunately, was made of the condition of the few pairs available for examination. The feet were washed with cool water and mild soap, which brought only temporary relief; the discomfort returned as soon as the feet were dry. At the most, only light, dry dressings could be endured, and the patients were more comfortable with no dressings at all. Applications of mineral oil were not well tolerated. Lanolin was not tested. General supportive measures were instituted, such as would be employed for men who were extremely tired physically and who had been without food and sleep for long periods of time. Sedatives were given as necessary to insure sleep and rest.

Contrary to the usual course in trenchfoot or immersion foot, recovery in these cases was fairly rapid. Most of the casualties were evacuated by ship to hospitals in Hollandia within 36 hours of their admission to evacuation hospitals on Leyte. When they arrived in Hollandia, most of them were almost entirely free from symptoms and signs of the injury. Pain, swelling, excoriations and vasomotor manifestations had, for the most part, disappeared during the voyage, apparently as the result of rest, and healing was usually complete by the time the men were admitted to general hospitals in New Guinea.

Gangrene did not occur in any of these cases, and no recurrences of sequelae were recorded. The uniform absence of thrombosis and gangrene was believed due to the relatively high temperatures in which the injuries occurred.

The additional cases of cold injury which occurred on Leyte in December 1944 and which brought the total number on that island up to 167 were similar in all respects to those already described. The 55 cases which occurred in the Visayan Islands, most of them in January and February 1945, were considerably milder but were otherwise similar to those which occurred on Leyte.

It should be noted how closely the symptoms and signs of the variety of cold injury observed in the Philippine Islands resembled those of cold injury as it was observed in both the Mediterranean and the European Theaters of Operations, where the classical type of trenchfoot occurred. On Leyte, the degree of injury appeared, at least superficially, to be mild, but all of the men affected required hospitalization. They could not walk, let alone put on their

shoes, and they could not sleep because of discomfort. The most important difference between the cold injuries in the Pacific and those in other areas was that in the Pacific, in contrast to the course of events in both the Mediterranean and the European theaters, virtually all of the men affected could be returned to duty after being hospitalized, and there were no recorded recurrences. In other theaters, a large proportion of the trenchfoot casualties were lost permanently to combat duty, and there was a high percentage of recurrence in the soldiers returned to full and limited duty (p. 327).

The Surgical Consultants Division, Office of the Surgeon General, in commenting on 8 February 1945 on the report of this experience in Essential Technical Medical Data, United States Army Forces, Far East, dated 23 December 1944, took occasion to point out the gravity of the United States experience with trenchfoot in Europe in the winter of 1944–45 and recommended that any additional information on this extremely important medicomilitary subject be compiled.

Part II. The Wet-Cold Program

The actual experience with cold injury in the Pacific was limited to the type just described. There was general realization, however, that the invasion of the Japanese islands, which was planned for the fall of 1945, would again require combat operations in a cold-wet environment, and at temperatures which had produced the classical type of trenchfoot in the Aleutian Islands and in the Mediterranean and European theaters. By the time that planning for the invasion of Japan was undertaken, the lessons inherent in the serious losses from cold injury which had occurred in other theaters had already been well learned. Moreover, the successful prevention and control programs which had eventually been formulated and implemented in Italy and in Europe had shown that such losses were in large part neither necessary nor inevitable.

It was therefore taken into consideration early in the planning for the invasion of Japan that if similar misfortunes were to be avoided the fullest advantage must be taken of the knowledge which had been gained in the Mediterranean and European theaters. A considerable part of the losses from cold injury in the Mediterranean theater could be explained by the fact that the experience gained in the Aleutians had not been transferred to it. A considerable part of the losses from this cause in the European theater could be explained by the fact that the experience gained in Italy had not been transferred to it. Those errors were not repeated in the Pacific theaters. The wet-cold program there was planned against the background of what had been learned in other theaters. The program of prevention and control was worked out with the joint cooperation of the Office of the Surgeon General, the Office of the Quartermaster General, and the various levels of command in the Pacific. The war, fortunately, ended before it was necessary to test the program in combat, and the story of wet-cold injury is therefore a story of planning and

prevention and not, as in other theaters, a story of the actual occurrence of trenchfoot. The planning was thorough and precise, and there is every reason to believe that the program would have been highly effective, and that losses from cold injury would have been reduced to an irreducible minimum, had it been necessary to put it into operation.

As a matter of convenience, and to simplify the account, the programs of planning for the prevention and control of cold injuries are described under a number of separate headings, without any attempt at the integration which was in progress when the war ended.

OFFICE OF THE SURGEON GENERAL

The first formal recognition by the Office of the Surgeon General of the possibility of cold injury in the Pacific appeared in an article prepared in that office and published in the February 1945 issue of *Health*.[2] In it a number of facts about future fighting in the Pacific were emphasized:

1. Warfare in this area would extend northward during the fall and winter months, and a range of temperature particularly favorable to the occurrence of cold injury would therefore be encountered.

2. The terrain of the lowlands, where most of the fighting in Japan would probably take place, was also favorable to the development of cold injury, since drainage was poor and the numerous rice paddies made much of the ground little more than swampland.

3. The same general conditions would also be encountered if fighting should be necessary in the northern provinces of China.

4. Trenchfoot would not occur in the mountainous regions of Japan and the north Asian mainland, where dry cold rather than wet cold would be encountered, but frostbite was a possibility seriously to be considered in these areas.

5. Attention was directed to the recorded experiences with cold injury among Japanese troops during the Russo-Japanese War.

For the next several months, the Preventive Medicine Division and the Surgical Consultants Division, Office of the Surgeon General, continued, in various ways, to emphasize the potential dangers of cold injury in the Pacific theaters and the necessity for the prompt institution of preventive measures. Among the specific actions taken were the following:

On 12 February 1945, Brig. Gen. Stanhope Bayne-Jones, acting chief of the Preventive Medicine Service, initiated the preparation of a communication for the signature of The Surgeon General, to be sent to the commanding general of the Army Service Forces. This communication was sent to General Somervell, in the form of a memorandum, through the Quartermaster General on 24 March 1945.

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[2] Monthly Progress Report, Army Service Forces, War Department, 28 Feb. 1945, Section 7: Health.

This memorandum, to which was attached a copy of the article on cold injury which had appeared in the February 1945 issue of *Health*, contained meteorologic data to support the strong probability that cold injury would be encountered in Japan. It recommended the use of the shoepac (12-inch height), with two pair of wool ski socks, as well as the use of other modern cold weather protective garments and equipment developed by the Quartermaster General. The memorandum also recommended that all troops taking part in operations in cold climates receive training in foot hygiene, in accordance with Section IV, War Department Circular No. 312, and War Department Technical Bulletin (TB MED) 81.

On April 7, a memorandum prepared by Maj. Gen. (later Lt. Gen.) LeRoy Lutes, Acting Chief of Staff, Army Service Forces, was sent to the director of Plans and Operations, Army Service Forces, directing that the Planning Division initiate a study on trenchfoot immediately. This study was to include all available data on incidence, causes, preventive measures, and similar matters. As soon as the study was completed, it was to be sent to the commanding general of the United States Army Forces in the Pacific, with a covering letter to be prepared for the signature of the Chief of Staff. The memorandum concluded: "It is General Somervell's belief that the language of this letter should be so couched that General MacArthur would understand that there should be no excuse for trench foot developing in the Far East due to the ample warning given to him on this subject."

On April 11, a memorandum containing the material to be included in the proposed letter to General MacArthur was sent by General Kirk to General Somervell, for the attention of the director of Plans and Operations, Army Service Forces. In this memorandum, the unfortunate experience of the United States Army in the Mediterranean and European theaters was recounted, and it was emphasized that it was urgently necessary to institute a prompt and energetic program of prevention for the United States Army troops in the Pacific. It was also pointed out that the far better record of the British Army in respect to cold injury in both the Mediterranean and the European Theaters of Operations seemed to be the result of the far more effective measures of prevention employed in this army.

On 27 April, a communication from the War Department on the subject of trenchfoot was addressed to General MacArthur.[3] It contained the following information:

1. Large numbers of troops had been incapacitated by trenchfoot during the winter campaigns in the Mediterranean and European theaters.

2. The majority of these losses could have been avoided if troops had been properly indoctrinated concerning the cause and effect of cold injuries and the measures necessary to prevent them.

3. The Pacific fighting was about to advance into areas in which conditions conducive to trenchfoot would exist during certain seasons of the year.

[3] Letter, The Adjutant General, War Department, to Commander in Chief, United States Army Forces in the Pacific, 27 Apr. 1945, subject: Trench Foot.

4. The disastrous losses suffered in other theaters need not be duplicated in the Pacific if the risks of the situation were recognized and the necessary preventive measures taken.

Since the role of the Medical Department in the prevention of cold injury is entirely advisory, it was specifically stated in this communication that the control of trenchfoot "is primarily a command problem that can only be solved by proper indoctrination of troops prior to entering the combat zone and continuous follow-up supervision backed up by a strict disciplinary policy during the period in which the troops are exposed to the condition. Troops must be made trenchfoot conscious."

Enclosed with this letter was a résumé of all available information on trenchfoot secured in the study made in the Office of the Surgeon General on General Lutes' instructions (p. 218). A graphic training aid (8–16) was also enclosed. The letter noted that Film Bulletin No. 180, a training film on trenchfoot (p. 223), had already been sent to the commanders of the Pacific Ocean Areas and Southwest Pacific Area.[4]

This letter was received at General Headquarters, SWPA (Southwest Pacific Area), on 8 May 1945 and was forwarded for necessary action to the Commanding General, USASOS, SWPA (United States Army, Services of Supply, Southwest Pacific Area), on 12 May 1945. It was received on 15 May 1945.

On 30 June 1945, a memorandum addressed by General Rankin to The Surgeon General again stressed the seriousness of cold injury and the importance of its prevention. It was suggested that the programs conceived and in process of execution for the prevention of cold injuries in the Pacific should be critically reviewed by all divisions in the Surgeon General's Office, so that past experiences could be utilized to the fullest advantage in future planning.

A conference for the purposes suggested in this memorandum was held on 9 July 1945 under the chairmanship of General Bayne-Jones. The clothing and equipment then in production and planning for troops in the Pacific were fully discussed, and it was noted that representatives from the Office of the Quartermaster General were already in the Pacific theaters giving instruction in the wearing and use of the winter outfit, including shoepacs (p. 226). The training of troops in foot discipline was discussed, and plans were made for the full utilization of such aids as films, film strips, graphic portfolios, posters, manuals, and pamphlets which would call the attention of the soldiers to their individual responsibility for the care of their own feet.

Efforts had been begun on 14 June 1945, by the Preventive Medicine Division, Office of the Surgeon General, to obtain the release from the European theater of certain medical officers who were thoroughly experienced in cold injury, so that they could be assigned to the Southwest Pacific for supervision

[4] The consolidation of the United States Army Forces in the Pacific under General MacArthur was occurring just as the planning for the prevention of cold injury in that area was getting under way. His appointment, in fact, was made after a team from the Office of the Quartermaster General had already begun to operate in the Pacific Ocean Area. A second team from this office was latter assigned to General MacArthur's headquarters (p. 228).

of the program of prevention to be instituted in that area. The first request, which was sent formally on 19 June, was refused by the theater on 23 June. In retrospect, it was thought that the reason for the refusal was that the radiogram requesting the release was weakly worded and provided no explanation of the urgency of the need for these officers for this assignment. A second, more strongly worded radiogram to the European theater was drafted on 24 June and sent on 9 July. When no reply to it had been received by 19 July, a tracer radiogram was sent. The consent to the transfer of these officers was finally received on 23 July.

The original request had been for the release of Lt. Col. (later Col.) Richard P. Mason, MC, and Maj. William L. Hawley, MC, both of whom had had considerable experience in the European theater. Later, Colonel Gordon's release was requested. On their arrival in the Zone of Interior, these officers were temporarily assigned to the Office of the Surgeon General and participated in the conference on medical matters in the Pacific held 30 July–1 August 1945.

On 4 July 1945, General Kirk wrote personally to Brig. Gen. (later Maj. Gen.) Guy B. Denit, the Surgeon, AFPAC (United States Army Forces, Pacific), to inform him of the expectation that the officers whose release from the European theater had been requested would be sent to the Pacific to aid in the setting up of the cold injury prevention program. It was hoped, General Kirk wrote, that General MacArthur would see these officers himself, to secure firsthand information of the seriousness of the experience in the European theater. The activities of the teams from the Office of the Quartermaster General, which were already in the Pacific, were discussed, and all the material then available on trenchfoot was enclosed. The letter ended with another reminder of the seriousness of the problem in the European theater and with the statement that it would be equally serious in the Pacific if preventive measures were not taken. Trenchfoot, it was pointed out again, is an essentially preventable military hazard.

A similar letter to General MacArthur was prepared in the Office of the Surgeon General, for the signature of the Chief of Staff, but does not seem to have been dispatched.

MEDICAL PLANNING IN THE PACIFIC

The first published mention of cold injury in the Pacific theaters took the form of a memorandum (Technical Memorandum No. 10) issued from the Office of the Surgeon, USASOS, SWPA, on 9 July 1943. This memorandum, which was entitled "Immersion Foot," was obviously prepared with shipwrecked persons in mind. The causes of the injury, the clinical picture, and the management were discussed. Preventive measures were listed as removal of constricting footgear, which would be of no use for warmth if the feet were in water; exercise of the feet and legs, to maintain vascular and muscular tone;

and the application, when possible, of a thick coating of grease. The affected parts were not to be rubbed, and heat was not to be applied to them.

The problem of wet-cold injury did not arise in the hot jungles of New Guinea, New Britain, the Admiralty Islands, and the Schouten Islands, where all the fighting occurred in this area before the invasion of Leyte in September 1944. The outbreak of a form of cold injury which occurred in Leyte has already been described (p. 211). Col. I. Ridgeway Trimble, MC, Consultant in Surgery, Office of the Surgeon, USASOS, SWPA, who was familiar with the losses from trenchfoot in the Aleutians and in the Mediterranean theater, reacted to this outbreak in two ways:

1. He wrote Major Glenn on 8 December 1944, suggesting that the men with these injuries be considered for sympathetic block. When this suggestion reached Major Glenn, the patients had already recovered.

2. Colonel Trimble also prepared a technical memorandum on the subject of trenchfoot, based on War Department Circular No. 312, to be issued by Headquarters, USASOS. This memorandum, which was not issued, recognized that the disability sustained by a number of troops on Leyte, although it had occurred in the Tropics, was actually a form of cold injury or trenchfoot. With proper preventive measures, the number of men disabled from this type of trauma could be held to a minimum. It might not be possible, the memorandum continued, to carry out, during the exigencies of jungle warfare, all the preventive measures recommended, but every effort should be made to follow the directions outlined. Particular emphasis was placed on the provision of extra dry socks for each man.

With the concurrence of General Denit, Colonel Trimble also discussed with the Surgeon, Sixth U. S. Army, Brig. Gen. William A. Hagins, the indoctrination of troops in the prevention of wet-cold injuries, in view of the impending fighting on Luzon.[5] In General Hagins' opinion, which events proved to be correct, this was an unnecessary precaution at this time, since conditions on Luzon during the rainy season would not be comparable to those encountered on Leyte.

Between 30 April and 16 July 1945, Colonel Trimble, on General Denit's instructions, prepared a number of memoranda and drafts and revisions of circular letters on the subject of cold injury. They were chiefly exploratory and preparatory and were designed to keep the Office of the Theater Surgeon informed on this matter, and to have all the necessary material in readiness when the time came to issue circular letters and technical memoranda. In these various drafts the following points were made:

1. Trenchfoot could be expected to become a problem of great seriousness as fighting developed in colder climates.

2. In spite of the experience in the Aleutians in 1943 and in Italy in 1943–44, some American units went into combat in Europe without proper footgear. As a consequence, they suffered seriously from cold injury.

[5] Check Sheet, Surgical Consultant, Headquarters, United States Army Forces, Western Pacific, to the Chief Surgeon, 16 July 1945, subject: Trench Foot, Summary of Program to Date.

3. The rate of cold injury under similar circumstances varied from unit to unit, depending upon the efficiency of commanding officers in enforcing preventive measures.

4. British and Russian troops, who had better winter footgear than United States troops and who had been better schooled in foot hygiene, had almost no trenchfoot.

5. Strenuous measures must be taken in the Pacific to avoid a repetition of the previous United States Army experience, most of which was preventable.

6. Appropriate memoranda should be published at once, through technical and command channels, concerning these preventive measures, which were a command and not a medical responsibility.

7. It was urgent that requisitions be placed at once with the Office of the theater chief quartermaster for sufficient supplies of shoepacs, wool socks, and other winter equipment. In the memorandum dated 8 May 1945, it was noted that these supplies were already on order and that teams trained to give instruction in the proper use of the new winter clothing would arrive in the Southwest Pacific Area in August.

Colonel Trimble, with General Denit's concurrence, also held conferences with a representative of the theater chief quartermaster concerning the protection of ground troops in cold, wet weather. Originally, the use of white clothing for camouflage had not been contemplated, but, after Colonel Trimble had raised the question, his suggestion was approved and 10,000 suits, enough for two regimental combat teams, were put on order.

The new items of clothing and footgear were demonstrated for Colonel Trimble who wrote in a memorandum to General Denit on 16 July 1945: "The temperature then in Manila was 105° F. in the shade. It was rather painful to observe the demonstrating soldier put on in layers a pair of 'long johns,' a wool shirt, two pairs of wet resistant pants, two pairs of wool ski socks, an Eisenhower jacket, an M–1943 jacket, a cap with ear muffs, and a high shoepac."

On 27 June, Colonel Trimble submitted a recommendation to General Denit that all United States Army officers and enlisted men of ground combat elements be given a special foot examination by their unit medical officers, to determine the status of the two main arteries of the foot.[6] Men in whom the pulsations in these arteries were absent would have further examinations, including roentgenologic studies, to detect or exclude insufficient circulation due to arteriosclerosis and other causes. The rationale of this recommendation was the peculiar susceptibility of this (small) group of soldiers to cold, and the possibility that they would contract trenchfoot under conditions in which those with normal circulation would suffer no disability whatsoever. This recommendation was approved by General Denit.

On 12 July 1945, General Denit received from General MacArthur's headquarters a letter incorporating the information about cold injury which had been

[6] Check Sheet, Surgical Consultant, United States Army, Western Pacific, to the Chief Surgeon, 27 June 1945, subject: Comments on Indoctrination Program Cold-Wet.

sent to the latter by the War Department on 27 April 1945 (p. 218). On General Denit's instructions, Colonel Trimble prepared a circular letter on the subject, to be issued as a command directive from General MacArthur's headquarters.[7]

Various changes were made in this letter as it passed through various hands. One change was the deletion of the recommendation that all soldiers should have an investigation of the pulsations in the pedal arteries as part of their physical examination. Another was the deletion of a paragraph in which it was stated (1) that the great majority of cold injuries in other theaters could have been avoided if troops had been properly indoctrinated concerning the cause, effect, and prevention of cold injury and (2) that the disability rate in armies subjected to the same climatic conditions varied enormously with the efficiency of their commanding officers.

Had the war continued and had it been necessary to issue technical memoranda and circular letters on the subject of cold injury, their preparation would have been a simple matter, since the material had been thoroughly worked over and was readily available for use. Instruction on the prevention of trenchfoot and the training of troops in foot hygiene was included in the medical planning for the impending OLYMPIC and CORONET operations against Japan, and provision had also been made for shoepacs and other winter footgear.[8]

On 17 July 1945, Col. Charles W. Mayo, MC, who had been placed on temporary duty in the Office of the Chief Surgeon, AFWESPAC (United States Army Forces, Western Pacific), as a special consultant in cold injury, prepared a memorandum for General Denit, in which he made the following suggestions:

1. That a wet-cold indoctrination program, similar to the program already instituted in other parts of the Pacific, should be carried out in the Philippines. The Quartermaster Corps would provide the program on instruction in the use of winter clothing, and there would be a related medical program on the care of the feet.

2. That training film 180 should be made compulsory viewing for all personnel and officers, on the ground that it would probably be the greatest single aid available in persuading troops to carry out the preventive measures advised. It was recommended that it should not be combined with films shown for entertainment, and that there be no comment upon it afterward unless an exceptionally able medical speaker was present, since it was sufficiently informative and impressive in itself.

The war in the Pacific ended before these plans could be put into effect.

Colonel Gordon and Major Hawley, who had been released from the European theater for service in the Pacific (p. 219), arrived in Headquarters, MIDPAC (United States Army Forces, Middle Pacific), on 11 August 1945.[9] They held conferences with the surgeon and members of his staff, representa-

[7] Circular Letter (draft), Office of the Commanding General, AFPAC, 12 July 1945, subject: Trench Foot.

[8] Check Sheet, Surgical Consultant, Office of the Chief Surgeon, Headquarters, United States Army, Western Pacific, to the Chief Surgeon, 24 June 1945, subject: Outline of Studies Being Conducted on Medical Support for Next Operation.

[9] Memorandum, Col. John E. Gordon, MC, Headquarters, MIDPAC, to General Willis, 17 Aug. 1945, subject: Trenchfoot Control.

tives of the quartermaster, a representative of the surgeon of the Central Pacific Base Command, and others, to review the entire wet-cold program and related subjects. One day was spent at Headquarters, 98th Infantry Division. Extended conferences were held with medical officers of the marine forces, the Pacific naval force, and the United States Navy, Pacific. Two general conferences were held with medical units alerted for service in Japan.

At all of these conferences, the principal topic of discussion was the medical aspects of cold injury and the epidemiologic features of its control. It was the opinion of Colonel Gordon and Major Hawley that adequate attention had been given by Headquarters, MIDPAC, to the probability of cold injury in forthcoming military operations, and that sound measures had been taken for its prevention. The excellent training of the 98th Infantry Division furnished proof of these statements.

When Colonel Gordon and Major Hawley reached Manila, they were informed by General Denit that he desired the trenchfoot program to be carried out as planned, but with such modifications as would make it suitable for an army of occupation. The scope of the mission was extended to include considerations of acclimatization. Later, it was decided to defer indoctrination until all troops in the Philippines had been moved to Japan, since the confusion attending their deployment made the institution of a formal program impractical at this time. For various reasons, the medical phase of the program was never instituted, although the instruction of the troops in the use of winter clothing went forward as planned (p. 228).

ACTION BY COMMANDERS IN PACIFIC

The training directive issued on 20 January 1945 from Headquarters, Army Ground Forces (p. 76 and appendix B), was received by General MacArthur's headquarters and was transmitted for informational purposes to the commanding general of USASOS, on 21 March 1945.

On 27 April 1945, a communication from the War Department to General MacArthur (p. 218) pointed out that the prevention of trenchfoot is primarily a command problem and directed that adequate indoctrination of troops be undertaken before they entered combat zones. This communication was transmitted by General MacArthur's headquarters to the commanding general of USASOS, SWPA, on 12 May 1945, for necessary action.

On 18 July 1945, a letter directive from General Headquarters, AFPAC, (appendix H, p. 533), to the various headquarters in the Pacific announced the wet-cold indoctrination program and placed the responsibility for its technical and administrative control on the commanders logistically responsible for the troops in the Western and Middle Pacific areas. The commanding generals of the Sixth and Eighth U. S. Armies and of the Far East Air Force in turn were charged with responsibility for the indoctrination of personnel in their commands. Direct contact between the various commands was authorized

for the purposes of the program. Appropriate directives containing pertinent information were issued to all subordinate echelons.

A second communication on the subject of cold injury was in preparation in General MacArthur's headquarters on 12 August 1945, the day of the Japanese surrender, for distribution to the various commands in the Pacific. In it the following points were discussed:

1. Attention was called to the earlier letter on the subject, in which the responsibility for the training program was placed specifically upon command, with unit commanders responsible for the dissemination of information and for enforcement of preventive measures.

2. The European experience with cold injury was briefly reviewed, and it was emphasized that only the strict application of correct preventive measures could forestall a repetition of that experience in Japan.

3. The importance of rotation of troops was stressed.

4. It was again directed that the wet-cold indoctrination program be included in all training programs.

This letter was accompanied by an outline intended for the guidance of officers responsible for the training of troops. Details of the required preventive measures were described.

The rationale of these measures was stated as follows:

1. Men who have lived in the Tropics for approximately 2 years are physiologically attuned to weather varying from warm to extremely hot and have probably all but forgotten modes of living imposed by cold weather. They must therefore be prepared for sustained out-of-doors life in circumstances of extreme cold.

2. The mere provision of suitable winter clothing is not sufficient. The experience in Europe clearly demonstrated that troops must also be taught how to wear such clothing and how to maintain it. Knowledge of the proper fit and sizing of garments is also essential.

3. Protection of the soldier in winter combat is the responsibility of all echelons of command, from senior commander to squad leader. The experiences of United States Army troops on Attu, in Italy, and in Europe clearly showed the importance of this attitude and achievement, as did the British experience. Because their officers and leaders were aware of their responsibility, the incidence of trenchfoot in British troops was negligible.

4. Trenchfoot is chiefly a disease of infantrymen. It causes actual losses among men who carry the fight to the enemy; also, soldiers who become chilled beyond the point of comfort are neither mentally nor physically fit for efficient combat.

To implement the program planned for the prevention of cold injury, it was directed—

1. That the wet-cold indoctrination program be given top priority in all echelons and be incorporated into the requirements of all training programs for operations contemplated in temperate climates.

2. That the implementation of training doctrines be made the responsibility of command in all echelons.

3. That individual organizations be held responsible for further indoctrination of troops in various echelons, the basic program being designed only to orient, as fully as possible, all command and staff officers and key enlisted men in these echelons.

4. That the program be limited to ground combat and service elements of the Army and to Military Government personnel. Other provision would be made for the instruction of Marine Corps and Air Forces personnel.

5. That the program occupy approximately 8 weeks, with an additional 2 weeks allowed for the dissemination of the doctrines of the preliminary courses to organizational personnel by individual commands. The officers detailed to the area by the Office of the Quartermaster General, who were already in the area, would be available for consultation. Courses of instruction were outlined for higher headquarters and for ground combat and ground combat service support echelons.

6. That indoctrination be provided at the latest date practical before staging, the program being phased to meet this objective. A refresher course in living and fighting in wet-cold areas should be included in shipboard orientation programs, but, as far as practical, should be delayed until convoys had passed out of the tropical zone, so that normal cold weather conditions would help to emphasize the doctrines to be employed at the target area.

THE QUARTERMASTER CORPS

The Quartermaster General employed in the Pacific areas the same policy which he had employed in other theaters of operations. Observers were sent into the area to introduce new equipment and to lay the basis for future requisitions.[10] The action taken in the Pacific was greatly influenced by the serious consequences of the failure in the European theater to accept the advice of his office concerning the best type of clothing and equipment. Long-range planning was essential in the Pacific because the long distances would make procurement and transportation difficulties more serious than in either the Mediterranean theater or the European theater.

The observers sent to the Pacific from the Quartermaster General's Office also had the responsibility of indoctrinating the troops in the correct wearing and care of the new winter clothing. The same general routine was followed that had been followed in other areas, but the observers in the Pacific area had two advantages: They had seen the results of training in the Mediterranean

[10] (1) Report, Capt. William F. Pounder and Capt. Clarence J. MacManus, Military Planning Division, Research and Development Branch, Office of the Quartermaster General. (2) Report, Col. Charles P. Bellican, QMC, Senior Member Quartermaster General Liaison Group in Pacific Areas, 1 Nov. 1945, subject: Quartermaster General Liaison Indoctrination Program in Wet-Cold Clothing Concepts, also Cold Weather.

theater in the winter of 1944–45, and they had also seen the serious situation which developed in the European theater because requisitions for the proper kind of clothing and footgear had been placed too late for the material to be delivered when it was needed for the winter campaign.

When the first observer from the Office of the Quartermaster General, Capt. (later Lt. Col.) William F. Pounder, QMC, arrived in the Hawaiian Islands (then MIDPAC) on 5 April 1945, the logistic responsibility for the assault operations on Japan had not yet been firmly established. Almost as soon as the requisitions for winter clothing and equipment had been completed and approved by the supply staff of MIDPAC, these responsibilities were assigned to AFPAC. The requisitions prepared in MIDPAC, which were thus left without authorization, were forwarded to the Office of the Quartermaster General, to serve as a guide for the specific amounts of individual wet-cold winter items considered necessary for the invasion.

The team headed by Captain Pounder eventually consisted of seven other officers from the Office of the Quartermaster General and two Quartermaster Corps officers who were attached to it locally. Its mission was threefold, to plan the quantities of supplies needed for the forthcoming winter operations, to train the troops in the use and care of their personal winter equipment, and to observe the functional adequacy of individual items of wet-cold clothing and equipment. All previous operations in the Pacific had required only tropical clothing and equipment, and the change from supplies of that type of clothing to supplies of clothing and equipment suitable for winter combat would represent, in itself, a major logistic operation. The advice of the representatives of the Quartermaster General, contrary to the experience in Europe, was accepted at once. When the war ended, large amounts of winter clothing and equipment were already on hand in the various commands in the Pacific, and more were en route. It is certain that, if the war had continued into the winter, all the troops would have been properly protected for combat in a cold environment. The first demonstration of the new clothing was given on Oahu on 12 April 1945.

Training Memorandum No. 11 for the United States Army Forces, Pacific Ocean Areas, was issued on 16 May 1945. In it, the date for the completion of all unit training in MIDPAC was set for 1 September 1945. Training was practically completed in the Hawaiian Islands by 20 June, when the team left Oahu for the training of other units elsewhere.

Work carried out elsewhere by this team was as follows:

1. Establishment of the program of indoctrination at Fleet Marine Headquarters for all Marine units in the Pacific areas.

2. Indoctrination of troops on Johnson Island, Kwajalein, Saipan, Tinian, Guam, Iwo Jima, and Okinawa.

3. Assistance to the second team working on Mindanao and Luzon by two members detached from the first team.

4. Indoctrination of troops in Korea and Japan and in Kyushu (Sasebo), Honshu (Yokohama), and Shanghai, after V–J Day. Indoctrination was expedited in Korea, where it grows steadily colder after the first part of October. Each major unit was helped in the planning of requisitions and the distribution of clothing, and the actual distribution was supervised by two officers from the team attached to the XXIV Corps.

The final phases of the work of Captain Pounder's team were carried out under the direction of the liaison group from the Office of the Quartermaster General, which had arrived in the Pacific on 21 May 1945. The initial activities of this team, on Oahu, consisted of conferences with the first team and additional planning for wet-cold clothing and equipment for Operation OLYMPIC.

The second team, which was headed by Col. Charles P. Bellican, QMC, operated in four sections; namely, a planning section assigned to the Commander in Chief, AFPAC, for coordination purposes, an operating section in MIDPAC, and two operating sections in AFWESPAC. The planning section was later assigned to the administrative control of the Commanding General, AFWESPAC, who then had general logistic control of Operations OLYMPIC and CORONET. After command responsibility had been approved by the Commander in Chief, AFPAC, and a general directive had been prepared dealing with the capabilities and limitations of wet-cold clothing, supply problems connected with its issue, and similar matters, the entire program was placed in the hands of the liaison group.

Training directives were first prepared for the various separate commands. Teams were then dispatched from the operating sections of the group to the lowest tactical elements of the various commands, to insure that all soldiers received proper individual instruction. This phase of the work lasted from June until the middle of August.

When the Japanese surrendered, the indoctrination program was at once modified to fit the needs of an army of occupation, and plans of instruction were modified to meet the needs of the changes of tactical units within the several commands and assignments in the areas of occupation. The program was hampered by delays in the delivery of winter clothing, due to the shortage of ships; by the shortage of port facilities, due to the destruction caused by bombing during the war; by the necessity for using harbors which were still mined; and by the very bad weather. As late as 28 September, only small amounts of winter clothing had been received in the Tokyo area.

In spite of these difficulties and delays, Colonel Bellican was able to report to General MacArthur on 3 November 1945 that as of 1 November, the original target date for the completion of the program, approximately 96 percent of the army of occupation had been indoctrinated and that the program had been completed 100 percent in the XXIV Corps and the Eighth U. S. Army. Arrangements had been made for the training of the elements of the Sixth U. S. Army not yet indoctrinated.

PRACTICAL CONSIDERATIONS OF THE WET-COLD INDOCTRINATION PROGRAM

It was originally estimated that the program of wet-cold indoctrination for troops in the Pacific would cover a total of 1,500,000 men. The necessity for a program of such magnitude is readily explained: The training program instituted in the Zone of Interior (p. 74) had been in operation too short a time to affect most of the troops in the Pacific. Many of the troops deployed to the Pacific from the European theater had arrived late in that area, had had little combat experience, and had also had little training in the prevention of cold injury. Finally, troops which had fought only in the Pacific had had no indoctrination at all, and without it they would have been completely unprepared for combat in wet-cold weather. Training en masse was far more efficient than an endeavor to isolate the groups and individuals making up the small minority which had already been trained.

There were a number of factors which complicated the indoctrination program:

1. All the military bases in the Pacific were islands, and there were therefore enormous distances between the groups of men to be indoctrinated.

2. No specific organization was in existence for meeting the special problems posed by the prevention and control of cold injury. Command, staff, technical personnel, and enlisted components alike had to undergo comprehensive indoctrination on all phases of this type of trauma at the same time that administrative facilities for organization and implementation of the program were being developed.

3. The varying character of the troops in each command required the setting up of a number of special programs. Combat troops, service troops, and the various organizations of the Army Air Forces all had to be instructed differently.

4. Facilities for instruction ranged from indoor theaters and classrooms on Oahu to demonstrations in makeshift areas deep in mud. Extreme heat and frequent drenching rains added to these difficulties.

5. The size of the class was often determined by the availability or lack of availability of a public address system.

6. Language difficulties also arose. Instruction had to be given to soldiers of several nationalities, including Chinese and Filipinos. When Film Bulletin No. 180 was shown, the sound track was translated as the showing progressed.

7. The program was timed to permit completion just before the invasion, so that the troops would not forget what they had learned about cold weather during the additional period they had to spend in tropic temperatures.

8. Written records required from commanders concerning the progress of indoctrination within their units proved essential but were sometimes produced unwillingly.

9. Training aids had to be of convenient size to be carried no matter how

the instructor might be traveling. Large, heavy, bulky materials, no matter how valuable, were not practicable.

Training directives.—Although class schedules had to be widely varied according to the extent of the area of each base, the complexity of commands, the type of personnel to be instructed, and other considerations, training directives could be practically uniform. The training directive for the Pacific Ocean Areas (Training Memorandum No. 11) was issued on 16 May 1945 (p. 227). It was reproduced with only minor changes as Training Memorandum No. 1, AFWESPAC, 2 August 1945. This latter directive furnished the authority for the indoctrination of all troops in the Philippine Islands and all adjacent areas under the administrative control of AFWESPAC. A separate directive was issued on 4 August for service troops.

These directives covered the following points:

1. The indoctrination of all individuals liable for service under wet-cold conditions; the training of supply personnel in supply, storage, care, maintenance, proper fitting, and issue of clothing and equipment; effective instruction in the use of these items; command responsibility for the training; specified dates for the completion of the program.
2. Description of the new wet-cold clothing and equipment.
3. Details of the training courses, which were 2 hours for officers and enlisted personnel; 4 hours for instructors; 1 hour for supply personnel; and a refresher course when the winter clothing was to be issued.
4. The function of the indoctrination teams from the Office of the Quartermaster General.
5. Training aids and references (p. 231).
6. Provision for unit status-of-training reports to be submitted to headquarters before operational commitment of troops or before transfer of units between major echelons, the date to include the hours of training accomplished per individual and the commander's estimate of the unit's proficiency.

Three courses of instruction were provided in the wet-cold program, one for officers and enlisted men for indoctrination purposes, one for instructors who would conduct future courses, and one for supply officers and enlisted supply personnel. The best results were obtained if the instructor took for granted that his audience had never seen the new winter clothing and equipment, as indeed most of them had not.

The material was usually presented as follows:

1. Explanation of the purpose of the course.
2. Necessity for the course, because of past experiences in wet-cold climates.
3. Statement of cold injury casualties in the Aleutians and in the Mediterranean and European theaters, with a discussion of the responsible climatic factors.
4. Brief descriptions of trenchfoot, frostbite, and the respiratory diseases, with special references to their relationship to the incorrect use of uniforms and equipment.

5. Showing of Film Bulletin No. 180 on trenchfoot.

6. Explanation of the difference between wet-cold and extreme cold.

7. Climatologic data on Japan and the coast of China. Information was also included on Russia, to provide for all contingencies.

8. Principles of living in cold and wet-cold.

9. Demonstration of the winter combat unit, with special reference to the layering principle.

10. Explanation of the importance of the correct fit of garments, methods of ventilation, washing of woolens and cottons, provision of dry socks and insoles, and similar matters.

11. Display of posters on the proper use of clothing.

12. Demonstration of the correct use of special equipment, including the sleeping bag with water-repellent case, the poncho, the pack, and the mountain cook set.

Each course of instruction was concluded with a summary, a question period, and inspection of the items of clothing and equipment by the audience.

Training aids and references.—The chief training aid was the combat uniform itself, which troops in the Tropics had never seen before. There was some delay in the receipt of the first sets to be used for teaching purposes, but eventually sufficient numbers were available to be shipped ahead to all the islands on which instruction was to be given.

In addition to material of interest only to supply personnel, the following training aids were employed:

TM 10–275, Principles of Cold Weather Clothing and Equipment.

FM 70–10, Mountain Operations.

FM 70–15, Operations in Snow and Extreme Cold. This manual was not of very great value, since extreme cold was only relatively important in the Pacific.

Trenchfoot, Cause and Prevention (Sect. IV, WD Circular No. 312, 1944).

Prevention of Trenchfoot and Frostbite (Letter, Headquarters, Army Ground Forces, 20 Jan. 1945).

FB–180, Trenchfoot. As noted elsewhere, it was the general opinion that this film bulletin was the greatest single aid in the prevention of cold injury because it showed so vividly the possible consequences of cold injury; namely, gangrene and amputation. When the technicolor Navy film on trenchfoot became available, it was shown to medical officers and other personnel who might be interested. Film strips on cold weather operations were of little value and were seldom used.

Posters, radio announcements, and publicity in Yank, Stars and Stripes, and other Army publications were utilized to keep the indoctrination program in the minds of men who had received instruction but who were still in tropical areas and who would be inclined to think of clothing and personal hygiene accordingly.

Instruction After V-J Day

Inquiry at theater headquarters after the surrender of Japan revealed that combat maneuvers and patrols would be discontinued at once and that the chief task of the troops would be policing. It was expected that forces in both Japan and Korea would be billeted in heated quarters and would not be subjected to extraordinary exposure to cold-wet conditions.

At the desire of the theater commander, the program was continued after V–J Day, with modifications in the emphasis and the content of the courses. The film bulletin on trenchfoot was no longer shown, but the correct fitting and use of the winter combat uniform were still emphasized. To maintain the interest of the troops, which naturally decreased as the acute need for protection against wet and cold was lessened, the usefulness of this special clothing for hunting and fishing in civilian life was stressed. The 2-hour period formerly allotted for the course was now reduced to 1 hour.

Acclimatization Program

The Chief Surgeon, AFWESPAC, 30 June 1945, concurred in the proposal made earlier by the theater quartermaster to G–4 of the theater concerning the institution of an acclimatization program for all troops who were to move from tropical to cold climates in the forthcoming operations against Japan.[11] In his concurrence, General Denit stated that a medical officer would be delegated to collaborate with the theater quartermaster in setting up the technical aspects of the program and to assist in the correlation of its technical and administrative control. It was suggested that the program be so phased that instruction would be given at the latest feasible time, which would not be before 15 July 1945.

Shortly after this proposal was accepted, Maj. (later Lt. Col.) Paul Siple, QMC, an experienced climatologist who had been in the Antarctic with Admiral Byrd and who had made an extensive study of the clothing used in the European theater during the trenchfoot outbreaks the preceding winter (p. 431). was temporarily assigned to the Office of the Chief Surgeon, AFPAC, as a representative of the Quartermaster General. His special mission was to devise plans for the proper, gradual acclimatization of troops who would suddenly be transferred from tropical to colder climates.[12]

It was estimated that under these circumstances men would be considerably below peak efficiency for about 2 weeks, at least that period of time being required for the establishment of compensatory vasomotor controls. It was believed that the time could be shortened if training were instituted during the journey on the transports from southern bases to the target areas farther north. It was therefore recommended that during this journey, particularly

[11] Check Sheet, Chief Surgeon, AFWESPAC, to G–4, 30 June 1945, subject: Indoctrination Program, Wet-Cold.

[12] Letter, Col. Charles P. Bellican, QMC, Quartermaster General Liaison Group, Headquarters, AFWESPAC, to Brig. Gen. Georges F. Doriot, Military Planing Division, Office of the Quartermaster General, 9 Aug. 1945.

during the last 2 weeks, troops should be encouraged, as they entered cold waters, to expose themselves to the cold as much as possible, by remaining on deck for long periods with minimum clothing. It was expected that they would object to being uncomfortable, but it was considered more desirable to impress upon them the value of acclimatization while they could still get warmed up occasionally than to let them suffer the rigors of getting used to cold weather in the midst of combat.

The acclimatization program came to an end with the end of the war, before the theories on which it was founded could be put to the test. One of the indirect results expected from it was the saving of tons of shipping space; it was estimated that men who had been acclimatized would require for efficient comfort at least one layer of clothing less than men who had not been trained to withstand cold weather.

INDOCTRINATION OF OTHER SERVICES

In June 1945 representatives of the Office of the Surgeon General made contact with the Bureau of Medicine and Surgery, United States Navy, to inform the appropriate officers of the Army experience with trenchfoot in the European theater and of the plans for its prevention and control in the Pacific.[13] Transmission of this information was considered essential, since the Navy had had little experience with the ground type of cold injury which would be encountered in the Pacific, where large numbers of Marines would be involved in forthcoming operations. Medical officers of the Navy were informed on all phases of the Army program, and the Army officers, in turn, were given a print of the Navy film in technicolor on cold injury. This film later proved useful in the indoctrination program in the Pacific.

When demonstration classes were held on Oahu for Army officers, at the beginning of the indoctrination program, they were also attended by Marine officers, who were much impressed with the potential dangers of winter warfare to Marines whose entire previous combat experience had been in tropical areas.[14] These officers were also greatly concerned about the possible efficiency of their winter uniform, which was still an unknown quantity under wet-cold combat conditions. Marine equipment did not include such items as shoepacs, overshoes, trigger-finger mittens, water-repellent jackets with hoods, and sleeping bags. When the Army uniform and equipment were demonstrated to the Marine Corps Command on 22 May 1945, the comparison was so greatly in favor of the Army items that the Marine Corps immediately submitted requests for many of them. After a conference with the representatives of The Quarter-

[13] Memorandum for Record, Lt. Col. A. L. Ahnfeldt, MC, Director, Sanitation and Hygiene Division, Preventive Medicine Service, Office of the Surgeon General, 30 June 1945, subject: Conference on Trenchfoot at Bureau of Medicine and Surgery, Navy.

[14] See footnote 10 (1), p. 226.

master General on 11 June,[15] Navy officers also decided that Army clothing would be better for their land-based personnel than their own uniforms for their seagoing personnel.

As soon as it was realized that wet-cold indoctrination was essential for all Marine personnel who would participate in future winter operations, the necessary directives were issued. On Okinawa, which was a combat area, direct instruction was given to Marine contingents by members of the army quartermaster team.[16] Elsewhere, the general plan was to train Marine officers as instructors who would serve as instructors for other officers, who were then responsible for the indoctrination of their own units.

SUMMARY

The most important conclusion to be derived from the story of the wet-cold program in the Pacific is that for the first time in World War II the problem of cold injury was attacked in advance of its occurrence, and was attacked by all the elements whose responsibility it was to be. Command, staff, Quartermaster Corps, and Medical Corps all participated in the endeavor to prevent it. It is true that coordination of the separate efforts had not yet been fully accomplished when the war ended, but the originally divergent lines of action were clearly beginning to converge. There seems no doubt that, had the fighting continued, the program as set up and implemented would have proved an effective means of preventing the cold injuries which had been responsible for such heavy losses in theaters of operations earlier in the war.

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[15] Letter, Capt. William F. Pounder, QMC, to Brig. Gen. Georges F. Doriot, Military Planning Division, Office of the Quartermaster General, 11 June 1945.

[16] (1) Letter, Capt. William F. Pounder, QMC, G-3 Section, Headquarters, Army Garrison Forces, Okinawa, to Brig. Gen. Georges F. Doriot, Military Planning Division, Office of the Quartermaster General, 27 July 1945. (2) Letter, Captain Pounder, G-3 Section, Headquarters, Army Service Command I, to General Doriot, 12 Aug. 1945.

CHAPTER IX

Pathogenesis and Pathologic Process

PATHOGENESIS

Generally speaking, both the clinical manifestations and the pathologic process in cold injury depend upon two mechanisms: (1) The duration of the exposure to cold or wet cold, and (2) the degree to which the temperature of the tissues is reduced. The comparison has frequently been made and is valid that cold injuries resemble thermal burns with one exception: in cold injury there is no coagulation of the components of the blood serum.

The altered physiologic processes resulting from exposure to cold have been described by a number of observers, notably Ariev,[1] Blackwood,[2] Burdenko,[3] Lange and Boyd,[4] Lewis,[5] and Kreyberg and his associates.[6] Of these descriptions, Lewis' articles and the various contributions of Kreyberg best summarize current concepts of the mechanisms involved in injuries caused by cold. As a matter of convenience, their material will be summarized separately.

Theories of Pathogenesis (Lewis)

A discussion of the pathogenesis of cold injury necessarily begins with the mechanism of simple cooling and its effects on the blood flow to the skin.

A comfortably warm person, who sits unclothed, at rest, in a room without a source of radiant heat, progressively loses body heat if the room temperature is 61° F. (16.1° C.). In many persons, the cooling process begins at 64° F. (17.8° C.), and in some persons it begins at 68° F. (20.0° C.). Progressive

[1] Ariev, T. V.: Fundamental Outlines of Present Day Knowledge of Frostbite. Medgiz: Moscow, 1943.

[2] Blackwood, W.: Injury from Exposure to Low Temperature: Pathology. Brit. M. Bull. 2(7): 138-141, 1944.

[3] Burdenko, N. N.: The Effect of Frostbite on the Sympathetic Nervous System. Am. Rev. Soviet Med. I: 15-22, October 1943.

[4] (1) Lange, K., and Boyd, L. J.: Use of Fluorescein Method in Establishment of Diagnosis and Prognosis of Peripheral Vascular Diseases. Arch. Int. Med. 74: 174-184, September 1944. (2) Lange, K., and Boyd, L. J.: The Functional Pathology of Experimental Frostbite and the Prevention of Subsequent Gangrene. Surg., Gynec. & Obst. 80: 346-350, April 1945.

[5] (1) Lewis, T.: Observations on Some Normal and Injurious Effects of Cold upon the Skin and Underlying Tissues. I. Reactions to Cold and Injury of Normal Skin. Brit. M. J. 2: 795-797, 6 Dec. 1941. (2) Lewis, T.: Observations on Some Normal and Injurious Effects of Cold upon the Skin and Underlying Tissues. II. Chilblains and Allied Conditions. Brit. M. J. 2: 837-839, 13 Dec. 1941. (3) Lewis, T.: Observations on Some Normal and Injurious Effects of Cold upon the Skin and Underlying Tissues. III. Frost-bite. Brit. M. J. 2: 869-871, 20 Dec. 1941.

[6] (1) Kreyberg, L., and Rotnes, L.: La Stase Expérimentale. Méthode pour la Mettre en Évidence au Moyen de Préparations Spéciales. Compt. rend. Soc. de biol. 106: 895-897, 21 Mar. 1931. (2) Kreyberg, L.: Some Notes and Considerations Regarding Injuries from Cold. Report to the Commanding Officer, 108th United States General Hospital, 12 Apr. 1945. (3) Kreyberg, L.: Tissue Damage Due to Cold. Lancet 1: 338-340, 9 Mar. 1946. (4) Kreyberg, L.: Experimental Immersion Foot in Rabbits. Acta path. et microbiol. Scandinav. 27: 296-308, 1949.

cooling becomes apparent chiefly in certain parts of the body, particularly the extremities and even more particularly the digits, in which the temperature eventually approaches that of the surrounding air. The cooling process varies according to the precise circumstances of exposure and also varies from subject to subject. The result is naturally influenced by whether or not clothing is worn, especially if the room air is in motion, since clothing holds a layer of warm air on the surface of the skin. Cooling occurs very much more rapidly if the part is immersed in water.

Effect of cooling on blood flow.—The first reaction of the skin to cold is vasoconstriction, which is manifested clinically by a sensation of cold and a contraction of the smooth muscle of the skin (gooseflesh). Vasoconstriction resulting from cold, however, is not a simple reaction. It involves three separate components: (1) A direct and persistent response of the superficial vessels, in the form of local constriction; (2) a transient general vasoconstriction brought about by reflex action through the central nervous system; and (3) a persistent general vasoconstriction. This general vasoconstriction is caused by the return of cold venous blood from the cooled skin and the consequent lowering of the temperature of the general circulation. The cooled general circulation acts, in its turn, upon a central nervous mechanism which is extremely sensitive to cold. All surface vessels, including arteries, arterioles, capillaries, venules, and veins, are involved in these mechanisms, and the total response constitutes the general defense of the body against cold.

In the very act of conserving general body heat, the subcapillary plexuses of the venules, which are so extensively involved in the process, may themselves be sacrificed. As these vessels constrict to safeguard the organism against an excessive fall of temperature, there is, necessarily, a fall in the temperature of the limb. As the limb cools, more and more of the regional vessels constrict, so that eventually a vicious circle is set up by which the temperature of the limb gradually approaches the environmental temperature.

Local defense.—When the temperature has fallen to 50° F. (10° C.) or lower, the clinical effects of cooling become manifest. The skin feels numb. Touch sense and pain sense are lost. There are also certain muscular effects, which Lewis describes as "local defence." This is a process of alternate vasoconstriction and vasodilatation, by means of which the mean temperature of the exposed part is raised several degrees. The mechanism depends upon axon reflexes which are called into play by the cold injury and which are similar to the reflexes called into play by burns, cuts, and other local injuries to the skin.

Lewis' explanation is that all of these injuries cause the release of histaminelike substances from the cells of the skin. He has been able to show that the production of pain is associated with actual damage to the skin. The sensation of pure coldness begins to change to stinging or pain at about 59° F. (15° C.). The defensive mechanisms just described are easily recognized when the temperature is below this level, and in exceptional cases they can be observed up to 64° F. (17.8° C.). The hypothesis of injury to the skin by cold is further supported by the release of a vasodilator substance, as the result

of cellular damage caused by supercooling, hypersensitivity to cold (in some persons), and the swelling which follows prolonged cooling.

The maximum response to cold occurs in the vascular system. Vasodilatation and increased cellular permeability result in inflammation, which is manifested clinically by redness, heat, and swelling.

Supercooling.—The supercooling property of the skin is attributable to the protective effect of its dry, horny layers. The dryness of these layers is the important consideration. Wetness tends to destroy the supercooling property, which is always more evident in skin that remains unwashed.

Mechanisms of special cold injuries.—The predisposing cause of chilblains, Lewis points out, is almost certainly a habitually defective circulation, associated with repeated exposure to cold. He also implies that erythrocyanosis, trenchfoot, and immersion foot occur on the same basis. In the early stages, all of these conditions present the common characteristics of itching, tenderness, coldness, and high vascular coloration. In more severe cases, swelling, blistering, and ulceration occur. Except in the extremely severe forms of frostbite, necrosis of tissue occurs more frequently in trenchfoot than in other forms of cold injury. The initial damage in trenchfoot may not appear to be as great as in frostbite, but the injury is of the silent type, which means that trauma continues over a long period of time and anoxia is correspondingly prolonged, while the temperature of the tissue is not sufficiently low to retard metabolic or degenerative activity. The circumstances of the injury also play a part. In trenchfoot, it may be some time before the soldier realizes that he is injured, or, if he does realize it, he may be unable to seek care or be unable to do anything for himself, because he is pinned down by enemy fire. Under these circumstances, immobility and dependency begin to exert their influence.

Indolence and slow healing are characteristic of all cold injury. According to Lewis' theory, a reduced blood supply permits greater cooling on exposure to cold in chilblains, erythrocyanosis, and trenchfoot alike; and failure to prompt healing, at least in chilblains and erythrocyanosis, is attributable to the same cause. All three conditions may present the same acute inflammatory processes observed in a number of other injuries, such as those caused by heat.

In frostbite, in which there is actual freezing of the skin, the deeper tissues may be involved. Although the freezing temperature of the skin lies between 32° F. (0° C.) and 28° F. (—2.2° C.), the supercooling property of the skin may prevent freezing until a temperature of 23° to 14° F. (—5° to —10° C.) is reached. Once freezing has begun, however, the process is rapid, and large areas of the skin surface may become involved in a very short time.

As freezing increases in severity, Lewis' triple-response phenomenon appears, that is, local reddening, wheal formation over the affected area, and a surrounding bright-red flare. This reaction is the result of reflex vasodilatation, and in Lewis' opinion it depends upon the release of histaminelike substances from skin cells injured by ice crystals. Later, after the wheal disappears, local redness is persistent. Some edema is also persistent, and warming gives rise to both pain and tenderness. Skin which is damaged to this degree shows,

on microscopic examination, edema of both epidermis and dermis, together, with perivascular infiltration of the superficial dermal layers with lymphocytes, extravasated red cells, and some polymorphonuclear cells.

Theories of Pathogenesis (Kreyberg)

Lewis' observations on the pathogenesis of cold injury, which have just been summarized, were confirmed by the observations of Stray and of Kreyberg, whose work was done independently. Kreyberg's observations are in large degree similar to those of Lewis, but he follows the various physiopathologic processes more nearly to their ultimate conclusions.

Immediate reactions.—The immediate reaction of the skin to cold, as Kreyberg describes it, is blanching, caused by contraction of the blood vessels, including the minute vessels (the minute end organs or terminal loops of blood vessels, in which the exchange of fluid and metabolic processes take place). At skin temperatures of 77° to 59° F. (25° to 15° C.), cyanosis appears, as the result of local oxygen deficiency, and the skin is cold to touch. As the temperature of the skin becomes progressively lower, a series of other color changes occurs. After the cyanotic stage, when the temperature is about 59° F. (15° C.), the color of the skin is bluish red. At about 50° F. (10° C.), it is reddish purple or red, and below that level it is bright pink. At this point, pain begins to be felt. From the cyanotic stage onward, an increasing tissue anoxia accentuates tissue damage. Paradoxically, however, the red stage is explained by a surplus of oxygen in the local skin areas, this being the result, according to Kreyberg, of a lack of consumption, and a lowered dissociation, of oxygen. At this stage, as well as at the blue stage, the sensations of touch and of pain are reduced.

Once the bright-pink stage is reached, the alternating constriction and dilatation described by Lewis begin to occur, and there is a resultant rise in the skin temperature. The high color is the result of the presence of blood in the minute regional vessels, which remain constantly dilated during this phase. The sensation of cold is lost, and there is further reduction in touch and pressure sense. With exposure to still lower temperatures, however, these minute vessels contract, and there results a second white stage, which must not be confused with the white appearance of frozen tissues containing ice crystals. There is not, incidentally, full agreement with the theory of the formation of ice crystals, and there is also considerable debate over whether or not, if they do occur, they are of great significance.

Up to this time, according to Kreyberg's thesis, reactions which have occurred as the result of exposure to cold are chiefly physiologic and are reversible if and when the environemntal temperature returns to normal. The position, however, is borderline, and prolonged exposure in any of the stages of cold described may be sufficient for the process to pass over into actual pathologic damage to the tissues. Further loss of body heat from protracted moderate exposure thus may result in trenchfoot or immersion foot, with severe tissue

damage, while additional exposure to low temperatures may cause actual freezing of the skin and tissues.

Effects of cold on the vascular supply.—One of the effects of exposure to cold, according to Kreyberg, is greatly increased permeability of the capillary walls, which is most likely to occur during the red or hyperemic stage. As a result, there is a transudation of plasma through the vessel walls, combined with a slowing down of the flow of blood through the minute vessels. When the injury is severe enough, all the plasma passes through the vessel walls, leaving the blood cells tightly packed in the lumen and preventing further blood flow by what amounts to mechanical occlusion of the vessel. Kreyberg regards it as most important that this phenomenon be recognized as true stasis and not be interpreted as intravascular coagulation. By the use of vital dyes, he and Rotnes (one of his associates) were able to demonstrate both capillary permeability and blood cell stasis in the ears of rabbits which had been injured by cold. Their observations were confirmed by Lange and Boyd, who demonstrated transudation into injured tissue spaces by the use of intravenous injections of fluorescein combined with examination by ultraviolet light. Reversibility of the process was observed in frogs, but it remains to be proved that stasis in man is a reversible process.

Although the initial edema in cold injury can be explained as the result of the imbalance between the outpouring and the drainage of tissue fluids, an inflammatory factor enters the picture as capillary permeability increases. Kreyberg, by using vital stains, was also able to demonstrate this phenomenon in experimental animals which had been injured by cold.

From the cyanotic stage onward, as has already been pointed out, tissue damage is accentuated by increasing anoxia of the tissues. In the more severe types of injury, lack of oxygen brought about by the processes described leads to necrosis, which may involve both the tissues and the packed, static blood cells within the vessels. The final intravascular stage is the production of a hyaline mass from degeneration of the blood cells. Necrosis, in Kreyberg's opinion, is primarily the result of vascular stasis and anoxemia and is not influenced by cold per se.

All the reactions thus far described are known to be the result of local tissue damage in frostbite. Whether these same reactions result from long exposure to moderate cold and wet, as in trenchfoot, cannot be so readily demonstrated. Kreyberg, however, is emphatically of the opinion that the end results of exposure, with and without freezing to ice, differ only in degree and not in principle. The reaction to severe or prolonged cold, he believes, is the result of a single factor; namely, acute aseptic inflammation from tissue damage caused by the lowered temperature, the freezing to ice, and the deprivation of oxygen. By the term "acute aseptic inflammation" he means the combined vascular and cellular local reactions which occur after the introduction of an element foreign to the tissues. Dead and damaged tissues and abnormal metabolic products may act as the foreign elements. Either a cellular or a vascular type of reaction may predominate.

Two forms of tissue damage, according to Kreyberg's theory, thus progress during prolonged cooling, one caused by the cooling itself and the other by the resultant lack of oxygen in the tissues. One of the first effects of prolonged cooling is increased transudation and the development of edema. The passage of plasma through the blood vessel walls is augmented by the increase in hydrostatic pressure which may result from long standing or immobilization. It is also the result of constriction, which increases venous congestion.

Kreyberg also believes that cardiac disease and poor physical condition, whether from hunger, reduced protein intake, or reduced colloid pressure, may increase transudation. Whatever the various causes may be, a vicious circle is soon set up, consisting of increased local tissue damage and increased permeability of the minute vessels. The shift of body fluid may be sufficient, in some cases, to produce shock.

All of these reactions are retarded as long as the part is cold, partly because of the slowing down of all activities and partly because of the prolonged contraction of the arteries and arterioles. These facts account in large measure for the early clinical appearance of trenchfoot. They are of clinical importance, for they indicate that the tissues are not dead. Therefore, unless the process is of long standing when the patient is first brought under treatment, the chances are that with properly applied treatment it will not go on to necrosis.

Theories of Pathogenesis (Ariev)

According to Ariev, the reaction of the tissues to cold is comparable to a chemical reaction in which the speed of the reaction is proportional to the temperature at which it takes place. If the comparison is valid, the injury from frostbite would occur early but would become manifest only when the temperatures of the injured part had been raised. The behavior of cold injury suggests that this hypothesis is sound. The predominant early clinical features are pallor, edema, and numbness. When the part is warmed, the arterial circulation increases rapidly, while in the later stages of hyperemia, which is both reactive and inflammatory, blister formation, necrosis, and actual gangrene appear, according to the severity of the injury. These latter processes, however, remain latent and do not become manifest, because of the retarding effects of cold, until the injured part is warmed. If the injury is superficial and the underlying tissues are not dead, feet which seem to be seriously damaged may go on to recovery. This process is what Kreyberg describes as the "fulminating vascular reaction which precedes tissue necrosis."

As the circulation is reestablished, there may also occur, in addition to gross exudation, rupture of the minute vessels and bleeding into the tissues and the skin, with resultant ecchymotic areas and blister formation.

PATHOLOGIC PROCESS

The pathologic change in all cold injuries is essentially the same, such differences as exist being explained by differences in the duration and severity of the exposure. The process is essentially inflammatory and degenerative. The skin, subcutaneous tissues, muscles, nerves, and blood vessels are chiefly affected; but degenerative changes in the body structure and joint tissue have also been observed.

World War I Studies

The changes which occur in trenchfoot were first adequately described by Smith, Ritchie, and Dawson,[7] in 1915. After an intensive clinical study of 51 cases of "trench frost-bite," they carried out a series of experiments on rabbits, in which they were able to reproduce perfectly the edematous swelling characteristic of trenchfoot in man. The development of edema and its degree depended upon the controlled degree of the cold, wet, and constriction by which the condition was reproduced.

Microscopic examination of the affected tissues showed that the blood vessels were chiefly affected. The changes included dilatation of the lumen, which contained a certain amount of fibrin deposit; swelling of the endothelium of the intima; vacuolation of the muscle fibers of the intima; and an increase in the number of cells in the perivascular tissue.

The lymph vessels were sometimes normal and sometimes dilated and filled with masses of fibrin, but the walls were usually unaffected. The tissue spaces were filled with a copious deposit of threads and granules of fibrin. The collagen bundles of the fibrous tissue were separated and swollen and were undergoing solution in the exudate in whatever areas it was abundant. When the edema was of long standing, the swollen tissues were diffusely infiltrated with leukocytes. When the foot had been placed in warm water after exposure to cold, the tissues were diffusely infiltrated with red blood corpuscles, the infiltration in some areas amounting to actual hemorrhage.

The nerves of the affected area presented edematous swelling of the axis cylinders, apparently as a part of the general edema. Degenerative changes were not present, as they are in true frostbite. In the voluntary muscles, the staining was modified and there was a loss of striation. In longstanding cases, examination revealed leukocytic infiltration, edema, and deposit of fibrin between the fibers. These changes were in contrast to the definite disintegration and regeneration seen in the muscles in true frostbite.

The sinuses of the regional lymph nodes were dilated and the lymphoid follicles were hypertrophied. The sinuses contained a deposit of fibrin threads and granules, and red corpuscles, polymorphonuclear leukocytes and proliferated endothelial cells were observed in the meshwork of fibrin.

[7] Smith, J. L., Ritchie, J., and Dawson, J.: On the Pathology of Trench Frost-Bite. Lancet 2: 595–598, 11 Sept. 1915.

It was concluded by Smith, Ritchie, and Dawson that these changes duplicated the changes of trenchfoot in man and that they were inflammatory in origin, resulting directly from the action of cold on the tissues. The most important pathologic change, in their opinion, was in the blood vessels, the walls of which were so damaged that they could no longer function, with the result that an excessive amount of fluid was poured out and accumulated in the tissues. The deposition of fibrin followed, and the fibrous elements of the tissues underwent more or less disintegration. Congestion of the damaged vessels, such as would occur from the application of warmth, caused rupture of their walls, allowing the passage of red blood corpuscles into the tissues. Recovery from such a process, Smith and his associates pointed out, would naturally be slow, because the swelling had to subside and the damaged blood vessel walls had to be repaired sufficiently to withstand the strain of normal circulation.

Excellent correlation was possible between these experimental observations and the clinical phenomena observed in human patients, and a sound regimen of therapy was therefore outlined on the basis of the investigation. Two of the most important therapeutic observations were that the feet should not be warmed in any manner that would cause congestion and that the return of normal circulation in the part should be delayed and not hastened.

World War II Studies

During the early months of World War II, considerable attention was devoted to immersion foot, and extensive studies were published by Blackwood, Ungley, White, and Warren, and others (p. 10). Later in the war, the chief attention was centered on high-altitude frostbite (p. 13) and, still later, on the ground type of cold injury.

Observations from the Aleutians.—Patterson,[8] who treated wet-cold casualties from Attu (p. 95), reported that pathologic studies of amputated parts revealed diffuse, spotty fibrosis, thrombosis, and recanalization of blood vessels. There was total demyelinization of nerves at the demarcating zone, with regression to normal 10 cm. above this area. These changes were all observed in specimens obtained by amputation about 6 weeks, on the average, after injury and were what might have been expected, Patterson concluded, in casualties who had presented edema of the tissues, necrosis, and arterial and venous thrombosis soon after injury. No tissues were available for study immediately after exposure.

Observations from the Mediterranean theater.—In the Mediterranean theater (p. 101), only limited opportunities occurred for histologic study of the lesions of trenchfoot, but from the few specimens which could be examined

[8] Patterson, R. H.: Effect of Prolonged Wet and Cold on the Extremities. Bull. U. S. Army M. Dept. No. 75, pp. 62-70, April 1944.

Simeone [9] was able to reconstruct the following composite changes, which were essentially inflammatory and degenerative:

Edema was observed in all the subcutaneous tissues and in the nerves and muscles. Round-cell infiltration was noted in scattered areas throughout the dermis and around the arterioles and capillaries. Acute inflammatory changes were observed in one specimen, a bursa thought to be from the proximal metatarsophalangeal joint of the great toe.

Degenerative changes included atrophy of the epidermis, with decreased thickness of this layer, smoothing of the rete pegs, and atrophy of the sweat glands. Fat tended to disappear from the subcutaneous tissues. Fibrous tissue (collagen) was deposited subcutaneously about the nerves and blood vessels. Elastic tissue was apparently not affected.

Small blood vessels showed a similar deposition of fibrous tissue, which sometimes was almost sufficient to occlude the lumen. Fibrosis was also noted in the walls of the large vessels, in which the patency of the lumen was less affected.

Wallerian degeneration was noted in the nerves and was most marked peripherally. Regeneration of axis cylinders could be detected in specimens obtained some months after injury. Nerve endings were found still noninnervated as long as a year after injury. Fibrosis was observed in and about the nerves.

Muscle fibers showed early degeneration of the Zenker type. Later, atrophy and fibrosis of the muscles were found. Irregular areas of osteoporosis and new bone formation were observed in bones of the affected parts.

Studies at the Army Institute of Pathology [10]

As previous descriptions indicate, little material was available anywhere for the histologic study of trenchfoot, which would be expected in a condition not in itself lethal and seldom requiring radical surgery. Friedman, working at the Army Institute of Pathology in Washington, D. C., was able to overcome this difficulty and to reconstruct the pathogenesis of trenchfoot from an intensive study of 14 specimens representing various stages of the disease. Three of the specimens were secured at autopsy from patients who died 7 to 10 days after exposure, from conditions other than trenchfoot. In the other 11 cases, gangrene ensued and amputation of portions of the foot and leg was necessary from 1 to 5 months after injury. In 6 of the 14 cases, the injury had been sustained during the Attu invasion.

The findings in all 14 specimens permitted the conclusion that all injuries resulting from exposure to low temperatures exhibit a common pattern and result from a similar train of events. Friedman's conclusions concerning

[9] Report, Lt. Col. Fiorindo A. Simeone, to the Surgeon, Fifth U. S. Army, subject: Trenchfoot in the Italian Campaign, 1943–45.

[10] Friedman, N. B.: The Pathology of Trench Foot. Am. J. Path. 21: 387–433, May 1945.

the pathologic changes in trenchfoot are practically the same as Kreyberg's (p. 238), the only real point of difference being the occurrence of thrombosis in the damaged blood vessels. Kreyberg believes that thrombosis does not occur. Friedman's view is that the masses of red blood cells seen in the minute vessels are true agglutinative thrombi which are poor in fibrin.

The pathologic changes can be most conveniently summarized under the heading of the areas in which they occur. It must be remembered that the observations listed are composite and that all of the changes listed were not found in all the specimens.

Skin and subcutaneous tissues.—The edema in trenchfoot involved the skin and subcutaneous tissues as well as the nerves and muscles. Cellular exudates appeared in the dermis and subcutaneous tissues but were less notable than in the immediate vicinity of congested vessels. There was smoothing of the rete pegs, and the sweat glands showed atrophy, degeneration, cystic dilatation, and vacuolation.

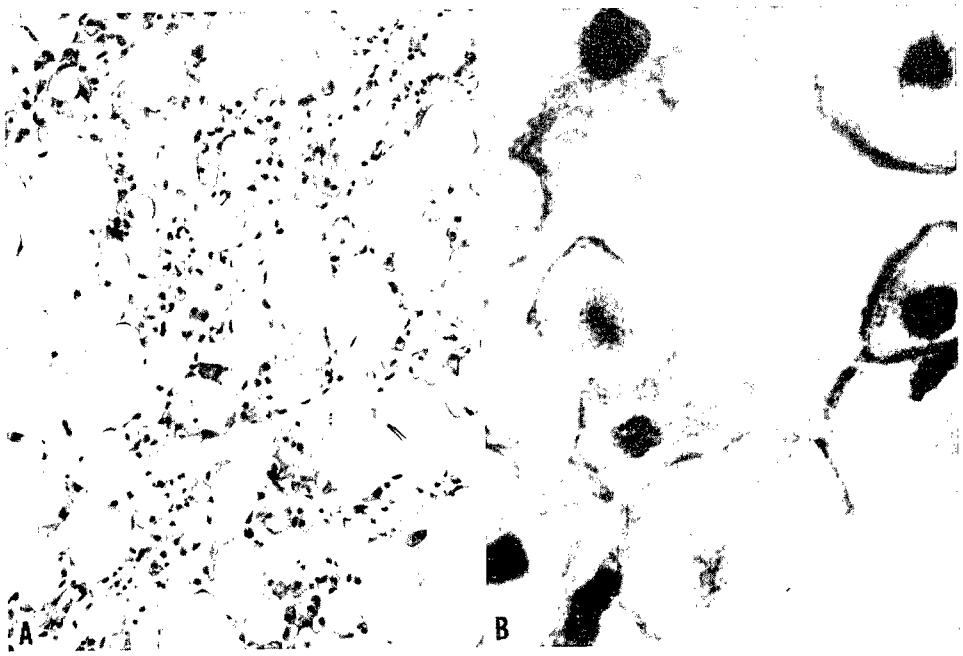
Changes in fatty tissue in early cases of trenchfoot consisted of infiltration by leukocytes in the deeper subcutaneous tissue and in the tissue around the appendages, even when the overlying layers were not involved; proliferation of the adventitial cells of the prominent capillaries and smaller vessels in the fat lobules; edema and leukocytic infiltration of the interlobular fibrous septa; and fibrinous exudation in the deeper tissues.

Changes in the fat were marked in late cases. Fat lobules were diffusely infiltrated with foam cells laden with finely divided fat (fig. 35). Occasional accumulations of giant cells of the foreign body and Touton types were observed in otherwise unaltered fat. In this study, actual fat necrosis with soap formation was observed only in areas of gangrene in a single specimen, which was secured 143 days after injury. Oil cysts (fig. 36), most of which were minute and which were lined by layers of foam cells, contained scattered, free fat globules. Fibrous replacement of adipose tissue was notable and seemed to occur in two ways:

1. In some regions, serous atrophy or actual replacement by loose areolar or mucinous connective tissue (fig. 37) left a collapsed, atrophic structure in which the original outline of the fat lobule was still preserved.

2. In other areas, thickening of the interlobular fibrous septa (fig. 38) resulted in conspicuous depletion of the adipose tissue component in the subcutaneous layer.

Blood vessels.—Marked engorgement of the vascular tree was characteristically present in the early stages of trenchfoot. Extravasations of red blood cells typically surrounded the engorged plexuses. Numerous vessels contained agglutinative erythrocytic thrombi (fig. 39) of the type found in stagnant blood rather than in a freely moving blood stream. The thrombi usually filled the lumen of the involved vessels completely, though some plugs were incomplete, and occasionally mural deposits of hyaline material or fibrin encircled a patent central lumen. Endothelial damage was not striking. Mural hemorrhage



AFIP 78629, AFIP 81141

FIGURE 35.—A. Phagocytosis of fat in subcutaneous adipose tissue in late case of trenchfoot. Foam cells are present throughout the lobule. Hematocylin and eosin stain. (× 145) B. High-power view of the lipoid phagocytes shown in A. Masson's trichrome stain. (× 1360)

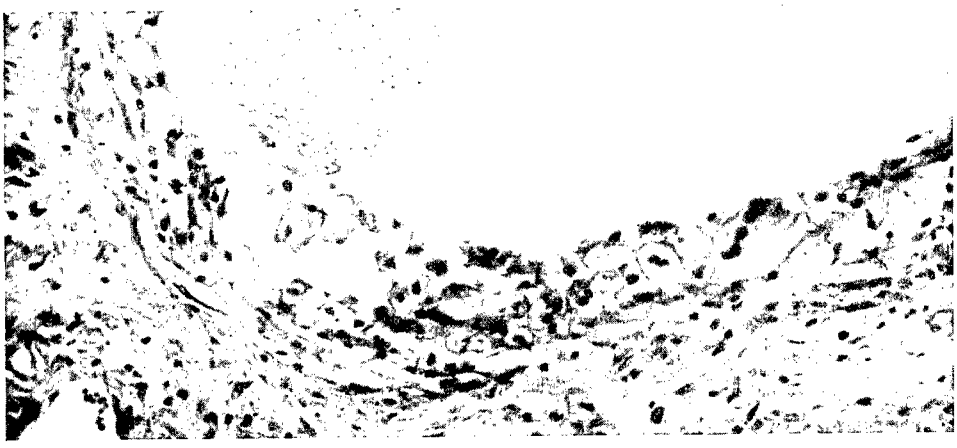


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FIGURE 36.—Oil cyst, lined by foam cells in subcutaneous fat in late case of trenchfoot. Hematoxylin and eosin stain. (× 205)

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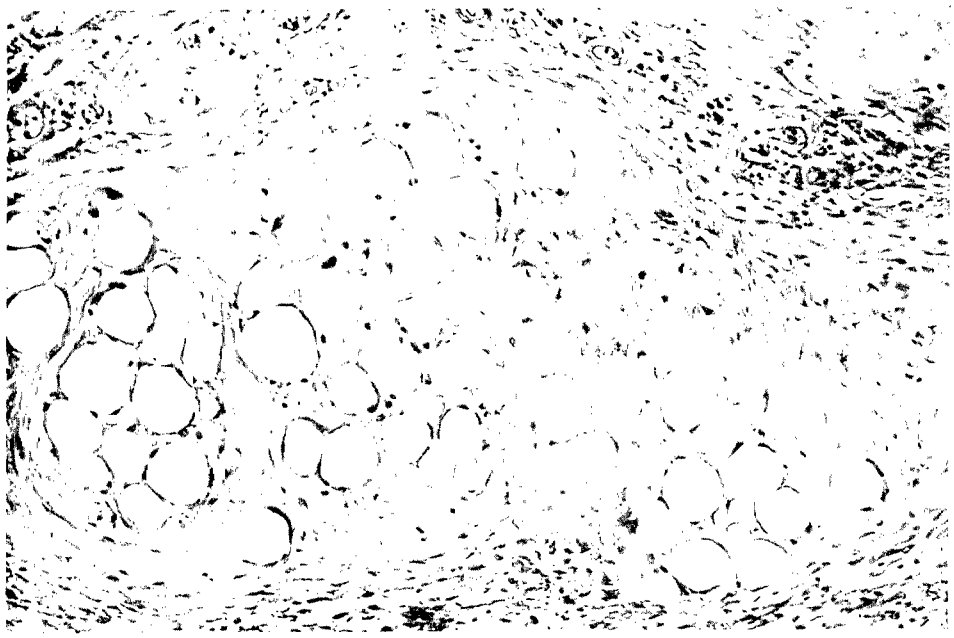

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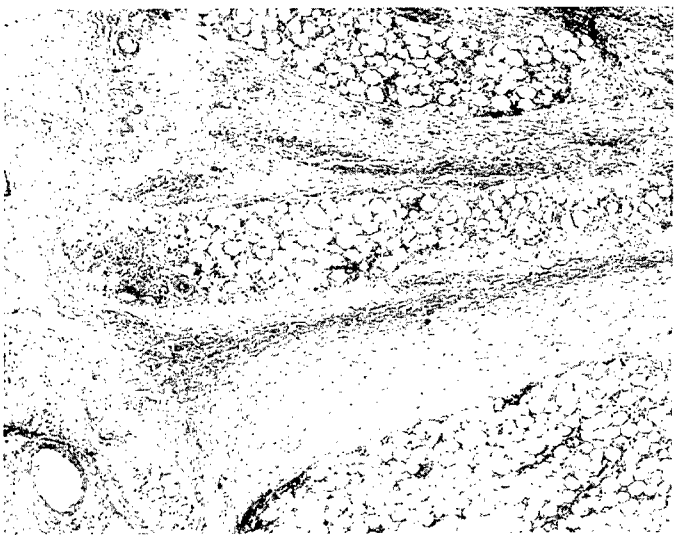
FIGURE 37. Connective tissue elements replacing cells of subcutaneous fat lobule in late case of trenchfoot. Hematoxylin and eosin stain. (× 145)



AFIP 81054

FIGURE 38. Atrophy and inflammation of subcutaneous fat lobules in late case of trenchfoot. The interlobular fibrous septa are thickened. Hematoxylin and eosin stain. (× 30)

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(fig. 40) and inflammation (fig. 41) could be observed in both patent and plugged vessels. There was no instance of periangiitis in any of the 14 specimens.

While many vessels, especially if they were thrombosed or inflamed, were dilated, marked vasoconstriction (fig. 42) was also observed. This was true even of the main trunks, well above the line of demarcation, though it was

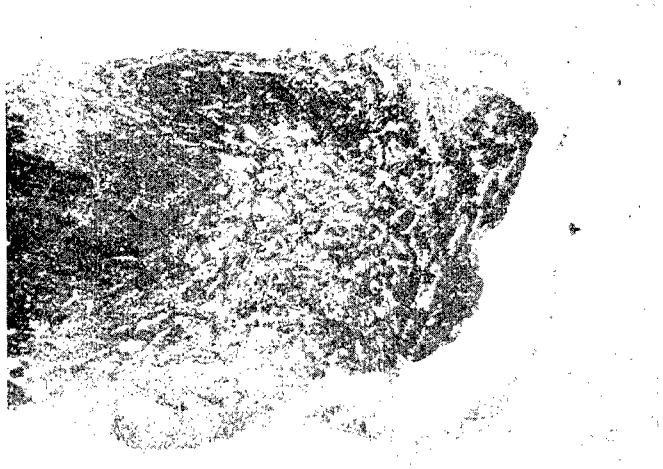

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FIGURE 39.—Thrombosis of posterior tibial vein in early case of trenchfoot. The thrombus consists almost entirely of agglutinated red cells. Hematoxylin and eosin stain. (× 65)

AFIP 81964

FIGURE 40.—Thrombosis of artery from gangrenous foot in late case of trenchfoot. Organization of the thrombus and hemorrhage into the vessel wall are shown. Hematoxylin and eosin stain. (× 50)

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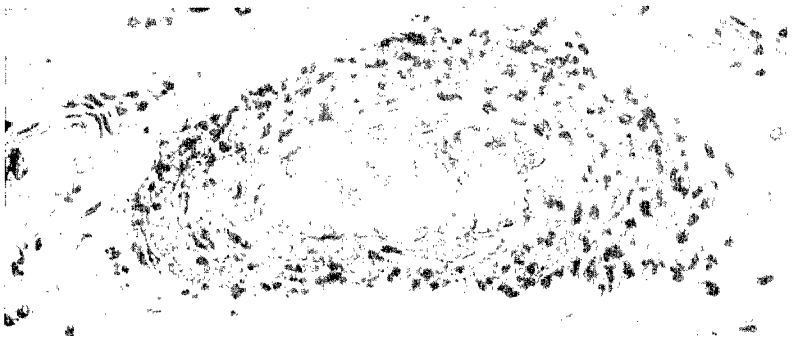
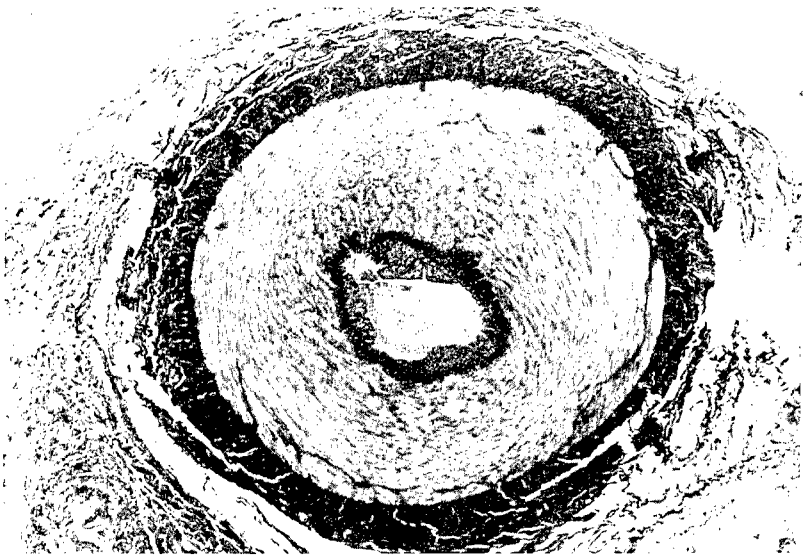


AFIP 82186

FIGURE 41. Mural angiitis in early case of trenchfoot. The wall contains chromatin debris and is infiltrated by leukocytes. The muscular elements are degenerated, and the media contain eosinophilic granular material. Hematoxylin and eosin stain. (× 500)



AFIP 82548

FIGURE 42. Construction of posterior tibial artery in early case of trenchfoot. Weigert's elastica and van Gieson's stains. (× 32)

not possible to say with certainty that the constriction was characteristically present during life.

In one specimen (fig. 43), secured 32 days after exposure, transitions were observed from the stage of thrombosis seen in early stages to a stage of endarteritis obliterans. Connective tissue and capillaries exhibited proliferation, and the development of a mucinous stroma seemed related to the presumably original thrombi, in which predominance of red blood cells and platelet agglutinations, together with a lack of fibrin, was still evident.

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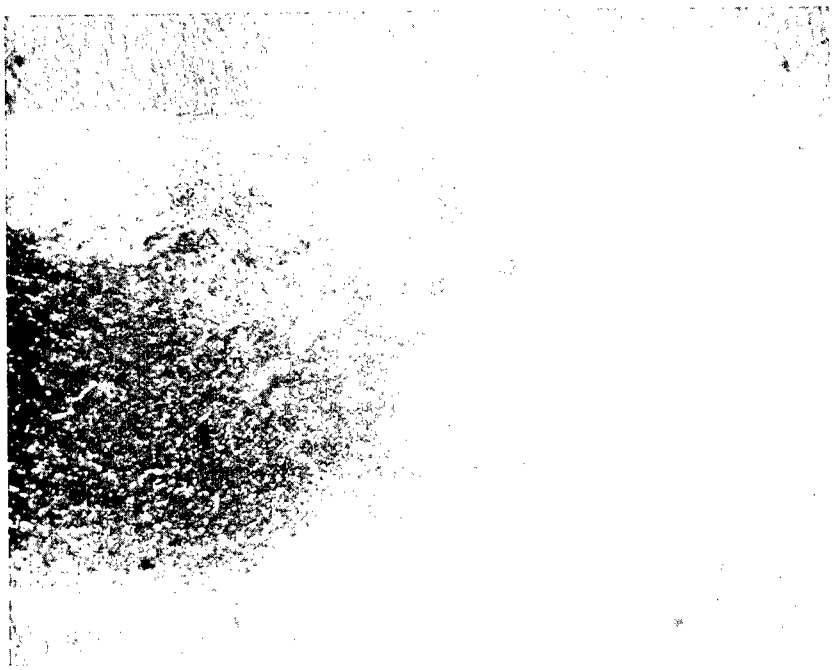

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FIGURE 43.—Longitudinal section of plantar artery in 32-day case of trench-foot. Organization is underway at the head of a thrombus. Hematoxylin and eosin stain. (× 75)

Almost all thrombi observed within 40 days after exposure were organized. Endangiitis obliterans was present in both arteries and veins, even in practically normal tissue above the line of demarcation. The degree varied from slight thickening of the intima to obliteration of the lumen. Arteries which were slightly involved showed subintimal proliferation of cells, often in a mucinous and edematous matrix (fig. 44). The intimal thickening was frequently eccentric but sometimes involved the entire circumference. In extreme cases, it produced a marked narrowing of the lumen. When the arteries were obliterated (fig. 45), the lumen was filled with fibroblasts, round cells, and hemosiderin-laden phagocytes. The central mass usually contained a number of discrete channels with definite muscular walls, which resembled arterioles (fig. 46). Similar recanalization was noted even in small arteries and arterioles. The proliferative reaction was central to the inner elastic membrane, which occasionally was destroyed (fig. 47) but which usually was intact and not reduplicated.

The veins, although they were less regularly involved than the arteries, sometimes showed nodular intimal thickening caused by edema, mucinous degeneration, and increase in cells, collagen, and elastica. The veins were sometimes obliterated.

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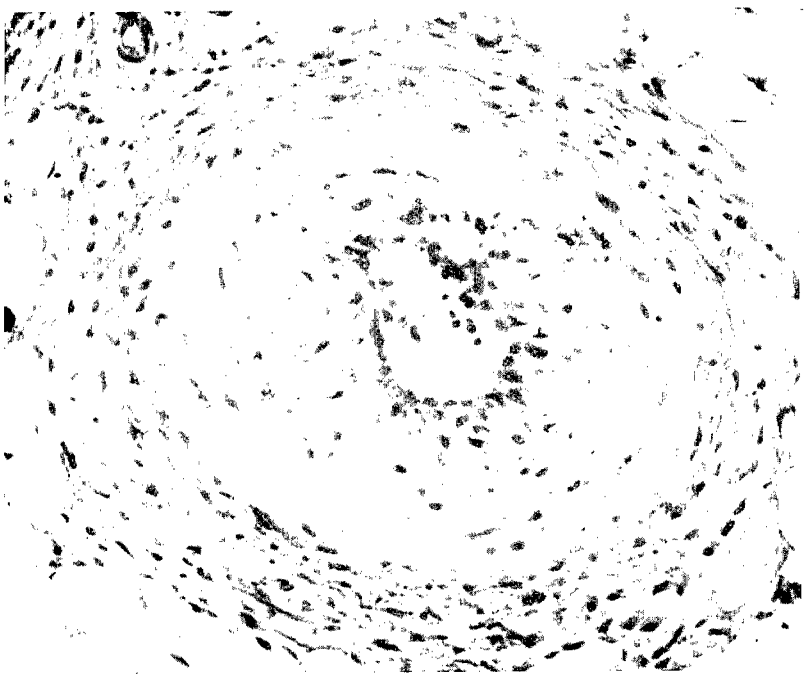

AFIP 78625

FIGURE 44.—Proliferation of intima and mucinous degeneration in a small artery. Hematoxylin and eosin stain. (× 175)

Muscles. In early cases, muscle tissues exhibited degeneration, necrosis, and cellulitis, but atrophy was not observed. In later cases (40 days or more after exposure), atrophy (fig. 48) was extensive in all of the specimens. Fibrils could be identified, but the cytoplasm was usually shrunken and homogenized. Cells laden with yellow pigment lay between atrophic fibers, which were occasionally separated from the endomysial network by spaces containing edema fluid.

The interstitial connective tissue of the muscle was the site of mucinous degeneration. A few true giant cells were identified in areas which had undergone less marked atrophy. Necrosis and inflammation were observed in areas of gangrene and cellulitis. In the zone of demarcation, and above, were circumscribed foci of necrosis, like infarcts. Hyaline degeneration and proliferation of sarcolemmal nuclei were occasionally encountered in isolated fibers. Numerous tendon sheaths exhibited severe exudative and proliferative lesions in which masses of fibrin were more prominent than in the regions of inflammation present elsewhere in the soft tissues.

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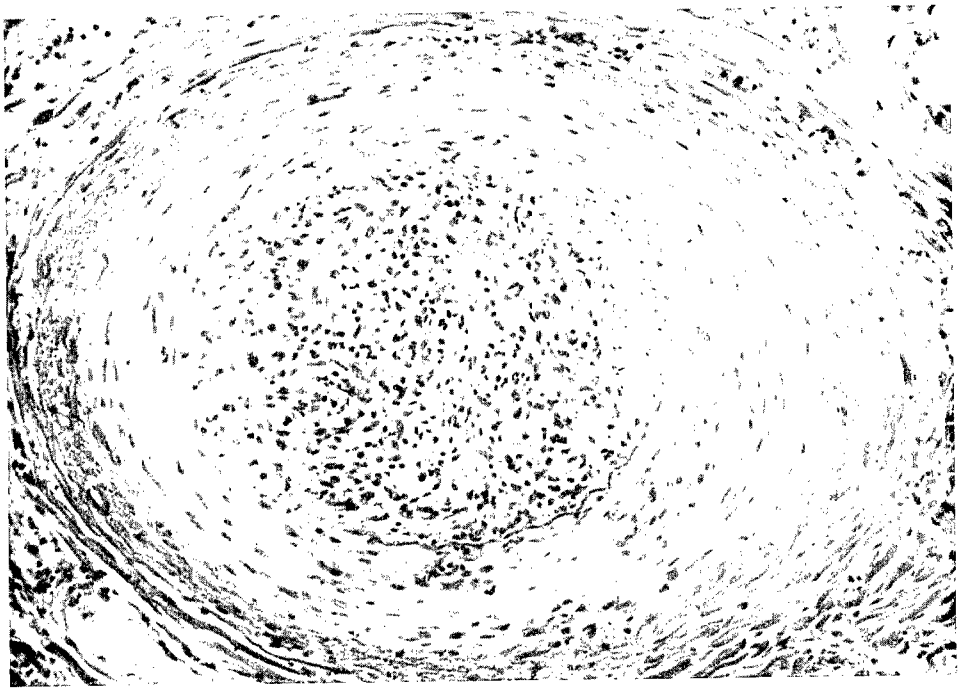

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FIGURE 45.—Obliteration of lumen of artery in late case of trenchfoot. The inner elastic membrane is ruptured, and the media and adventitia are scarred. Hematoxylin and eosin stain. (× 175)

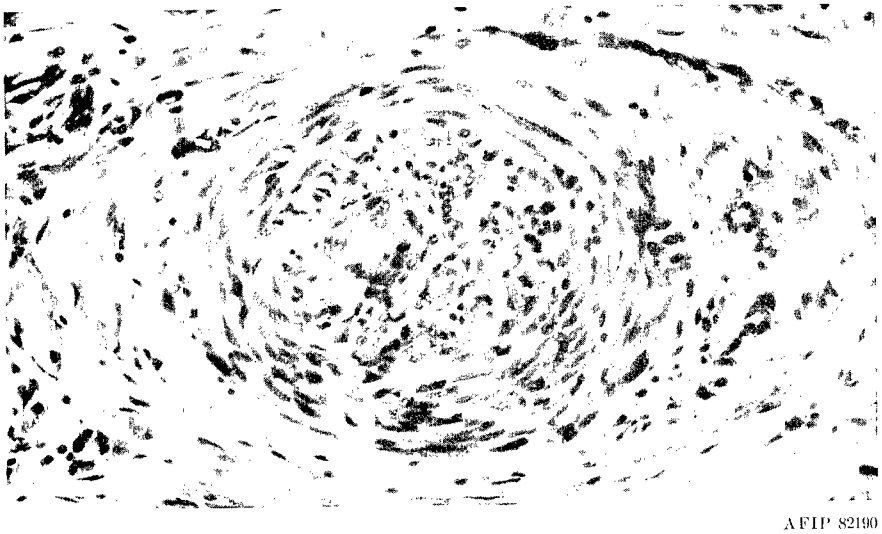

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FIGURE 46.—Recanalization of small, obliterated artery. Many new channels, some with muscular walls, have formed. Hematoxylin and eosin stain. (× 280)

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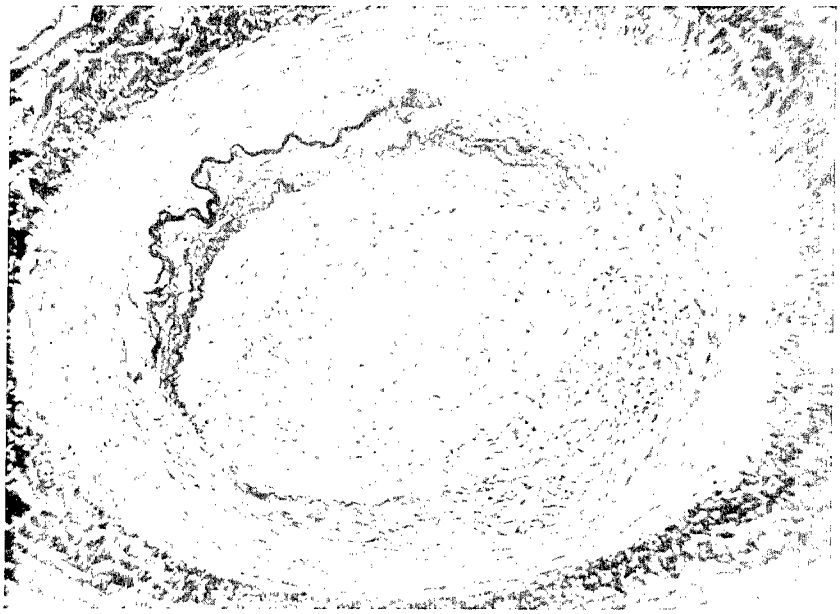

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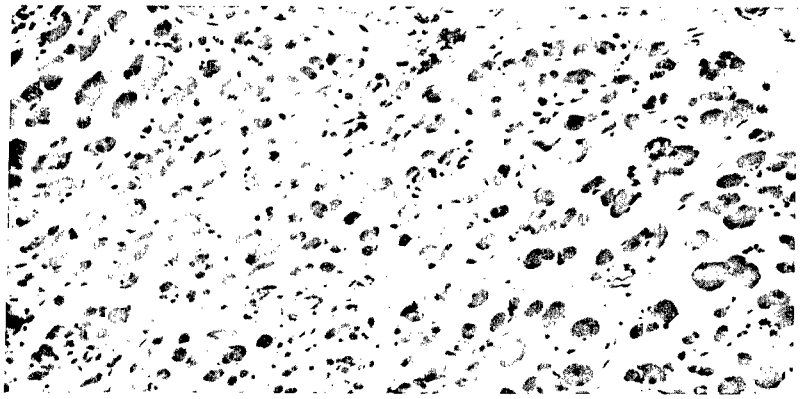
FIGURE 47. Organization and recanalization of artery in late case of trenchfoot. The elastica is ruptured, frayed, and distorted. Weigert's elastica and van Gieson's stains. (× 145).



AFIP 78633

FIGURE 48. Atrophy of muscle in late case of trenchfoot. The shrunken fibers are widely separated. Hematoxylin and eosin stain. (× 145)

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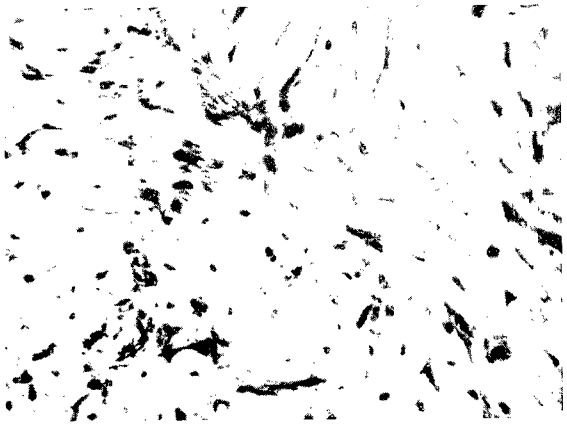
Nerves.—In specimens secured soon after exposure, nerves which traversed regions of inflammation were swollen and edematous, and, even at a distance from such areas, degeneration of both axis cylinders and myelin was observed. Demyelinization was especially marked in the distal portions of the nerves. The pronounced lipoid phagocytosis characteristic of late cases was not observed in early cases. Only large myelinated fibers which presumably represented the sympathetic components of the nerves were not significantly altered either in the main trunks or the small branches (fig. 49), and small intraneural vessels showed no essential abnormality.

In late cases, nerves in areas of gangrene and cellulitis were usually badly damaged. Demyelinization (fig. 50) was observed at all levels but was more



AFIP 77251

FIGURE 49.—Cross section of portion of posterior tibial nerve in early case of trenchfoot. The groups of small fibers are undamaged. Bielschowsky's stain. (× 500)

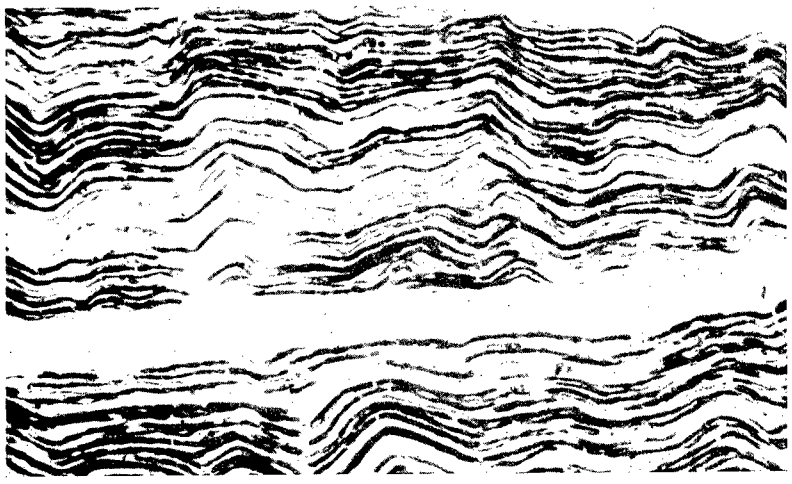


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FIGURE 50. Slight demyelinization of nerve above region of gangrene in late case of trenchfoot. Frozen section. Spielmeyer's stain. (× 125)

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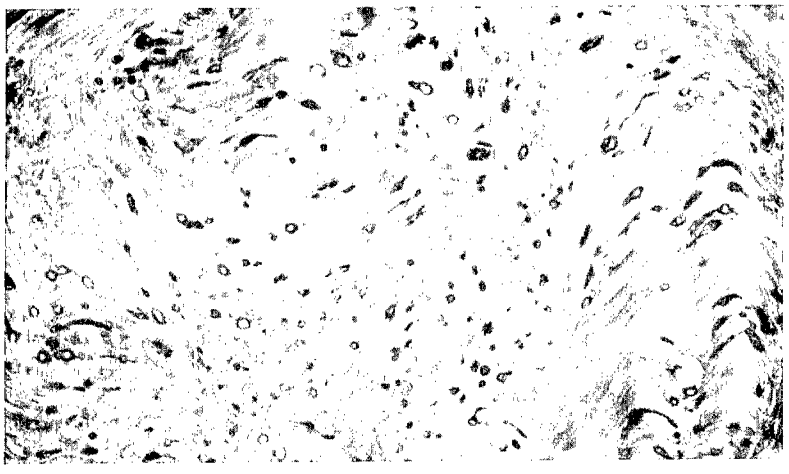
extensive below the zone of demarcation (fig. 51). Between the nerve fibers were many foam cells (fig. 52) containing sudanophilic material in fine droplets, presumably fat from broken-down myelin. Many axis cylinders had disappeared and those still present were irregular and ballooned (fig. 53). Damage was usually spotty. Some nerve bundles showed edema and separation of the fibers,

AFIP 77253

FIGURE 51.—Marked segmentation, beading, and loss of myelin in nerve from region of gangrene. This section is of the same nerve as is illustrated in figure 50 but was taken at a different level. Frozen section. Spielmeyer's stain. (× 220).



AFIP 81956

FIGURE 52.—Lipoid phagocytosis in a degenerated nerve in late case of trenchfoot. Foam cells are scattered between the damaged fibers. Weigert's stain. (× 230).

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FIGURE 53.—Degeneration of nerve in late case of trenchfoot. Many axis cylinders have been lost, and those which remain are ballooned. Bielschowsky's stain. (× 550).

and in a few instances it was thought that actual increase of the endoneural connective tissue elements might be present. Perineural fibrosis (fig. 54) was noted, with exaggeration of the epineurium and perineurium, and occasional nerve bundles were partially or completely hyalinized. Many small blood vessels in the nerves were thickened. The degeneration and phagocytosis observed in the subcutaneous adipose tissue were also observed in the perineural fat.

Panchenko [11] described characteristic changes in the perineural nervous system, nerve trunks, and spinal cord of 12 patients with frostbite who died of intercurrent disease. The changes included typical ischemic neuritis and signs of intensive fibroblastic hyperplasia and hypertrophy. Some of the nerve fibers were in a state of wallerian degeneration, while evidences of regeneration could be seen at the same time. Small axial islands of degenerative necrosis were usually found close to blood vessels. Changes in the cells of the anterior horn of the spinal cord and of the intervertebral ganglia varied from slight chromatophilic granular degeneration of the central area to complete degeneration of the cellular structure. These changes were found only at the levels of the spinal cord which corresponded to the innervation of the injured part. The extent of the damage was related to the intensity of the exposure to cold.

Bruneau and Heinbecker [12] also showed that the nerve degeneration occurs in dogs after prolonged chilling of an extremity.

[11] Panchenko, D. I.: Retrograde Changes in the Spinal Cord in Frostbite of the Extremities. Am. Rev. Soviet Med. 1: 440–443, June 1944.

[12] Bruneau, J., and Heinbecker, P.: Effects of Cooling on Experimentally Infected Tissues. Ann. Surg. 120: 716–726, November 1944.

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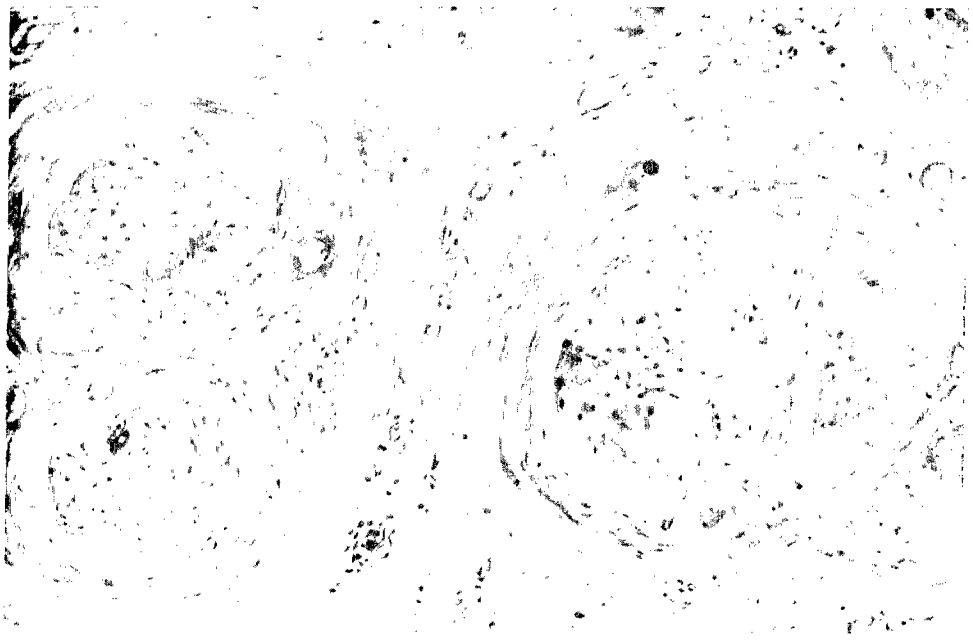

AFIP 81957

FIGURE 54. Sclerosis of nerves in late case of trenchfoot. The nerve bundles are embedded in dense fibrous tissue. Hematoxylin and eosin stain. (× 175)

Bones. The single specimen of bone, a section of the middle phalanx of a toe, available for study soon after exposure revealed no significant abnormality. In specimens from late cases, areas of osteomyelitis were observed adjacent to areas of cellulitis. The inflammatory exudate had occasionally undermined and eroded articular cartilages, but, except in these areas, there was little evidence of resorption or of osteoclastic activity. There was also no evidence of sequestration. Necrosis of bone had occurred near the zone of demarcation, and osteocytes had disappeared from the lacunae. A sharply defined layer of viable bone surrounded the dead lamellae. In some areas adjacent to necrotic trabeculae, numerous osteoblasts were actively laying down new bone (fig. 55). In some of these areas, the bone marrow was necrotic or was involved in the osteomyelitic process. In other areas, serous atrophy was present, with fibrosis, hemorrhage, and infiltration of inflammatory cells. Occasional small oil cysts were noted, and there were many foci of lipoid phagocytosis comparable to those observed in the subcutaneous panniculus. The altered bone marrow contained an increased number of thin-walled, dilated blood vessels.

Summary. The essential early change in trenchfoot which Friedman's studies revealed was thus a disturbance in the circulatory mechanism; namely, the consequent stagnation of blood leading to thrombosis and, subsequently, to gangrene. In many ways, the gangrene resembled ordinary peripheral ischemic necrosis complicated by secondary infection. There were, however,

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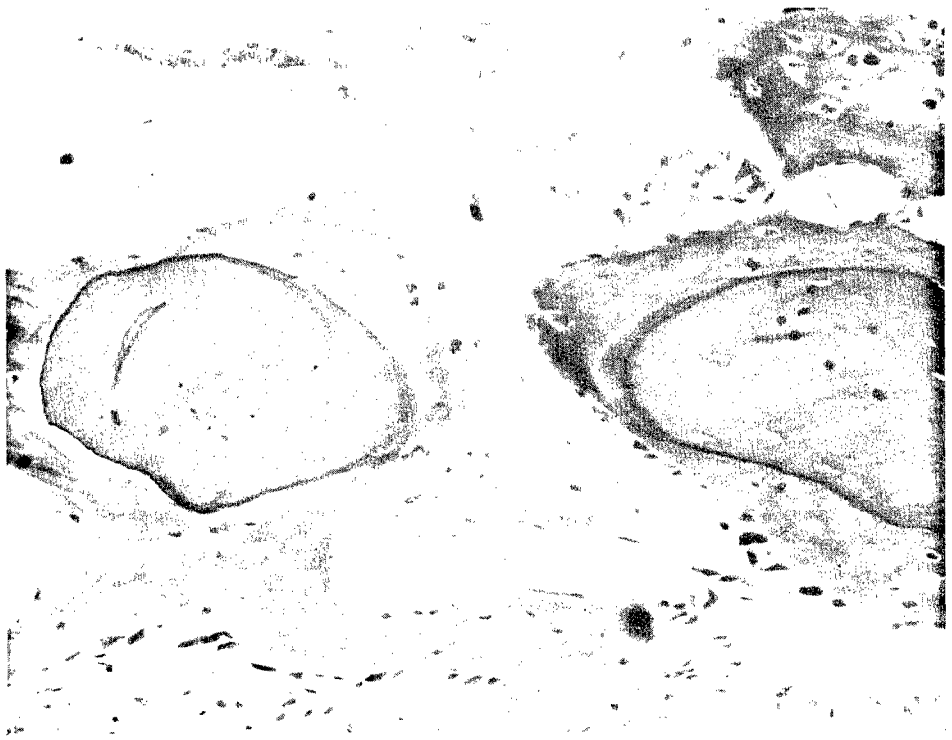

AFIP 81960

FIGURE 55.—Necrosis of bone. Dead trabeculae with empty lacunae have been sheathed by viable bone. Osteoblasts line the newly formed trabeculae. The marrow is fibrotic. Hematoxylin and eosin stain. (× 145)

certain unusual features. Particularly notable were the agglutinative thrombosis, the profound changes in the fatty tissues, and the interesting neuromuscular and osseous alterations. While Friedman regarded most of the changes, whether superficial or deep, as secondary to vascular occlusion, he called attention to a possible direct thermal effect on structures rich in lipoids, especially adipose tissue and myelinated nerve fibers. The nerve fibers, he thought, might have a special susceptibility to cold.

Friedman suggested two essential lines of future morphologic investigation to clarify the pathogenesis of trenchfoot: (1) Investigation of the early changes in the myelin sheaths and the fat of the subcutaneous panniculus to determine whether tissues rich in lipoid are especially sensitive to cold and (2) detailed examination of the sympathetic fibers which supply blood vessels and of the arteriovenous anastomoses to determine whether the initial lesion of cold injury is vascular or neural.

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CHAPTER X

Clinical Picture and Diagnosis

GENERAL CONSIDERATIONS

The symptoms and signs of cold injury, while they have always been of the same general character in all recorded wars, have varied in degree from area to area and person to person in relation to the severity of weather conditions, the duration of exposure, the extent of tissue damage, the length of time the man has remained in the line after his initial injury, and the kind of treatment he has received between the first point of triage and the first medical installation in which he has received definitive therapy. It has been the universal experience that, if the casualty could not be evacuated by litter or ambulance, the trauma of walking, particularly over rough ground, has increased the severity of symptoms, the extent of tissue damage, and the period of incapacitation.

In general, the symptoms, signs, and clinical progress of cold injury may be summarized about as follows:

The initial symptoms variously include numbness, tingling, and a feeling that the feet have become wooden. Walking may be impossible, or the man may complain that he is unable to feel his feet moving when they touch the ground as he walks. In other instances, there may be dull or severe drawing pain in the feet and in the back of the legs. There is a universal complaint that the feet are cold. At this time, examination shows the skin mottled and the color light bluish gray. Edema and blister formation may or may not be present. This is the composite picture in the ischemic stage.

In the more severe cases, the next symptom is exquisite pain on touch or on exposure to warmth. The feet are swollen, flushed, dry, hot, tense, and shiny. The edema present is of the pitting variety. Blisters are frequent, and intracutaneous ecchymosis may be pronounced. This is the composite picture of the hyperemic stage. Soldiers in World War II frequently called it the "hot foot" stage.

As edema subsides, hyperthermia decreases. Blisters break. The surface layers of skin begin to desquamate. The ecchymotic areas turn black and become hard and mummified. The appearance of the lesions suggests dry gangrene. This is the composite picture of the posthyperemic stage.

If ecchymosis has involved the deeper areas of the skin, particularly under heavy callous formation, exfoliation may not be complete for a month or more. The nails are sometimes lost, and entire casts of the toes may be shed. As the mummified layers peel off, the underlying skin appears normal but proves to be

extremely delicate. The soldier is unfit for any kind of duty until the plantar surface of the foot and other areas exposed to friction are covered with cornified skin. It was the universal experience in World War II that when a soldier had lost the superficial skin on the sole of his foot, he was unlikely to return to duty for a considerable period of time, if ever.

In World War II, the incubation or lag period of cold injury, from the beginning of exposure to the first clinical manifestations of damage, averaged 3 days. It varied, however, from person to person, and was greatly influenced by what had happened during the period of exposure. If the soldier were pinned down in a state of immobility, exposure of even a few hours might give rise to extremely severe injury. If he were fully ambulatory and especially if he had had opportunities to dry his feet, massage them, and change wet socks for dry, his injury was likely to be mild, or he might escape injury altogether. Surprisingly, insignificant factors sometimes weighted the scale in one direction or the other. Experiences are recorded in which the man who left the foxhole daily to secure the rations for his comrades escaped intact while the other soldiers in the same foxhole all sustained cold injury.

Although the clinical picture of trenchfoot was essentially the same wherever the condition was observed, there were certain variables in each theater which influenced the symptoms and signs. It therefore seems worthwhile to present the observations from each area separately, even at the cost of some repetition.

THE ALEUTIANS

The first clinical description of cold injury sustained in combat in World War II concerned the casualties from the Attu campaign.[1] The men, because of the circumstances of this campaign, were cared for in field hospitals and were then evacuated as soon as possible by hospital ships, chiefly to the 183d Station Hospital and then to general hospitals in the United States. The following description is a composite of the data secured at the 183d Station Hospital, Fort Richardson, Alaska; McCaw General Hospital, Walla Walla, Wash.; McCloskey General Hospital, Temple, Tex.; and Letterman General Hospital, San Francisco, Calif.

Clinical manifestations were unusually prompt and often very severe in the Attu campaign. Within 12 to 14 hours after exposure to wet cold, many of the men affected began to complain of throbbing, tingling, and cramping pain in the feet. There were also frequent complaints of cramps in the muscles of the calf. Numbness became progressively more troublesome, and many soldiers said that they felt as if they were walking on wooden feet. Some could not walk at all. Only 40 soldiers in a provisional battalion consisting of more than 350 men were

[1] (1) Annual Report, 183d Station Hospital, 1943. (2) Lesser, A.: Report on Immersion Foot Casualties fron the Battle of Attu. Ann. Surg. 121: 257–271, March 1944. (3) Patterson, R. H.: Effect of Prolonged Wet and Cold on the Extremities. Bull. U. S. Army M. Dept. No. 75, pp. 62–70, April 1944. (4) Orr, R. D.: Report on Attu Operations, May 11–June 16, 1943.

able to walk at the end of 5 days; over the same period, the number of killed and wounded in action amounted to only 30. Many of the men presented extensive lacerated, ulcerated lesions of the knees that they had sustained from crawling over the ground because the terrain and the tactical circumstances had made litter evacuation impossible.

When the boots were removed, it was usually impossible to replace them, swelling of some degree being present in practically every case. The appearance of the feet varied from man to man. Sometimes they were blue, or mottled blue and white, and the soles were waxy white. Sometimes they were red and hot. Sometimes they were blistered; in such cases, swelling was intense.

McCaw General Hospital.—Twenty-five men received at McCaw General Hospital about 3 weeks after they had been removed from combat presented particularly severe clinical manifestations. Some of them (p. 93) had gone to Attu by submarine and had averaged 10 days without a change of shoes or socks. They had been practically without food during their 6 days in action, and they had had no real physical rest or sleep. They became wet almost as soon as they landed, and they were constantly exposed thereafter. Nine of them had battle wounds of varying severity.

Aside from general fatigue, exhaustion, and numbness and discomfort in their feet, these men had had little actual pain until their shoes were removed. Then there was an immediate onset of pain and swelling, and, within 6 to 12 hours, areas of blackish discoloration were observed, followed by gangrene, which in some instances promptly became infected. When they were received at McGaw General Hospital, all of these men seemed physically exhausted. Both the red blood cell count and the hemoglobin level were lowered, and the white blood cell count was sometimes moderately, and sometimes greatly, increased. The most severe cold injuries were associated with septic temperature elevations. In the other cases, the temperature elevations were low grade.

When the fingers were affected, numbness was seldom experienced earlier than 3 days after exposure, in contrast to the frequent onset of symptoms within 6 to 12 hours when the feet were affected. The longer timelag was probably to be explained by the opportunities to exercise the hands, even when the men were immobilized by enemy fire, and the consequent maintenance and stimulation of the circulation. Hypesthesia was a usual complaint. Physical findings included desquamation of the fingertips, slight swelling, and hyperesthesia. The coloration was likely to be mottled and cyanotic. Gangrene was exceptional. There was no record in the Aleutians of the type of case reported from other theaters in which there were complaints of transient paresthesia and hypesthesia of the fingertips but in which edema and color changes did not develop.

McClosky General Hospital.—At this time, there was no standard system of grading cold injuries, and the various hospitals developed their own systems. Some merely divided the cases into early and late groups, depending upon the

time at which the patients were received. At McCloskey General Hospital, which had received 121 casualities with trenchfoot from Attu by 10 July 1943, four degrees of injury were recognized. First-degree injuries were characterized by small patches of damaged skin, without peeling or blistering. Second-degree injuries were characterized by damage to the superficial cutaneous layers, with associated peeling or blistering. Third-degree injuries were characterized by the loss of thick layers of skin and, occasionally, of subcutaneous tissues also. Fourth-degree injuries were characterized by gangrene of a part or the whole of an extremity.

Letterman General Hospital.—At Letterman General Hospital, three clinicopathologic groups were recognized, in addition to minimal, first-degree injuries, for which hospitalization was not required:

Patients with second-degree injuries suffered from smarting, tingling, and throbbing sensations in the feet rather than true pain. These sensations, while chiefly limited to the toes, were often present in the ball of the foot also. Patients in this group were further classified into three clinical subgroups. About 45 percent had a mild type of injury. The feet were only slightly swollen, or were not swollen at all, and sensory changes were limited to hypesthesia. Pulsations in the feet were good. About a third of the men had cold, sweaty, slightly swollen feet, with areas of anesthesia. One or more of the normal pulsations was absent. The remaining patients, who represented about a quarter of the total number, presented extensive areas of desquamation. The feet were dry, very warm, flushed, and edematous and became congested on dependency. Most of the foot was anesthetic.

Patients with third-degree injuries presented areas of superficial destruction. Thick layers of skin and subcutaneous tissues became necrotic, nails were frequently lost, and, in numerous instances, the tips of the toes were also lost.

Patients with fourth-degree injuries presented true gangrene, with loss of the greater part of one or more of the toes and, occasionally, loss of the whole foot.

All the patients in the third and fourth groups complained of burning pain, most severe at night and most often located in the toes. They also complained of aching, pulling, or cramping sensations in the foot or in the muscles of the calf. Hypesthesia was invariably present. It began at the ankle and increased to complete anesthesia as the toes were approached. The degree of anesthesia was usually, though not always, proportional to the degree of tissue damage. In two instances of severe gangrene, in both of which the entire foot had to be amputated, sensation was comparatively unaltered almost to the line of demarcation. In contrast, many patients with only moderate degrees of desquamation had almost complete anesthesia of all the toes. How complete the loss of sensation was in these cases is evident from the fact that in most of them it was possible to perform debridement and amputate the gangrenous toes without any anesthetic at all.

THE MEDITERRANEAN (FORMERLY NORTH AFRICAN) THEATER

Simeone,[2] who studied cold injury in the North African theater from the time the first cases appeared in November 1943, recognized three clinical stages, the preinflammatory, the inflammatory, and the postinflammatory. The postinflammatory stage was further divided into an early and a late stage. Edwards and his associates [3] recognized four classifications of injury in the 351 patients whom they observed at a general hospital.

Special Investigation

In the preinflammatory (prehyperemic, ischemic) stage (plate 2A and B), the soldier's first warning of trouble was that his feet felt cold and numb. Then he began to experience aching pain in the ankle and the arch of the foot, with tingling, lancinating pains when he put his weight on his feet. Sometimes these pains radiated to the groin. Later, the only complaint might be stiffness and numbness of the feet, which made him feel as if he were walking on blocks of wood. Ataxia might be severe and incapacitating, and only the soldier who had not been instructed in the dangers of cold injury and whose pain was minimal would be likely to continue on duty for several days longer before he reported sick. During this time, irreparable damage to tissue might occur, as the following case history indicates:

Case 1.—A 25-year-old soldier, who had lived in New Jersey all his life, had no previous history of frostbite or circulatory disturbance. His company was exposed to wet cold on a hillside in Italy from 4 December through 9 December 1943. The ground was continuously wet and muddy. There was no snow in the immediate vicinity, but the tops of neighboring mountains were snow covered. There was frost on the ground every morning, and, during one night, the water in his canteen became partly frozen. During the daytime, he moved about as much as possible. During the night, he slept in a foxhole, in a cramped position. He subsisted on K rations, with nothing hot to eat or drink, during the 5-day period of exposure. At first, he wore two pairs of light-weight (35 percent) wool socks. They became wet almost immediately, and, when he changed to dry socks on the third day, they also became wet almost as soon as he had put them on.

When he changed his socks on the third day, there was nothing wrong with his feet. On the fourth day, he first noticed numbness in the toes. On the fifth day, the greater part of the foot was affected, and his knees, ankles, and toes were stiff. He noted that he was unable to walk in a straight line.

The company was relieved from duty on 9 December at 0200 hours. When the bivouac area was reached, the man went promptly to the kitchen, where he ate a hot breakfast while seated about 4 feet from a hot gasoline range. When he sat down, he had no complaints except stiffness and numbness. When he rose from his seat to report to the dispensary because of the condition of his feet, he was unable to walk and had to be carried to the medical officer. At this time, the left shoe came off easily and could be replaced readily, but the toes looked dark.

[2] Report, Lt. Col. Fiorindo A. Simeone, MC, to the Surgeon, Fifth U. S. Army, subject: Trenchfoot in the Italian Campaign, 1945.

[3] Edwards, J. C., Shapiro, M. A., and Ruffin, J. B.: Trench Foot. Report of 351 Cases. Bull. U. S. Army M. Dept. No. 83, pp. 58-66, December 1944.

The patient was removed by ambulance to a clearing station, where both shoes and socks were removed, and thence to an evacuation hospital. Here his feet became progressively more swollen. Within 24 hours, blisters were present on both feet, and the right foot and leg were red and edematous to the knee.

When the man reached a general hospital, 48 hours after leaving the line, both feet were red, swollen, and blistered, and edema on the left side now extended above the knee. Both feet felt numb. Pulses on both sides were bounding. On this day (11 December), the morning temperature was 102.8° F. (39.3° C.) and the evening temperature 103.2° F. (39.6° C.). The morning pulse rate was 108 and the evening rate 78. Sulfadiazine was begun by mouth.

The following day, both morning and evening temperatures were 102.4° F. (39.1° C.) and the pulse rates were, respectively, 144 and 120. The blood-glucose level was 162 mg. percent. On 13 December, the morning temperature was 100.2° F. (37.9° C.) and the afternoon level 102.2° F. (39.0° C.); the pulse rate was constant at 92; the blood-glucose level was 125 mg. percent.

Edema began to subside on 14 December. The skin over both shins was shiny and wrinkled (fig. 56). There were large blisters on the dorsal and plantar surfaces of both feet (plate 2 C and D). The areas which were not blistered were hot and dry. Both dorsalis pedis pulses were palpable. The toes were anesthetic, and motion in them was feeble. The patient complained of very little pain. The blood-glucose level was 115 mg. percent.

A phenolsulfonphthalein test of renal function on 15 December showed a total excretion for 2 hours of 53.8 percent; no dye was excreted during the first 30 minutes after injection. A glucose-tolerance test showed decreased tolerance (147 mg. percent at the end of 3 hours, as contrasted with a fasting level of 98 mg. percent). The nonprotein nitrogen of the blood was 30.4 mg. percent and the serum-protein concentration 9.8 gm. percent.

On 16 December, the non-protein-nitrogen level was 45.3 mg. percent. Urinalysis 17 December showed no abnormality. The serum-protein concentration was 8.96 gm. percent. On 18 December, the white blood cell count was 6,200 per cubic millimeter. On 19 December, it was 9,950 per cubic millimeter, and the serum-protein concentration was 8.8 gm. percent. The sulfathiazole blood level on 16 and 17 December was 1.3 mg. percent.

On 22 December, under Pentothal Sodium (thiopental sodium) anesthesia, the right leg was amputated 8 inches below the knee. The wound was sutured, but drainage was instituted. There was no reaction to the operation, and on 27 December, under spinal analgesia, five toes were removed from the left foot, by disarticulation at the metatarsophalangeal joints.

PLATE 2.—Various stages of trenchfoot. A. Preinflammatory stage of trenchfoot observed in clearing station, after 5 days' exposure to wet and cold near Rapido River, Italy, and directly after removing wet shoes for first time. The feet are still wet and cold, but edema has not yet begun to develop. Note coarse mottling of skin. B. Early inflammatory stage of trenchfoot observed in field hospital near front after 4 days of continuous exposure to wet cold. The trousers and underwear are still wet. The feet are warm and dry. Edema is beginning to develop in the left foot. C. Early inflammatory stage of severe trenchfoot. Detail of blisters and gangrene. In this case, the pulses in both dorsalis pedis arteries were bounding. This soldier had been exposed to wet cold, without snow, between 3 and 9 December 1943. The water in his canteen partly froze during one night. D. Inflammatory stage of severe trenchfoot in same case shown in view C. This photograph was taken after 2 weeks of hospitalization. Blisters are still present, along with gangrene. Only the toes were lost on the left foot, but amputation of the right leg below the knee was required. E. Late postinflammatory stage of trenchfoot without loss of tissue. Note cyanosis, probably resulting fom venular dilatation and arteriolar constriction in area affected by cold. Note also suggestive boot pattern. This foot is typical of the postinflammatory stage of trenchfoot from 4 to 8 months after injury.

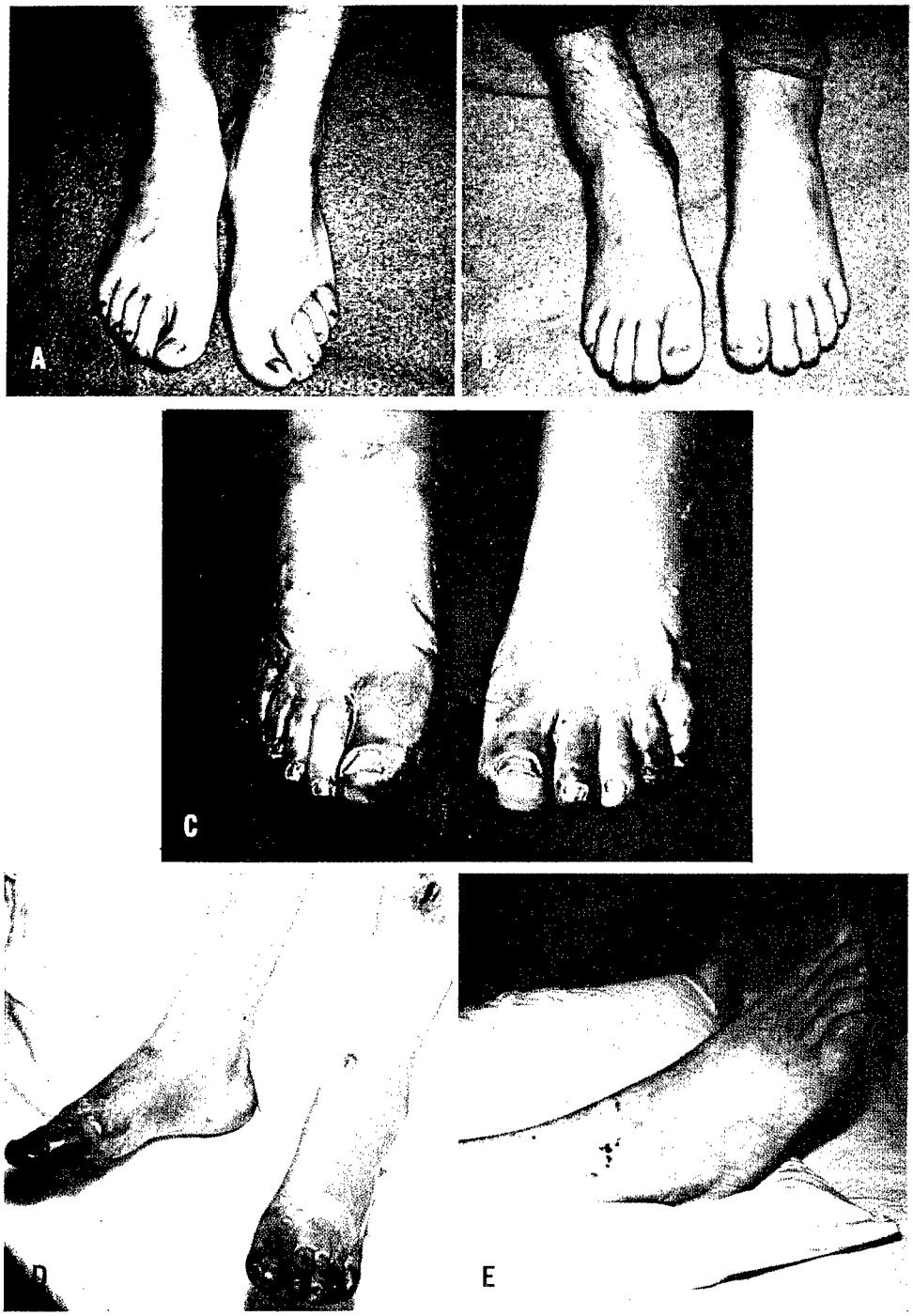

PLATE 2.—*(See opposite page for legends.)*

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FIGURE 56.—Subsiding inflammatory stage of trenchfoot. Note shrivelling of blister over right great toe and wrinkling of skin. In this patient, the dorsalis pedis pulses were bounding, and the skin was red, hot, and dry.

The white blood cell count on 22 December, just before the first operation, was 15,000 per cubic millimeter. The following day, it was 9,950 per cubic millimeter, and the serum-protein concentration was 8.8 gm. percent. On 27 December, just before the second operation, the white blood cell count was 15,000 per cubic millimeter. It was 17,300 on 23 December and at practically the same level on 24 December. Daily urinalyses showed no abnormalities. On 27 December, the sulfathiazole level was 1.5 mg. percent and the serum-protein concentration was 9.2 gm. percent.

On 29 December, when the sutures were removed from the right stump, healing was found to be fairly satisfactory. The heads of the metatarsal bones were exposed in the left foot, and the dorsalis pedis pulse on this side was of greater than normal volume. The patient's physical status and the laboratory data were substantially unchanged when he was evacuated to Africa on 4 January 1944.

This was a typical case of severe trenchfoot, except in one respect, that pain was never a major complaint. There was considerable systemic reaction, as evidenced by fever early in the course of the disease, but leukocytosis was not observed until after amputation of the leg. The evidence of depressed renal function is interesting, but the results of a single test cannot be regarded as significant. The non-protein-nitrogen concentration in the blood was within the upper limits of normal. There is no apparent explanation for two unexpected findings; namely, hyperglycemia early in the illness, with depressed glucose tolerance, and the increased concentration of protein in the serum. It is possible that if amputation had been postponed longer in this case more of the right leg might have been saved.

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Simeone's first observations on trenchfoot were made in November 1943, in a battalion aid station and in clearing and collecting stations on the Italian Front. All of the men had been exposed to wet cold for periods ranging from 4 to 15 days, with an average of 6 days. The weather at this time was not unduly severe, and the opinion was expressed that, as rain and cold increased, symptoms would ensue within shorter periods of time. This proved true during the following winter, particularly at times when the temperature was near freezing between midnight and sunrise but rose to 50° F. (10° C.) during the day, with consequent thawing of the ground.

On the initial inspection, the feet of these first casualties were wet, cold, and numb. Variable degrees of pallor and purple mottling were observed. Edema, if it was present at all, was slight. Whether it was or was not present at this time apparently depended, at least in part, upon whether or not the feet had been warmed during the course of the exposure. Questioning of the men revealed that the swelling was most likely to develop during the warmer parts of the day. If the shoes were removed then or if they were removed after swelling had already occurred, it was often impossible to replace them.

Not infrequently, casualties were unaware during the preinflammatory stage of trenchfoot that there was anything wrong with their feet. In 125 cases studied by Boland and his associates [4] during one period of the fighting in Italy, 8 percent of the patients stated that they had not known that their feet had been injured by cold until they reported to the aid station for treatment of wounds or other unrelated conditions. This lack of awareness of the injury was sometimes a serious matter, not only because treatment was delayed but also because the man remained on his feet and thus sustained additional trauma.

The ischemic or preinflammatory stage of trenchfoot usually lasted only a few hours after the shoes had been removed and the feet had been dried. In an occasional case, in which there was severe spasm of the larger arteries or in which actual thrombosis had occurred, it lasted considerably longer. In the following (fatal) case, this phase lasted 3 days in one leg and 4 days in the other:

Case 2.—A 22-year-old soldier, on 6 January 1944, was obliged to cross a river that in midstream was over his head. Just as he reached the opposite bank, at 0900 hours, he was felled by shell-fragment wounds of both thighs and a compound comminuted fracture of the right femur. For the next 26 hours, until aidmen could reach him, he lay as he had fallen, wet and cold. At the aid station, his right leg was splinted, and he was given 500 cc. of plasma. When he was received at an evacuation hospital on 7 January at 1500 hours, the diagnosis was recorded as bilateral severe immersion foot, bilateral severe frostbite of the hands, moderately severe penetrating wounds of both thighs due to shell fragments, and severe compound comminuted fracture of the right femur.

Within the first 6 hours after he was admitted to the evacuation hospital, the patient received 1,500 cc. of blood, of which 250 cc. was mismatched; it was type A and he was type O. There was no noticeable immediate ill effects from the error. Nine hours after admission, the blood pressure was 130/90 mm. Hg and the pulse 110. The hands were cold, cyanotic, and edematous, but both radial pulses were palpable. The feet were cold, numb, and cyanotic, but were not swollen. The dorsalis pedis and posterior tibial pulsations were palpable in both feet.

[4] Boland, F. K., Claiborne, T. S., and Parker, F. P.: Trench Foot. Surgery 17: 564–571, April 1945.

At 0400 hours on 9 January, the wounds were debrided, and a long hip spica was applied. The patient's condition was excellent after operation.

The following day, the left foot was blue and ice cold, and mottling was present from the toes to the malleoli. Edema extended up to the knee but was most pronounced in the foot, in which no pulsations could be felt. The calf was moderately tense. On the right side, the tips of the toes were blue. The forepart of the foot, to the midtarsal region, was mottled and bluish white. Edema was moderate and did not extend to the leg, which was cool. The dorsalis pedis and posterior tibial pulsations were not palpable on this side.

The left hand was blue, and motion was feeble in the fingers, though they were warm. There were large bullae filled with clear fluid on the dorsal aspect of the hand. The radial pulse was normal. Both cyanosis and edema were more pronounced in the right hand. The fingers, except for the thumb, were cold. There were bullae on the dorsal aspect of the hand. The radial pulse was normal on this side also.

On 11 January, the left foot was warm, except for the toes, but continued to be edematous and cyanotic. Bullae were present on the plantar surface (fig. 57). The patient complained of pain when the foot was covered by blankets. The right foot also continued to be cold, anesthetic, mottled, and cyanotic, and edema was more pronounced. The leg was warm down to the malleoli. The calf still felt slightly tense. Both hands were warm but were moderately edematous, cyanotic, and anesthetic and were covered with huge bullae (fig. 58). The right hand was more extensively involved than the left. Both hands and feet were protected by sterile dressings.

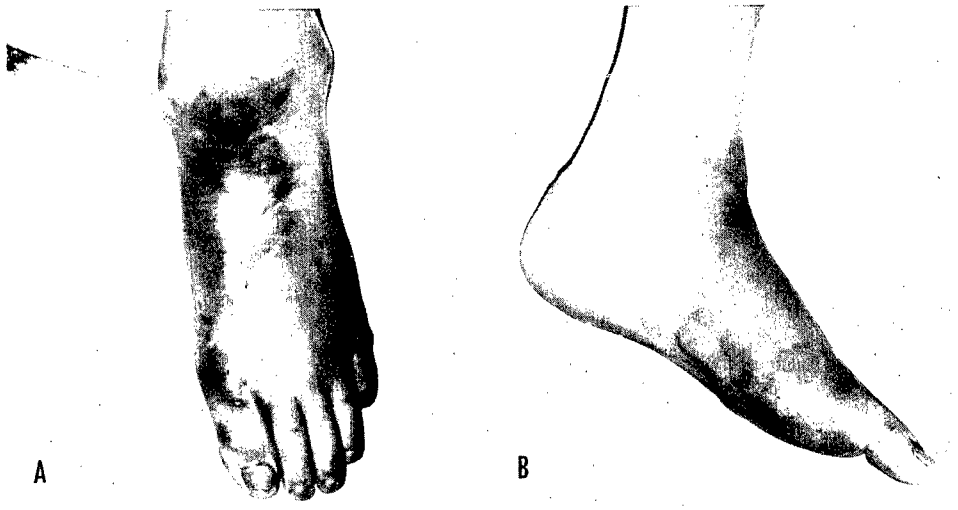

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FIGURE 57.—Trenchfoot third day after exposure. Ischemia had persisted up to this time, and the discoloration of the skin suggested impending gangrene, though the foot was warm and dry. A Dorsal view. B. Lateral view. Note blister on plantar surface.

Urinalysis had been negative until 11 January. On this day, two specimens were amber and contained albumin (1 to 3 plus). The concentration of nonprotein nitrogen in the blood was 174.8 mg. percent.

On 12 January, the toes on the right foot were somewhat less cyanotic, but they were cold and motionless. Urinalysis showed 2 plus albumin and 1 to 4 white blood cells per high-power field. The color was clear amber. The following day, two specimens showed 2 plus albumin but were otherwise negative.

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FIGURE 58.—"Trench hands" after 3 days of hospitalization. Merthiolate (sodium ethylmercurithiosalicylate) has been applied to the skin about the blisters.

On 14 January, signs of heart failure were apparent, with gallop rhythm and Cheyne-Stokes respiration. Three urine specimens, one of which showed an alkaline reaction, were negative except for albumin (a trace to 1 plus) and 1 to 3 white blood cells per high-power field. The nonprotein nitrogen of the blood was 199.5 mg. percent. Two specimens examined on 15 January showed, respectively, 1 and 2 plus albumin. The following day, both specimens showed 1 plus albumin. Throughout the period of hospitalization, the daily urinary output had ranged from 1,200 to 2,000 cc., and the specific gravity had varied from 1.014 to 1.021.

On 16 January, the patient became progressively drowsier and weaker. Physical examination revealed hepatomegaly and pulmonary congestion. Digitalization was not effective, and death occurred on this day. Autopsy revealed bilateral pulmonary edema, hydrothorax, pneumonia of the left lower lobe, and passive congestion of the liver. Microscopic examination revealed pigment nephropathy. The pheripheral vessels revealed multiple thrombi and acute inflammatory changes, and the anterior tibial muscle showed degenerative changes and necrosis.

This case is of interest for several reasons. The cause of death, uremia without anuria, can most reasonably be attributed to the transfusion of 250 cc. of mismatched blood, even though no untoward clinical reaction seems to have occurred after it. The prolonged period of exposure, however, may have played some part in the development of renal insufficiency, and prolonged shock may also have played a part. The case was additionally complicated by ischemia of the left leg, which was sufficient to cause degeneration and

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necrosis in the anterior tibial muscle, as shown by histologic examination of sections after death. It is possible that the muscle necrosis had the same effect on the kidneys as crushing injuries which cause renal damage. Histologically, it is impossible to differentiate these conditions on the basis of renal changes. Finally, the patient lay on cold, wet ground for 26 hours, and the ischemic stage was unusually prolonged. The feet remained cold on the left side for 3 days and on the right side for 4 days after hospitalization. Although it was then general policy in the North African theater to employ active measures to promote the circulation in the feet in cases such as this, these measures were omitted in this particular instance.

Classification

Inflammatory stage.—In some cases of cold injury observed in Italy, the ischemic stage was mild and transitory, no detectable second or inflammatory stage ensued, and casualties could be promptly returned to duty from the clearing station or evacuation hospital. This was not the usual experience. In most instances, the inflammatory stage was clear cut and lasted at least a week. In many cases, it lasted 2 weeks, and it sometimes lasted as long as a month. In 25 of the 50 cases studied intensively early in the cold injury experience in Italy, the inflammatory stage lasted about a week. Practically all of the 50 patients had passed into the postinflammatory stage by the third week of hospitalization. In no patient in the group did the inflammatory stage last longer than a month.

Patients in the inflammatory or hyperemic stage of trenchfoot were sometimes seen in clearing stations (fig. 59) but were usually first seen in evacuation hospitals. The story was generally the same. Within an hour or two after the shoes had been removed and the feet had become warm and dry, the feet began to swell, even though the patient was recumbent. Within the course of the next few hours, they became hot, dry, red, and painful, thus presenting all the classical signs of acute inflammation. At this time, the dorsalis pedis pulse was easily palpable and was usually increased in volume.

The patients complained of tingling pain when the feet first became warm. As they became warmer, burning, throbbing pain ensued, and discomfort was extreme. External heat was intolerable, and the feet were most comfortable when they were exposed to cold air. The affected parts were extremely sensitive and tender to palpation except for portions of the toes, particularly the tips and the plantar surfaces, which were likely to show hypesthesia and anesthesia. Often, however, hyperesthesia was present and might be so severe that even light bed coverings could not be tolerated. Small, patchy areas of ecchymosis appeared at pressure points (plate 3A).

Clinical progression could be correlated with the severity of the injury. In the mildest cases, inflammatory signs reached a maximum during the first 24 hours of hospitalization, then rapidly subsided (plate 3B). Areas of super-

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FIGURE 59.—Inflammatory stage of trenchfoot 2 days after exposure. Swelling was slight in the right foot and moderate in the left. Although this man's combat trousers and underwear were still wet, his feet were dry.

ficial thrombosis were sometimes seen. In the severe cases, symptoms and signs were progressive for 48 to 96 hours. At the height of the inflammatory reaction in the most severe cases, usually between the fourth and sixth days, edema extended to the knee and was sufficient to obscure the pulses in the foot. When regression set in and edema began to disappear, the skin become finely wrinkled. The color, which was originally bright red, first became brownish

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PLATE 3.—Various stages of cold injury. A. Inflammatory stage of mild cold injury, 2 weeks after exposure. The edema has almost entirely disappeared, but areas of ecchymosis remain at points at which the feet and toes were presumably subjected to trauma by rubbing against the shoes or by pressure from them. B. Early cold injury, in which inflammatory stage was practically over by the end of the first week after exposure. Edema had lasted only 2 days. Note superficial gangrene of left fifth toe, rather marked cyanosis over fifth metatarsophalangeal joint, and slighter cyanosis over base of fifth metatarsal bone. These areas of injury to the skin can be attributed to close contact with the shoe, which rendered cold a more effective injurious agent than it was in parts of the skin in less direct contact with the shoe and the environment. Exposure in this case was in the hills about Venafro, Italy; the temperature was never below freezing. C. Early postinflammatory stage of cold injury. Note especially desquamation of superficial layers of skin, with exposure of atrophic skin beneath. D. Late stage of cold injury, about 6 months after exposure to nonfreezing cold. Note sequelae of injury in skin and nail of right fifth toe. The skin is very delicate, soft, warm, and moist. Hyperhidrosis occurs in feet such as this, particularly after marching, and maceration of the skin, with trichophytosis, is a frequent complication. E and F. Plantar and dorsal views of feet during late inflammatory stage of cold injury 1 month after exposure. Gangrenous (partial-thickness) skin has separated, and islands of residual viable skin remain to epithelize the surface. The toes were gangrenous throughout and eventually had to be amputated. The case illustrated, however, that even what appears to be extensive gangrene may be only skindeep and that a major amputation can usually be avoided.

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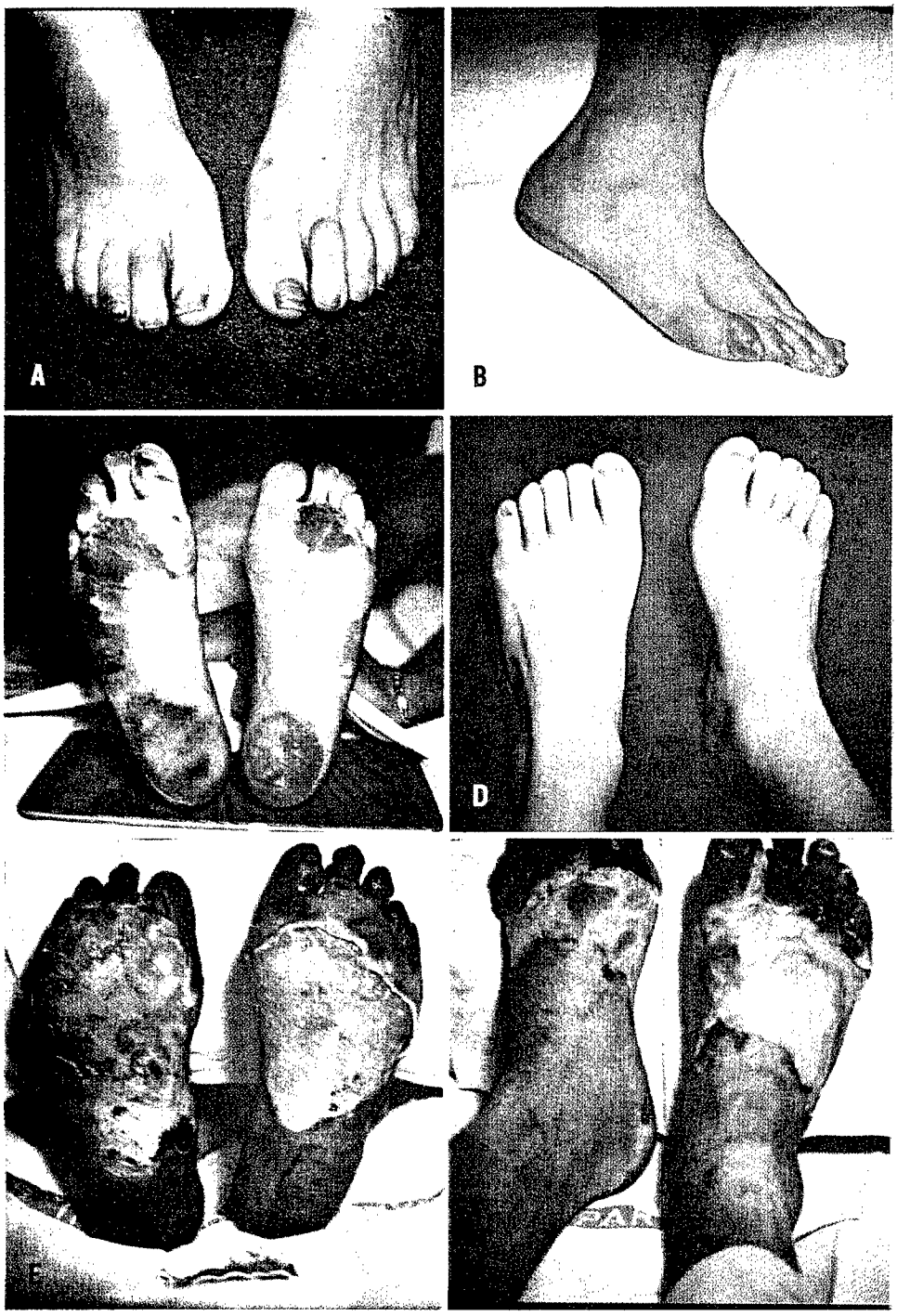

PLATE 3.—*(See opposite page for legends.)*

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and then faded to normal. The dorsalis pedis pulse became less bounding. Exfoliation usually occurred, revealing delicate underlying skin (plate 3C).

In the most severe cases of trenchfoot, blister formation and signs of circulatory insufficiency became apparent early in the second stage. They were sometimes present when the shoes were removed. The blisters usually contained clear fluid, though it might be hemorrhagic. In some cases, small areas of redness and induration appeared during the first week of the inflammatory stage. Acute tenderness was complained of on palpation, and the whole clinical picture was suggestive of cellulitis. Impending gangrene sometimes progressed to frank gangrene within 48 hours.

The clinical progress of the 50 patients with trenchfoot included in the initial survey can be summarized as follows:

At the end of the first week of hospitalization, 51 of the 100 feet were edematous. The edema was pitting in slightly more than half of the extremities and was slight in the remainder. Initially, it had been slight in nine cases. At the end of the second week, 45 feet were still edematous, but the edema was now slight in 37 of these. At this time, it was unilateral in 7 cases and was of the same degree on both sides in only 8 of the bilateral cases (plate 3D). At the end of 3 weeks, pitting edema was not present in any case, but 18 patients still had slightly edematous extremities. Subsequent observations on much larger numbers of patients showed substantially the same distribution of edema.

After a week of hospitalization, 46 of the 100 feet were warm. In 31 extremities, edema was associated with the warmth; 11 were moist and 20 dry. Of the 15 warm feet without edema, 7 were moist and 8 dry. Of the 54 cold feet, 20 showed edema; 7 of these were moist. Of the 34 cold feet which showed no edema at this time, 14 were moist.

At the end of 3 weeks, 44 of the 100 feet were warm. Of the 14 which still showed edema, 11 were moist. Of the 30 without edema, 23 were moist. Only 4 of the 56 cold feet still showed edema; 3 of the 4 were moist. Of the 52 cold feet without edema, 40 were moist.

In mild cases of cold injury, acute pain often disappeared by the end of the first week, leaving the patient quite comfortable thereafter. Much more often, the burning pain originally present was replaced by a deep-seated ache in the ankle, in the transverse and longitudinal arches, and in the metatarsophalangeal joints, particularly the proximal joint of the great toe. It was frequently observed that the intensity of residual pain was related to the degree of previous edema. Edema almost always disappeared more rapidly than pain.

Abnormal heat disappeared fairly promptly. At the end of a week, only 2 of the 50 patients first studied had extremely hot feet, and none of the feet were abnormally hot at the end of 3 weeks. Sometimes, however, there were extraordinary variations in temperature. While the patients were actually under observation, the feet would change in a few minutes from warm and dry to cold and wet, or vice versa. The variability was particularly marked at night, both in the late inflammatory stage and the early postinflammatory

stage. A patient would complain that he had wakened with his feet "burning up," and, when the nurse or ward officer on night duty investigated, it would be found that feet which had been cool during the day had become hot to palpation.

Gangrene sufficient to require amputation of the toes or of larger areas of the feet was uncommon (figs. 56, 60, 61, 62, 63, 64, 65) (plate 3E and F). It was estimated that gangrenous changes occurred in from 1 to 1.5 percent of the cases of trenchfoot which occurred in Italy during the winter of 1943–44, and in about 0.5 percent of the cases observed the following winter. Six percent of the 125 patients observed by Boland, Claiborne, and Parker presented some degree of dry gangrene, including minor degrees in which loss of tissue was superficial, but this figure must be interpreted in the light of the fact that these patients were part of a selected group returned to a Communications Zone hospital because of the severity of their injuries.

In his personal study of trenchfoot, Simeone observed only one patient who required amputation of more than the toes (case 1), though another (case 2) would probably have required amputation of the leg if he had survived. Investigation of the proceedings of theater disposition boards for a 5-month

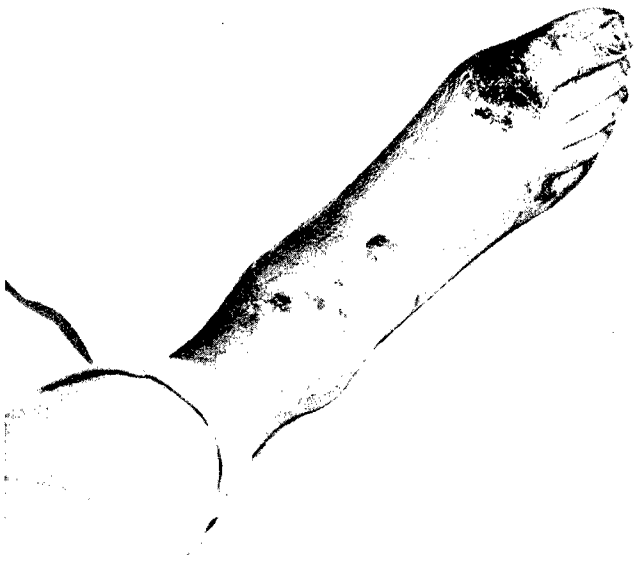

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FIGURE 60.—Postinflammatory stage of trenchfoot. Gangrene in this patient was superficial, and no amputation of tissues was necessary. Note small areas of gangrene on instep and anterior aspect of ankle; they represent points of pressure from shoe.

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FIGURE 61.—Late inflammatory stage of severe trenchfoot. Edema has almost entirely subsided. The skin was warm, dry, and scaling. Note location of gangrene, in tips of toes and over the prominence of the base of each great toe. It was thought that these particular areas represented areas of frostbite because they were in direct contact with the shoe and might have sustained freezing temperatures. The appearance of the remainder of the foot, however, was entirely typical of trenchfoot.

period in 1945 brought to light three other cases in which amputation of more than the foot was required:

Case 3.—A soldier who became separated from his unit just after landing at Anzio beachhead on 22 January 1944 wandered about a swamp for the next 8 days, continuously exposed to cold and wet. When he was finally hospitalized, both feet were seriously damaged. Gangrene affected all the toes and the distal halves of the dorsal surfaces of both feet. Alcohol packs were used to hasten demarcation. The lower third of the right leg was amputated on 25 March, under spinal analgesia, and on 5 April the lower third of the left leg was similarly amputated. Both wounds were sutured primarily. When this man appeared before the disposition board, which recommended evacuation to the Zone of Interior for additional care and final disposition, he had already been hospitalized for 91 days.

Case 4.—A soldier was admitted to an evacuation hospital on 17 February 1944, after having been exposed to cold and wet near Cassino for the preceding week. His feet first became painful on 13 February. When he was received in a general hospital on 23 February, both feet were swollen, blistered, and cyanotic (fig. 65). A definite line of demarcation gradually developed at the level of the malleoli in both legs. A staphylococcic infection of the gangrenous areas, which began to cause temperature elevations on 28 February, was controlled by sulfadiazine. The fever recurred, however, and dead tissue began to slough away as the result of secondary infection. A bilateral guillotine amputation was done at the junction of middle and lower thirds of both legs on 16 March, under ether anesthesia

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FIGURE 62.- Postinflammatory stage of trenchfoot. Note dry, scaly skin and dry gangrene, which was severest at tips of toes and margins of the great toes and the fifth toes. The center of the transverse arch, which is less likely to come into contact with the shoes, was affected less severely.

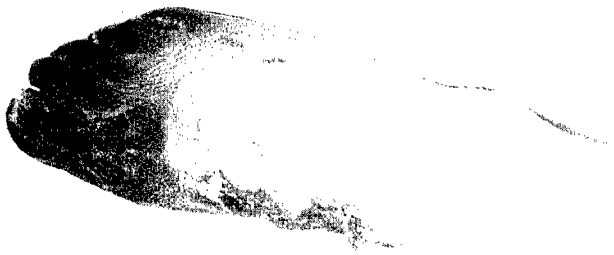

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FIGURE 63.—Early postinflammatory stage of severe trenchfoot. Note delicate skin beneath peeling, gangrenous superficial layer of epidermis, 5 weeks after exposure.

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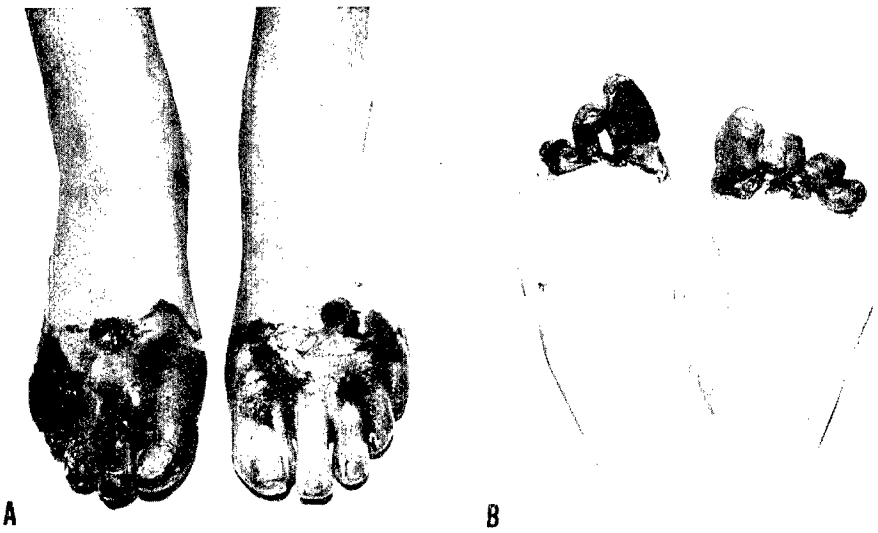

AFIP CA-44-131, CA-44-176

FIGURE 64. Subsiding inflammatory stage of trenchfoot. The right foot, on which the process was more severe than on the left, was treated by the local application of ice cold packs for a few days. The left foot was used as a control. A. Appearance of feet immediately after therapy. B. Feet shown in view A 4 weeks later. A better result had been expected, on the basis of the initial appearance of the feet. The wet ice treatment was considered of no value.

Skin traction was applied. The postoperative course had been uneventful up to the time the patient was returned to the Zone of Interior for further treatment and disposition.

Case 5. -This patient was admitted to an evacuation hospital on 15 February 1944, after having spent most of the previous week in a foxhole half filled with water. His feet were swollen and painful when he was first seen. Later, he became extremely toxic, and, when he was received in a general hospital, there was wet gangrene of the left foot, with a line of demarcation just below the malleoli, and both wet and dry gangrene of the forepart of the right foot. The lower third of the left leg was amputated on 27 February, and at the same time the right foot was amputated distal to the talus. When the patient appeared before the disposition board, which recommended evacuation to the Zone of Interior for further care and disposition, he had already been hospitalized for 24 days.

Postinflammatory stage.—The postinflammatory (posthyperemic) stage of cold injury began with the disappearance of signs and symptoms of inflammation. The foot, instead of being hot and dry, was now cool or cold and moist. Cyanosis was common when the feet were dependent (plate 2E). The dorsalis pedis pulse, instead of being bounding, was often not palpable at all. Patchy areas of cyanosis frequently remained, suggesting local thromboses. Occasional patients complained of hyperirritability and spasm of the muscles of the leg, the spasm being either spontaneous or readily invoked by ischemia. Burning pain was replaced by a deep-seated ache, much like the aching pain of rheumatoid arthritis. It was usually worse at night. It was most commonly located in the metatarsophalangeal joints, particularly in the great toe, but

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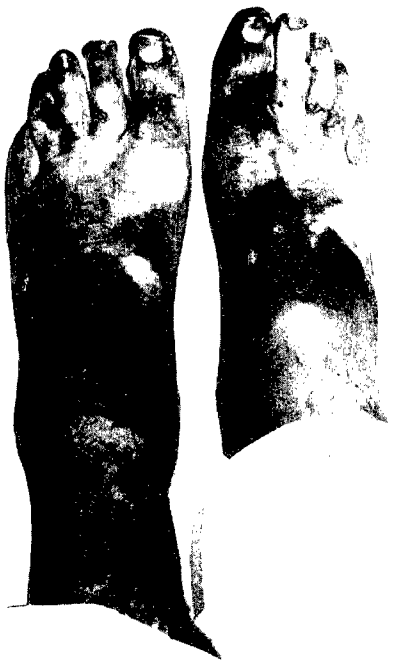

AFIP CA-44-186

FIGURE 65. Subsiding inflammatory stage of trenchfoot 12 days after hospitalization. The gangrene of the skin appeared to be superficial, but the record described the development of staphylococcic infection in gangrenous feet, and bilateral amputations of the lower leg were done 16 days after this photograph was taken. The outcome is surprising, in view of the appearance of the feet in this picture.

might also be experienced in the transverse and longitudinal arches. Less often, it was felt in the ankle. Ambulatory patients complained of pain in the weight-bearing parts of the transverse and longitudinal arches. Less often, it was felt in the ankle. Ambulatory patients complained of pain in the weight-bearing parts of the foot. The pain sometimes radiated up to the knee, and, occasionally, into the groin.

Hyperesthesia and paresthesias tended to disappear promptly. Anesthesia did not; it sometimes lasted 6 months or more. In one of the first 50 cases studied intensively, hyperesthesia appeared in the tip of the great toe when sensation first began to return, after 6 weeks of hospitalization.

The pain complained of in the postinflammatory stage was sometimes associated with thickening and stiffness about the joint. More often, the only

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abnormality found on physical examination was deep tenderness. In some cases, there was a general atrophy of the structures of the foot. The arches weakened, the tendons became prominent (figs. 66 and 67), contractures appeared, and the joints stiffened (figs. 67 and 68). Roentgenograms sometimes revealed osteoporosis. In the cases in which the feet were entirely normal on examination after the acute phase had passed, complaints of persistent pain provided major problems of management.

AFIP CA-44-416

FIGURE 66.—Late postinflammatory stage of trenchfoot. Note the delicate, waxy appearance of the skin, the absence of longitudinal and transverse arches, and the slightly valgus position of the great toes. This soldier was unable to do infantry duty because of hyperhidrosis, maceration of the skin, and pain in the feet.

AFIP CA 43-57

FIGURE 67.—Postinflammatory stage of trenchfoot. The feet were cold, sweaty, and cyanotic. Note prominence of extensors of toes and dorsiflexion at the metatarsophalangeal joints.

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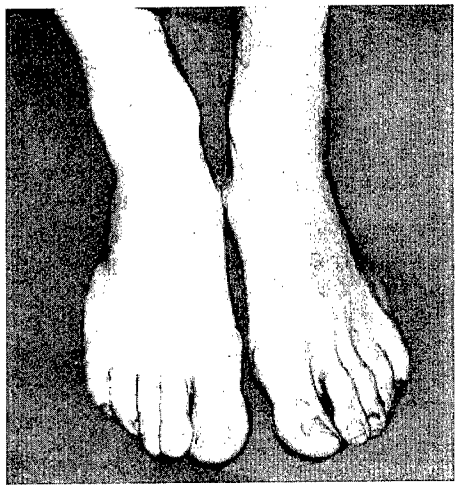

AFIP CA 41-413

FIGURE 68. Late postinflammatory stage of trenchfoot. The skin was delicate, and there was marked hidrosis. There is still a trace of edema in the right foot. Note relaxation of both longitudinal and transverse arches and slight dorsiflexion of metatarsophalangeal joints.

As time passed, it became more and more evident that the postinflammatory stage of trenchfoot was not a matter of sharply defined chronologic limits. It seemed likely, instead, that it could last for months and even years. Recovery was very slow. Sequelae were frequent (p. 284). An occasional man malingered, but observations both overseas and in Zone of Interior hospitals clearly showed that many of the men who had suffered from cold injury would be left with genuine disabilities.

Other Studies

Edwards, Shapiro, and Ruffin, who observed 351 cases of cold injury in a general hospital in Italy, confirmed Simeone's observations and described much the same clinical picture. The first evidences of cold injury in their cases were numbness and coldness of the feet. As a result, the men hesitated to exercise them. When the feet began to warm up after exposure, the toes tingled and burned or ached. Pain sometimes radiated up to the knee as vasodilatation began to occur in the damaged tissues of the feet. Then a sterile inflammatory reaction became evident, and blebs, some of which contained bloody fluid, might cover the whole plantar surfaces. Sometimes the symptoms and signs of injury were limited to coldness of the feet, perhaps associated with stiffness, for several days. In other instances, the toes were gangrenous and enormous blisters made normal walking impossible for weeks.

Edwards and his associates graded their cases as follows:

Grade 1. The feet were cool and the great toes numb. The soldier complained of slight aching or stiffness, but there was no evidence of discoloration, blebs, or swelling, and no decrease in the pulsations of the dorsalis pedis and posterior tibial arteries. Return to duty was possible in about 2 weeks. In another group of injuries, also graded as mild, the feet were cool, sometimes

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moist, and slightly cyanotic, but pain was not severe enough to interfere with sleep, stiffness did not develop, and no blebs formed. Pulsations of the regional arteries were normal. When the feet became too warm, there might be mild aching. Return to duty was usually possible within 6 weeks to 3 months.

Grade 2.—The feet were cold, cyanotic, and sometimes moist. Aching pain interfered with sleep for several days. The dorsalis pedis puslation was decreased, or might be absent part of the time. There was tenderness to pressure over the metatarsal pads. Within a week after the onset of symptoms, the feet might become warm, tender, and swollen. Return to duty was possible within 2 to 6 months (4 months on the average), but future combat infantry duty might be impossible.

Grade 3.—The feet were cold, mottled, and cyanotic, with large blebs or areas of ecchymosis. Pain and aching were continuous, day and night. Pain was always felt on motion of the toes or on pressure over the metatarsal pads. The dorsalis pedis pulse was often absent, and posterior tibial pulsations were feeble. Pulsations might disappear for several days, then reappear for several days before they disappeared again. This phenomenon was particularly likely to occur in the dorsalis pedis. After a few days, the feet might become warm and swollen, with little or no cyanosis. When this happened, the dorsalis pedis pulse became bounding. Desquamation of thick layers of skin always occurred. Return to duty was impossible for 6 months or more, and as a rule only limited duty was possible.

Grade 4.—The clinical picture was similar to that described in grade 3, but, in addition, there were areas of gangrene over the toes. The nail beds were black, and pitting edema was pronounced. Physiologic amputation of the toes sometimes followed, though in a surprising number of instances the blackened dermis peeled off gradually, leaving granulation tissue underneath. Amputation of an entire toe or of the whole foot was necessary in a few instances of gangrene and necrosis.

Edwards and his associates noted that, during the period of hospitalization, the feet became purple or cyanotic when they were dependent and became blanched when they were elevated, which suggested that the subcutaneous circulation was slow in spite of dilatation of arteries in the foot, with increased circulation in the deeper tissues. When the generalized swelling and sterile inflammation had subsided, the foot usually remained tender to pressure over the plantar surface of the metatarsophalangeal area. The great toe was more often affected by numbness, blister formation, and paresthesias than the other toes, but ecchymosis and superficial burning were frequent in all the toes, especially at pressure points in contact with the shoes. These symptoms and signs also occurred over the dorsum of the foot and on the heel. In both moderately severe and severe cases, even after sensation returned, the toes were likely to remain stiff for weeks or months, and 6 months or more might pass before flexions were straightened out.

When hikes were resumed, patients with milder grades of trenchfoot usually ceased to complain of aching pain after the first week, though in both

grade 1 and grade 2 cases mild aching and tenderness on the plantar surfaces of the metatarsal arch might persist for several months whenever the man walked for any distance. Grade 3 patients usually complained for 6 months or more of tenderness on walking, and few could return to full field duty within the holding period permitted in the theater.

Vascular Changes

The vascular changes associated with trenchfoot impressed all observers in the cases studied during the Italian experience. During the ischemic stage, the skin was usually pallid as well as cold. Areas of pallor were mingled with areas of purple mottling and blotching. It was assumed that pallor indicated arteriolar spasm and mottling indicated blood stasis and paralysis of venules. The dorsalis pedis and posterior tibial pulsations were not ordinarily palpable in feet which had this appearance.

In the early inflammatory stage, these pulsations were bounding, and the blood flow, at least superficially, seemed maximal. This was frequently true even when pitting edema was present. After a few days, however, evidences of increased blood flow became fewer and fewer, and later it might be impossible to feel any pulsations at all in the dorsalis pedis. This was the situation in 11 of the first 50 cases of trenchfoot studied intensively. In 3 of the 6 cases in which the pulsations were absent bilaterally, a history of previous frostbite was obtained. The dorsalis pedis of posterior tibial pulsations, or both, wera absent in a quarter of the cases studied by Boland and his associates. No relationship was evident between these phenomena and the severity of the injury, though it was observed that pulsations were always stronger in hot feet and weaker in cold feet. In evaluating these figures, it must be remembered that these pulsations are not always present in normal feet (p. 387).

As the inflammatory stage subsided, there was remarkable variability, as already noted, in the ease with which the dorsalis pedis pulsation could be felt at different times in the same foot. The observations sometimes varied from hour to hour. When this happened, there were always associated variations in the subjective sensation of heat or burning pain in the feet.

THE EUROPEAN THEATER

As part of the trenchfoot-study project initiated at the 108th General Hospital in Paris, in November 1944 (p. 186), an intensive study was made of 500 of the 5,000 patients with trenchfoot admitted to this installation. Clinically, the cases were classified into three groups, according to the severity of the injury, the size of all the groups being about equal.

Group 1.—In mild injuries, when the exposed foot was returned to a normal environmental temperature, a bright-red flush developed, the appear-

ance of the foot suggesting a mild sunburn. Slightly increased pulsations of the large vessels were observed for a brief period. The skin temperature was somewhat increased, and edema made the skin seem thicker than normal. The duration of the edema was from 1 to 6 days and averaged 3 days. The chief complaints were itching, burning, or moderate pain.

Bed rest was necessary for from 1 to 12 days and averaged 6.4 days. In some cases, for as long as 10 days, walking in shoes caused a painful reaction, though in others walking was possible and painless as soon as the patient became ambulatory. The average duration of discomfort from this cause was 4.2 days. Symptoms disappeared completely, and the feet resumed their normal appearance in from 3 to 21 days, or an average of 12.6 days.

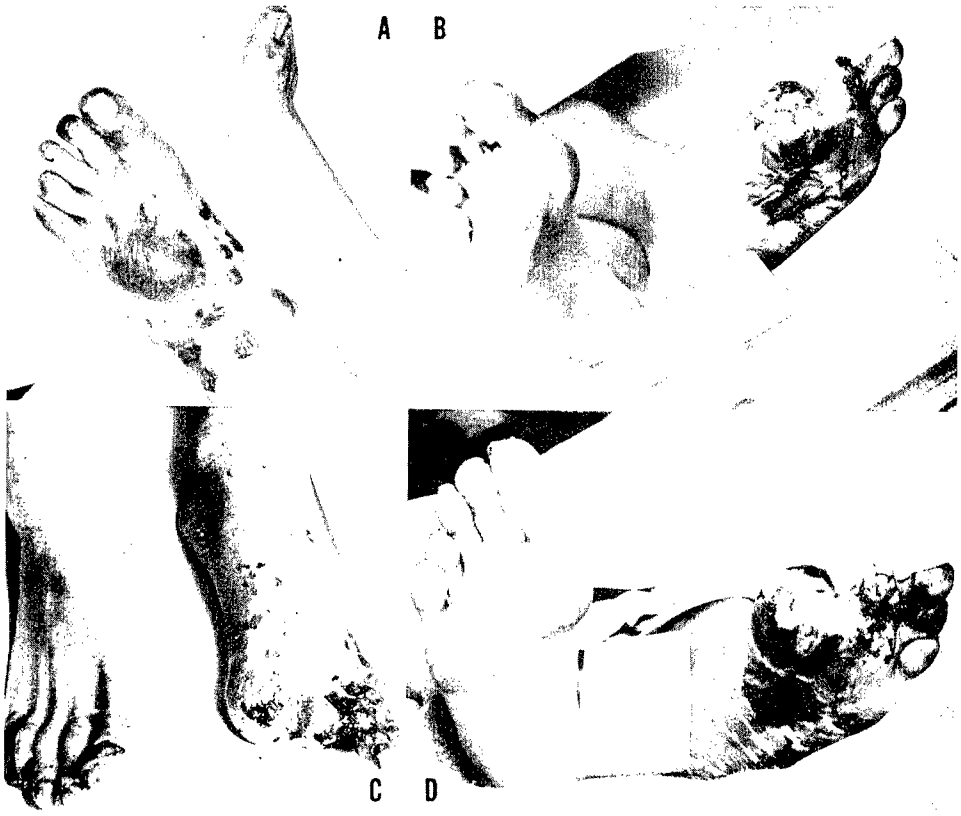
Group 2.—When exposure had been more prolonged or the environmental temperature had been lower, edema was fairly severe, blisters formed (figs. 69 and 70), and minute areas of intracutaneous ecchymosis were often present. Exfoliation occurred in varying degrees after edema had subsided. The only serious complaint was deep-seated pain, which was increased by heat and by walking. It was especially severe in the first metatarsophalangeal joint and across the plantar surface of the anterior arch of the foot.

In this group of cases, the edema lasted from 6 to 14 days, or an average of 10 days. Bed rest was necessary for from 11 to 46 days, or an average of 23.2 days. Walking in shoes without pain was possible only after an additional period which varied with the patient from 4 to 15 days and which averaged 8.4 days. After recovery had been sufficient for the man to resume marching, the only sign of abnormality in most cases was profuse hyperhidrosis. Marching in cold weather was likely to cause a recurrence of pain in the feet for a month or more. At the time this report was made, the final disposition of this group of patients was still unknown.

Group 3.—In third-degree cold injury, the initial reaction was intense. All the cardinal signs of inflammation were present, including burning pain, heat, rubor, and marked edema. The peripheral arterial pulsations were bounding. Large blisters appeared on the dorsal and plantar surfaces of the feet. Superficial skin necrosis over areas of intracutaneous ecchymosis produced lesions with the appearance of impending gangrene.

In this group of cases, the duration of edema was usually from 10 to 15 days but might be as long as a month or more. Superficial layers of skin gradually mummified and finally desquamated, leaving underneath normal pink skin, which was extremely sensitive. The extremity assumed a dusky, cyanotic color, on dependency or when placed in a cold environment. Muscular weakness was considerable and was associated with atrophy and stiffness of the joints. None of the casualties in this group were able to walk without great pain and disability during the 3-month period they remained under observation.

Only 5 of the 500 casualties studied intensively at the 108th General Hospital required amputation of the digits. Bilateral amputation for gangrene



AFIP B-361-b, c, d, e

FIGURE 69.—Second- and third-degree cold injury. A. Early changes. Multiple small blisters are present and in some areas have coalesced to produce bullae. On the right foot, only the great toe is involved, and the process is of moderate severity. On the left foot, the changes are more advanced. B. Appearance of feet shown in view A 28 days later. Gangrenous changes in the first and second toes of the left foot have produced spontaneous amputations. The wounds are still open and unhealed. On the right foot, the changes are superficial, and healing has progressed to scaling of the skin. C. Appearance of feet shown in view B 9 days later. Healing has continued bilaterally. The open wounds on the amputated stumps of the toes on the left foot show beginning epithelization. All blisters have disappeared, and most of the cutaneous lesions on the dorsum of the left foot have healed, leaving only residual changes. D. Appearance of feet shown in view C 4 days later. Healing is now almost complete on the right foot. On the left foot, the open areas are almost completely healed, and only some superficial cutaneous scaling remains.

was necessary in one case. This man had been trapped for 5 days behind enemy lines, where he escaped capture by feigning death. He spent the entire time in a snow and water-filled foxhole, in which his feet became encased in ice. At the end of the time, by walking and crawling for several miles, he reached friendly lines, and his shoes were finally cut off his frozen feet.

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AFIP B-387-a, b, c, e, f

FIGURE 70.—Serial changes in trenchfoot. A. Early phase of severe cold injury, with blister formation and beginning gangrenous changes in toes of both feet. Edematous changes have begun to regress, and blister formation on the dorsal aspects of both feet has begun to subside. B. Plantar view of feet on same date as view A. C. Appearance of feet shown in view B 8 days later. Regressive changes are evident on the dorsal aspects of both feet. Blisters have almost disappeared, and the skin is superficially wrinkled and dry. Mummification has begun in the toes. D. Appearance of feet shown in view C 9 days later. Note the cracked, scaly appearance of the skin, following disappearance of blisters, and the slowly progressive dry gangrenous changes in the toes on both sides. E. Plantar aspect of feet shown in view D on same date. The changes present in the dorsal view are also evident in this view. Most of the digits on both feet will inevitably be lost by spontaneous separation.

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OVERSEAS COMPLICATIONS AND SEQUELAE

Trenchfoot, as already pointed out several times, is a type of injury which is likely to continue to give trouble long after acute manifestations have subsided. Experiences in all theaters of operations in World War II bore out this generalization.

The Aleutians Experience

The experiences of casualties from Attu in Zone of Interior hospitals paralleled, in point of time after injury, experiences of other casualties in overseas hospitals. Some of them complained, often for many months after exposure, of pains deep in the foot, superficial burning, and aching, all increased by walking. Pain was particularly likely to occur in the metatarsophalangeal joints, whence it radiated into the ankle and sometimes into the calf muscles. In some cases, hypersensitivity persisted, and the slightest touch or the lightest pressure caused discomfort.

Osteoporosis was observed in 16 of the 93 patients treated at the 183rd Station Hospital,[5] where it was observed between the 6th and 12th weeks after exposure, in the course of the diagnostic endeavor to find the cause of the deep-seated pain of which these patients complained. The pathologic process, which was moderately advanced in all of these cases, involved the distal half of the metatarsals and the proximal three-quarters of the phalanges, usually in the first and second toes. The changes were particularly marked when there was a preexistent deviation from the normal foot structure, as in two cases of preexistent arthritis, or when there was evidence of faulty weight bearing of longstanding. The immediate factors which produced this complication were probably the result of prolonged disuse of the feet, which, in turn, resulted in nutritional and circulatory changes. It was least in evidence in the cases in which early supervised exercise had been instituted.

At Letterman General Hospital,[6] deformities of the feet were observed in the majority of the patients, even those in whom the injury was only of second degree. Most often, the deformity was of a claw-foot type, with varying degrees of pes cavus (fig. 71). The great toe was pulled downward into plantar deformity, and the spaces between all the toes were increased. The spread was especially prominent between the great toe and the second toe. A study of available pathologic specimens clearly explained the mechanism of the deformity. Varying degrees of inflammation and degeneration were observed in the nerves and vessels, the supply to the short muscles being more seriously affected. Long muscles usually escaped, probably because they receive their nerve supply farther up the leg, more distant from the involved zone. When smaller muscles of the feet were badly damaged, the large muscles took over their function. Since the long flexor to the great toe is stronger than its long

[5] See footnote 1 (1), p. 260.
[6] See footnote 1 (3), p. 260.

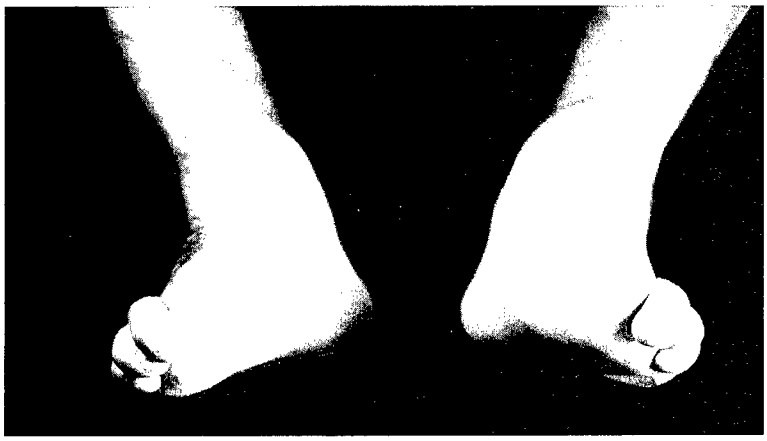

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FIGURE 71.—Severe flexion contractures of toes, for which amputation was subsequently necessary. On the right foot, amputations have already been performed proximal to the heads of the first and second metatarsals. On the left foot, amputation has been done at the head of the first metatarsal and through the proximal phalanx of the second toe.

extensor, the great toe was pulled downward, while the reverse mechanism in the small toes caused them to be pulled upward.

In many of the cases observed at McCaw General Hospital,[7] the gradual development of claw-toe deformities was a troublesome complication. The explanation was thought to be an exaggerated deposition of collagenous and fibroblastic material in the tissues following injury. Lumbar sympathetic block and surgical lumbar sympathectomy had no effect on the progress of this deformity, and, when rigid contracture occurred, with friction irritation from the shoes, surgery was necessary to straighten the toes.

The persistence of pain in the toes and feet, which was a principal complaint in many cases, was thought to be related to the extensive perineural fibrosis demonstrable in tissue sections. The delayed onset of pain was probably due to the late, progressive contracture of fibrotic tissues.

Psychoneurosis was observed in many of the patients at the 183d Station Hospital, where it was attributed to the lack of any specific means of therapy and the corresponding slow recovery. Some of the men were seriously concerned about possible permanent damage to their feet. Others were more concerned with their participation in an active engagement, in which they had become casualties, and because of which they felt they had done their share of fighting.

The Mediterranean Theater

Sequelae of trenchfoot became evident in the Mediterranean theater in the course of the 1943–44 experience (plate 3D). They included persistent pain and edema, hypesthesia and anesthesia, and vasospasm. The skin was delicate and

[7] See footnote 1 (2), p. 260.

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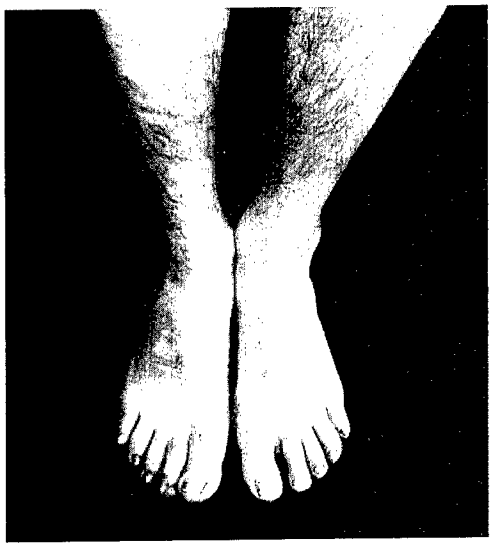
waxy after desquamation, and weight bearing was impractical until calluses had formed (fig. 72), a process likely to be long delayed. The patients were sensitive to cold but were also incapacitated by heat. Hyperhidrosis and associated trichophytosis resulted in maceration of the skin (figs. 66, 67, 68, 72, 73, 74, 75, 76).

AFIP CA-44-111

FIGURE 72.—Late postinflammatory stage of trenchfoot. This photograph was taken in June, after the soldier had been unable to remain with his infantry unit because the skin of the feet was so delicate and perspiration was so excessive that maceration ensued. Note absence of calluses on weight-bearing surfaces.



AFIP CA-44-115

FIGURE 73. Late postinflammatory stage of trenchfoot. Note delicate, waxy skin. This man's transverse arches were relaxed, but the longitudinal arches were within normal limits. This photograph should be compared with figure 66, which shows absence of both transverse and longitudinal arches.

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AFIP CA-44-211

FIGURE 74. Late postinflammatory stage of trenchfoot. After 4 months of hospitalization, the feet were still cold and sweaty and were blue on dependency. The patient complained of deep aches in the metatarsophalangeal joints and in the longitudinal arches.

AFIP CA-44-95

FIGURE 75. –Early postinflammatory stage of trenchfoot. After 2 months of hospitalization, edema had subsided. The skin was delicate, and the patient complained of aches in the metatarsophalangeal joints, particularly in the joints of the great toes. Note scanty amount of subcutaneous fat about these toes.

During the summer and early fall of 1944, many patients were admitted to hospitals in the Peninsular Base Section, Mediterranean theater, for what was termed recurrent trenchfoot, though actually the present condition was quite different from the original condition. Most of these men were returned from units which had participated in the drive north of Rome to the Gothic Line, because they could not keep up with the troops. Others were received from

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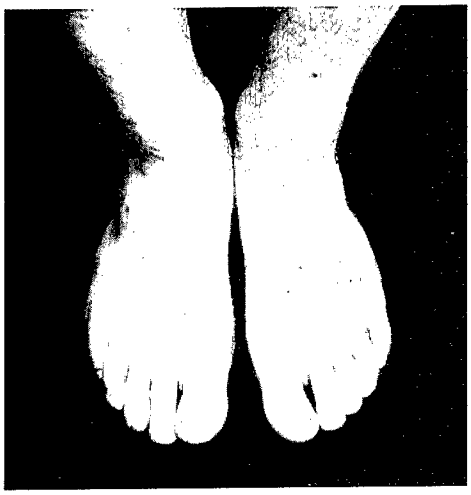

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FIGURE 76. Late postinflammatory stage of trenchfoot. This patient was unable to do infantry duty during the summer months because of excessive sweating and trichophytosis, with secondary infection, on the insteps.

units undergoing amphibious training for the invasion of southern France. Still others came from replacement depots and rehabilitation centers.

In a detailed report by Toone and Williams on these men (p. 330), it was pointed out that the feet appeared weak and atrophic and were painful on light pressure. The toes were numb and stiff. The skin was thin, of delicate texture, and bore scars of recently healed excoriations as well as new lesions. Plantar calluses were entirely lacking or were grossly inadequate. The men complained of excessive hyperhidrosis, and many had been incapacitated by recurrent episodes of trichophytosis. Earlier in the summer, Long had observed an apparently increased incidence of epidermophytosis and allied foot disorders in Peninsular Base Section hospitals, and had found that much of it was in patients who had suffered from trenchfoot the previous winter. He considered the complication sufficiently serious to warrant setting up new criteria for the disposition of patients with trenchfoot.

Edwards and his associates believed that this type of complication was preventable. Correspondence with a number of their patients who had returned to full duty showed them to be fully aware of proper foot hygiene and to be following instructions as faithfully as possible under combat conditions. Even when they could not bathe their feet, they removed their shoes, massaged their feet, and applied the foot powder issued by the quartermaster. As a result, they had a minimum of trouble with hyperhidrosis and epidermophytosis.

Ragan and Schecter,[8] whose study covered only casualties with early trenchfoot, observed them for too brief a period for muscle atrophy or other sequelae to develop. In two cases, however, both instances of moderately severe trenchfoot, the following curious sequence of events was observed:

The first patient presented nothing out of the ordinary when he was hos-

[8] Ragan, C. A., and Schecter, A. E.: Clinical Observations on Early Trench Foot. Bull. U. S. Army M. Dept. 4: 434-440, October 1945.

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pitalized for cold injury. On the 14th day, it was found that all the toes of the right foot, including the great toe, were so firmly held in dorsiflexion that even after considerable force had been exerted the contraction could be overcome only partly. This man stated that, in civilian life, 4 years before his induction into the Army, his feet had been frozen and that a similar contraction of the toes had occurred at that time.

The following day, the patient in the next bed, also on the 14th day of hospitalization, presented the same type of contraction, also on the right side, but without involvement of the great toe.

The circumstances naturally suggested hysterical contraction in both cases, but in each instance the contraction was held so firmly and so constantly throughout the day that the suggestion lost some weight. That night, both patients were heavily sedated and their feet were examined after they were soundly asleep. In each instance, the contracture was still present.

The next day, both patients were given ether anesthesia, under which complete relaxation of the contractures occurred. When Novocain was injected into the belly of the extensor hallucis longus of the first patient, the distal phalanx of the great toe relaxed but the proximal phalanx remained in dorsiflexion. In both patients, similar dorsiflexion could be induced in the unaffected (left) feet by occlusion of the circulation by inflation above arterial pressure of a blood pressure cuff placed around the thigh. The dorsiflexion was relaxed when the cuff was deflated. This phenomenon could not be induced in the first patient when he was under ether anesthesia. Dorsiflexion by the same method was induced in a control patient on the first attempt but could not be induced 48 hours later.

The first patient was kept under observation for 10 days after the appearance of the contracture. When he was evacuated, dorsiflexion was still present but was less firm. The second patient was observed for 23 days. At the end of this time, the contracture, although still present, could be readily overcome by minimal pressure. The phenomenon induced in the left leg by varcular occlusion could no longer be elicited.

A possible complication of trenchfoot or, more accurately, of a measure adopted to prevent trenchfoot was so-called shoepac foot, which was observed in both the Mediterranean and European theaters. This was an irritation of the feet caused by the continuous wearing of damp socks within shoepacs, by the heat generated within the shoepacs as the result of friction of wool socks on the wool inner soles, or by the poor ventilation inherent in a shoe made partly of rubber. The ball of the foot was most often affected, but the irritation also extended to the heel in some cases. Sometimes cleanliness, clean socks, and a brief period of rest cleared up the trouble. Sometimes, however, hospitalization was required for as long as 10 or 15 days. The soldier could usually be returned to full duty, but, if the causative conditions were permitted to recur, recurrence of the trouble could be expected.

Continued observation of patients with trenchfoot in the Mediterranean Theater of Operations showed only slow disappearance of residual complaints

of pain and tenderness. Complaints were fewer in warm than in cold weather, but long marches were still not possible. During the winter of 1944–45, a year after their injuries had been sustained, many men still complained of spontaneous aching whenever the weather was cold and damp, and the ability to walk and march was decidedly diminished, though the original level of incapacity was not again reached.

In February and March 1945, Paddock [9] studied intensively a number of soldiers who had contracted trenchfoot in the Apennines from 4 to 8 weeks earlier. All had injuries of mild to moderate severity, the damage being, on the whole, less severe than in the similar cases observed during the previous winter. At this time, acute edema, gangrene, and pseudogangrene had disappeared, and the chief residual complaint was pain, with tenderness of the soles of the feet. The men could be divided into two main groups, those with complaints of vascular origin, with a tendency to coldness and cyanosis, and those with complaints of neural origin, including pain on firm pressure over the soles, superficial hypalgesia, loss of proprioception, diminution of temperature discrimination, hyperhidrosis, and poor toe-flexion ability.

After employing a variety of tests and making numerous observations, Paddock reached the following conclusions:

1. The capillaries and venules in the injured feet were apparently normal, but there was increased arteriolar tone, apparently secondary to increased sympathetic stimulation. There was no evidence of arteriolar obstruction.

2. In addition to superficial hypalgesia, there was frequently diminution of temperature, vibration, and position sense in the affected feet. Poor toe flexion was not the result of any obvious structural abnormality. Deep-seated sensitivity to cold was usually absent.

3. In trenchfoot of moderate severity, it seemed reasonable to conceive of involvement of all the most superficial tissues of the foot, with a quantitative variation from patient to patient with respect to special tissues affected. The disabilities encountered in the later stages of mild to moderate cold injury were apparently more dependent on neural changes than on vascular changes. Microscopic evidence of damaged tissues tended to confirm this concept.

It was Paddock's opinion that the disabilities from which these men were suffering would persist for years, and that therapy directed at the blood vessels and nonneural tissues would be ineffective. Observations at Mayo General Hospital (p. 333) and other vascular centers in the Zone of Interior confirmed this impression.

The European Theater

The end of the fighting in Europe in May 1945 accounts for the fact that most of the residua of cold injury sustained in that theater were observed in hospitals in the United States rather than overseas. As early as April, however, the chief consultant in medicine in the European theater noted that cold

[9] Paddock, F. K.: Chronic Disability in Mild Cases of Trench Foot. New England J. Med. 234: 433–437, 28 Mar. 1946.

injury promised to constitute a continuing problem because of the increased susceptibility of the feet to trichophytosis after it. In Essential Technical Medical Data for the month ending 30 April 1945, the same observation was made. It was also noted that a number of men with neglected cold injuries were now presenting themselves for treatment. They had resisted evacuation when they sustained their injuries during the hard fighting in December and January of the previous winter, but now they were appearing with extreme vascular changes, usually in the form of cold, clammy, blue feet, frequently associated with edema.

OBSERVATIONS IN THE ZONE OF INTERIOR

The observations made on the 656 patients with trenchfoot treated at Mayo General Hospital in 1944 and 1945 may be taken as typical of the late clinical picture of cold injury of moderate to serious degree.

Exposure to Cold (Wet Cold)

Five hundred and eighty-six of these six hundred and fifty-six patients sustained their cold injuries after a single exposure in combat, the duration varying from 3 to 54 days and averaging 14 days. The injuries occurred between November 1943 and March 1944, at Cassino or on the Anzio beachhead, and between October 1944 and January 1945 in France, Germany, Luxembourg, Holland, and Belgium. In practically all instances, the environmental temperature had been in the neighborhood of freezing or only slightly higher, and rain had been almost continuous for long periods. For the most part, the men had lived in mud and water and had seldom been able to change their shoes and socks.

Sixty of the six hundred and fifty-six patients had suffered two attacks of cold injury. The first exposure, which lasted from 1 to 60 days and averaged 15 days, occurred between November 1943 and March 1944 at Cassino, Venafro, or the Anzio beachhead. The men were hospitalized for an average of 9 weeks each, then were sent to convalescent or reconditioning centers before they were returned to duty. The second exposure occurred between August 1944 and February 1945 in France, Holland, or Germany. All the patients had been hospitalized overseas for a second time before being evacuated.

Ten men had suffered three exposures each, the first at Cassino, the second at the Anzio beachhead, and the third in France, Germany, or Holland. They were returned to duty after the first and second attacks, after varying periods of hospitalization, and all reached the Zone of Interior about 2 months after the third exposure.

Some men who had suffered single exposures had remained on a patient status until they were received in general hospitals in the United States. Others had been returned to full duty after varying periods of hospitalization

but had been unable to perform their duties. Some men who had sustained their injuries in Italy in the winter of 1943–44 had had the first evidence of recurrent trouble during the march on Rome in July 1944 (p. 287). They complained of their feet almost at once, and pain, swelling, and blister formation eventually made them unable to keep up with their comrades in any kind of physical endeavor.

The patients with trenchfoot observed at Mayo General Hospital and other vascular centers in the United States were seen between 2 and 13 months after exposure. The average timelag was 4 months.

No correlation could be demonstrated between the duration of exposure and the degree of resulting damage to the tissues in 633 patients with cold injury treated at Mayo General Hospital (table 8). There was also nothing in the histories to suggest that men who had suffered previously from trenchfoot or frostbite were any more likely to suffer from gangrene than were men who had been exposed only once, though they were, obviously, more susceptible to cold injury.

TABLE 8.—*Tissue damage in relation to duration of exposure in 633 patients with trenchfoot, Mayo General Hospital* [1]

Lesion	Number of patients	Proportion (percent)	Average period of exposure (days)
No loss of tissue	548	86. 5	14
Superficial gangrene, slight	15	2. 4	6
Superficial gangrene, severe	33	5. 2	9
Partial loss of one or more toes or heel	23	3. 6	7
Total unilateral loss of one or more toes	7	1. 1	12
Unilateral loss of toes, partial loss of heel	1	. 2	4
Total bilateral loss of one or more toes	3	. 5	6
Bilateral loss of toes, partial loss of foot	2	. 3	7
Total loss of one or both feet	1	. 2	12

[1] 10 percent of the patients who lost part of 1 or more toes or part of the heel and 7.7 percent of the patients who experienced no loss of tissue had a previous history of frostbite.

Classification

Signs and symptoms of the later stages of trenchfoot observed in vascular centers in the Zone of Interior fell into three general categories:

Predominance of excessive sympathetic activity.—One hundred and forty-five (22.1 percent) of the six hundred and fifty-six patients observed at Mayo General Hospital presented symptoms and signs which seemed primarily the result of excessive sympathetic activity. The skin temperature of the toes was low, frequently lower than the environmental temperature. Hyperhidrosis was invariably present. It ranged from slightly more than the usual amount of perspiration to an almost continuous flow of sweat which rolled off the foot

in perceptible quantities. The amount was definitely increased by emotional disturbances. The cooling effect produced by the evaporation of perspiration was one explanation of why the skin temperature was often lower than the environmental temperature.

Cyanosis, particularly when the feet were dependent, was another prominent observation. Changes of color and temperature were often observed. A blue, cold foot would become red and hot after exposure in a warm room or after the man had walked a short distance in shoes. At other times, for no apparent reason, a blue, cold foot would become red and hot, and then would revert to its original status. Mottling was fairly common, sometimes as a transient phenomenon and sometimes for longer periods. It assumed varying patterns, sometimes in the same individual. For the most part, it took the form of sharply demarcated areas of rubor interspersed with numerous areas of pallor on a background of cyanosis.

Palpation of the large peripheral arteries in patients with signs of excessive sympathetic activity and without gangrene revealed absence of the dorsalis pedis pulsation on one side or both in about 6 percent of all cases (table 9). The significance of this observation, if there was any, could not be determined, since comparable observations were not made in normal subjects. There was no evidence of arteriosclerosis in any patient in this group. Impairment of the blood supply to the muscles of the leg seemed extremely unusual, a history of intermittent claudication being very seldom obtained.

TABLE 9.—*Residual manifestations of trenchfoot 4 to 13 months after exposure in 619 patients without gangrene, Mayo General Hospital*

[Frequency is expressed as percentage of the total group]

Symptoms	Frequency	Signs	Frequency
Hypesthesia	41. 5	Cyanosis	59. 1
Burning and tingling	21. 9	Sweating	50. 4
Numbness	16. 6	Abnormalties of gait	34. 0
Neuritic pains	14. 3	Coldness	27. 9
Tenderness in sole of foot	14. 1	Edema	17. 4
Aching	3. 8	Muscular atrophy	14. 9
		Stiffness of toes	10. 2
		Absence of pulsations in large arteries	6. 0

Tests of the efficiency of the circulation substantiated the view that the symptoms and signs in this group of cases were caused primarily by excessive sympathetic activity and not by organic involvement of the vascular supply of the lower extremities. Oscillometric readings were carried out on the first 40 patients admitted but were discontinued when they revealed no significant departures from normal. Indirect vasodilatation, accomplished by applying hot-water bags to the abdomen and chest and covering the patient with several

wool blankets, was carried out in 25 cases. In all instances, the skin temperature of the feet, which was lower than normal at the beginning of the test, rose to a level considered normal under the circumstances.

The reactive hyperemia test was performed on 10 patients with marked cyanosis. In all instances, the flush, which appeared within 10 seconds, faded out in 1 to 2 minutes. This type of reaction, which was interpreted as a normal response to a period of anoxia of the cutaneous arterioles and small vessels (capillaries and subpapillary venous plexuses), helped to rule out occlusive disease of the blood vessels. Paravertebral lumbar sympathetic block with procaine was carried out in 11 cases. In all instances, a normal skin temperature response was obtained, while, at the same time, cyanosis was replaced by a pink coloration of the feet. Hyperhidrosis also disappeared transiently.

Predominance of peripheral-nerve involvement.—Sixty-three (9.6 percent) of the six hundred and fifty-six patients with trenchfoot observed at the Mayo General Hospital Vascular Center presented symptoms and signs indicative of some type of peripheral-nerve involvement. Few objective abnormalities were noted in this group of cases, except that the feet, at rest, appeared pale. The chief complaint was tenderness in the sole of the foot, at times so severe that even the slightest pressure on the part could not be tolerated. Some men could not walk at all, or could walk only by putting the weight on the heel or along the lateral aspect of the foot.

Anesthesia was infrequent. Many patients had areas of hyperesthesia to cotton wool and pinpricks, corresponding closely to the sites sensitive to deep pressure. These areas also included the dorsal surfaces of the toes and the dorsum of the foot. There were frequent complaints of various types of paresthesias, such as burning and stinging sensations, shooting pains, sensations of numbness in the toes, and a feeling of pins and needles in the toes.

Combined sympathetic activity and peripheral-nerve involvement.—Four hundred and forty-eight (68.3 percent) of the six hundred and fifty-six patients observed at Mayo General Hospital presented symptoms or signs of both excessive sympathetic activity and some type of peripheral-nerve involvement. Many in this category (as well as in the other categories) entered the hospital still showing considerable desquamation of thick epidermis on the plantar surfaces of the feet (fig. 77). As the process of desquamation was completed, thin, new skin was revealed. Twenty-eight patients had prominent swelling of the toes and somewhat less marked swelling of the feet (fig. 78). This swelling did not disappear with rest in bed and elevation of the extremities but sometimes responded to treatment with typhoid vaccine (p. 337).

Most of the men presented varying degrees of atrophy of the small muscles. As a result, the arches of the feet seemed abnormally high (figs. 79 and 80). This phenomenon was particularly conspicuous in 11 cases. It was not possible to determine whether it was a nonspecific response to disuse or was part of the pathologic change in the syndrome of trenchfoot. The latter theory seems

AFIP (Mayo GH) 632-1

FIGURE 77.—Typical hyperkeratosis of skin observed in late trenchfoot. Note wrinkling, fissuring, and maceration, similar to findings observed after long immersion of feet in water. Note also dry gangrene at tips of toes. There was marked cyanosis on dependency. The patient complained of severe, throbbing pain in the right foot. Examination showed normal pulsations in the peripheral arteries on both sides.

This infantryman sustained his cold injury in Luxembourg, in November 1944, after 3 days' exposure to very cold, wet weather, with snow. In the battalion aid station, he complained of considerable burning and pain. Both feet were swollen. Multiple blisters, filled with blood, appeared on both feet after 2 hours' exposure to a hot stove.

more reasonable in the light of the histologic alterations in the muscles and nerves described by Friedman (p. 250) as part of the initial pathologic change in trenchfoot. Whether or not this atrophy is reversible can be determined only by long-term followup studies. Some patients at Mayo General Hospital showed no beneficial effects from the intensive and prolonged program of exercises designed to utilize the small muscles of the foot and still presented considerable atrophy at the time of disposition.

Other Observations

At the time they were admitted to Mayo General Hospital, an average of 4 months after injury had been sustained, occasional patients still presented vesicle formation. Frequently, one or more toenails had fallen off, leaving the nail bed exposed (fig. 81). In other instances, the nails were distorted,

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AFIP (Mayo GH) 680-2, 680-5

FIGURE 78. Persistent swelling of feet in late trenchfoot. A. Appearance of feet 4 months after injury, showing granulating wounds of both great toes, with infection and osteomyelitis. Note persistent swelling of toes and dorsum of foot. B. Appearance of feet after revision of amputation stumps.

This infantryman sustained his cold injury in Germany, in November 1944, after 8 days' exposure to cold, wet weather, with snow. The first note on the record mentions bilateral swelling of the feet, with deep gangrene of the tips of all the toes. Treatment consisted of bilateral lumbar sympathectomy, amputation of toes, and the application of split-thickness skin grafts to both great toes. The grafts did not take, and revision of the stumps was necessary.

and there was considerable debris beneath them. Dermatophytosis was a common finding.

In 34 cases, there was great stiffness of the toes, and the skin was shiny and seemed firmly attached to the underlying tissues. Sometimes the great toe was widely separated from the others and was either flexed (fig. 79) or was hyperextended in the form of a pseudo-Babinski sign. This phenomenon could probably be explained by disuse. There was no correlation between the degree of stiffness present and the severity of the original injury.

Osteoporosis was a fairly common observation in the more severe cases. It sometimes disappeared after 3 or 4 months of physical activity, but as a rule there was not much difference between the roentgenograms taken on admission and the final roentgenograms taken before disposition. The bone changes, like muscle atrophy, could be explained either as the response to a long period of inactivity or as an integral part of the trenchfoot syndrome. As with atrophy, whether or not osteoporosis represents an irreversible change in cold injury can be determined only by long-term followup studies.

Superficial and Deep Gangrene

A study of the early records of patients admitted to the trenchfoot centers suggested that by the time a man with trenchfoot had reached a fixed installation it could usually be determined whether or not he would eventually lose

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AFIP (Mayo GH) 1226-1

FIGURE 79.—Atrophy of small muscles of feet, characteristic separation of great toe from others (pseudo-Babinski sign), and moderate heel walking, 9 months after injury.

This patient sustained his cold injury in France, in October 1944, after 7 days' exposure to cold, wet weather, but not to freezing temperatures. The clinical course was characterized by excessive coldness of the feet, cyanosis, hyperhidrosis, stiffness and numbness of the toes, and pain in both feet. Cyanosis and hyperhidrosis were still present 9 months after injury but ability to flex the toes on the right foot had returned.

any significant amount of tissue. Fifty-three of the patients admitted to Mayo General Hospital still presented small areas of superficial gangrene, usually on the medial aspect of the foot (fig. 81) or the tips of the toes. The heels were affected much less often. For the most part, these gangrenous tissues separated spontaneously, revealing normal tissues beneath (fig. 81C and D). In a number of cases, the original lesions suggested the presence of a much more severe type of involvement than subsequent events proved to exist. These observations supported the general opinion that conservatism should be practiced in the early management of trenchfoot complicated by gangrene.

Observations from other vascular centers and from Camp Carson (p. 193) were to the same effect. At Camp Carson, 400 patients, about 8 percent of the total number admitted, had gangrenous areas of some degree when they arrived. It was regarded as significant, however, and the data were utilized in outlining the plan of management in these cases, that about half of the other patients received also had had areas of gangrene, which had healed spontaneously, earlier in the course of the injury. In 50 of the 400 patients

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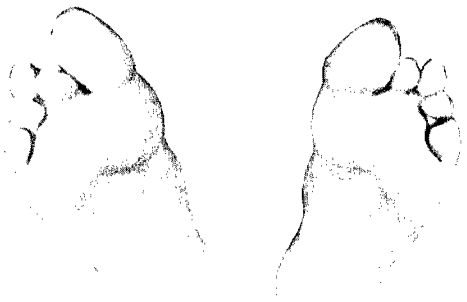

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FIGURE 80. Atrophy of small muscles of feet and peripheral neuritis in late trenchfoot. Note marked atrophy of small muscles of both feet 8 months after injury.

This infantryman sustained his cold injury in Italy, in December 1943, after 7 days' exposure to cold, wet weather but not to freezing temperatures. The clinical course was characterized by bilateral swelling of the feet, cyanosis, and elevated cutaneous temperatures. Gangrene did not develop. The patient complained of aching, painful sensations, and numbness. He was returned to duty 5 months after exposure but had to be rehospitalized after 3 months of duty because of aggravation of all symptoms. At this time, he complained of tingling and burning sensations and great tenderness on the plantar surfaces of the feet; all symptoms were increased by extremes of temperature. Areas of hypesthesia and anesthesia were present on both feet.

who arrived with gangrene, healing progressed so satisfactorily that spontaneous separation of the nonviable tissues occurred, and plastic revision of the scars was not necessary. Gangrene of a degree requiring amputation above the ankle was encountered in only three patients, all of whom were transferred to amputation centers. The remaining 347 patients required only amputation of localized gangrenous parts or some type of surgical revision of the scar left after spontaneous separation of the gangrenous areas.

The 37 patients with deep gangrene and subsequent extensive loss of tissue, observed at Mayo General Hospital, may be considered as being typical of all patients in this category. They had suffered only a single exposure, ranging from 1 to 34 days and averaging 8 days, either in Italy, between November 1943 and March 1944, or on the Western Front, between October 1944 and January 1945. In some instances, according to the records, gangrene had been present when the patients reached the battalion aid station. More often, it appeared after 6 to 10 days of hospitalization. Sometimes ulceration and infection had also occurred before the men received any medical aid. The development of gangrene had sometimes been preceded by the appearance of large hemorrhagic blisters, after which the involved areas quickly became black and mummified.

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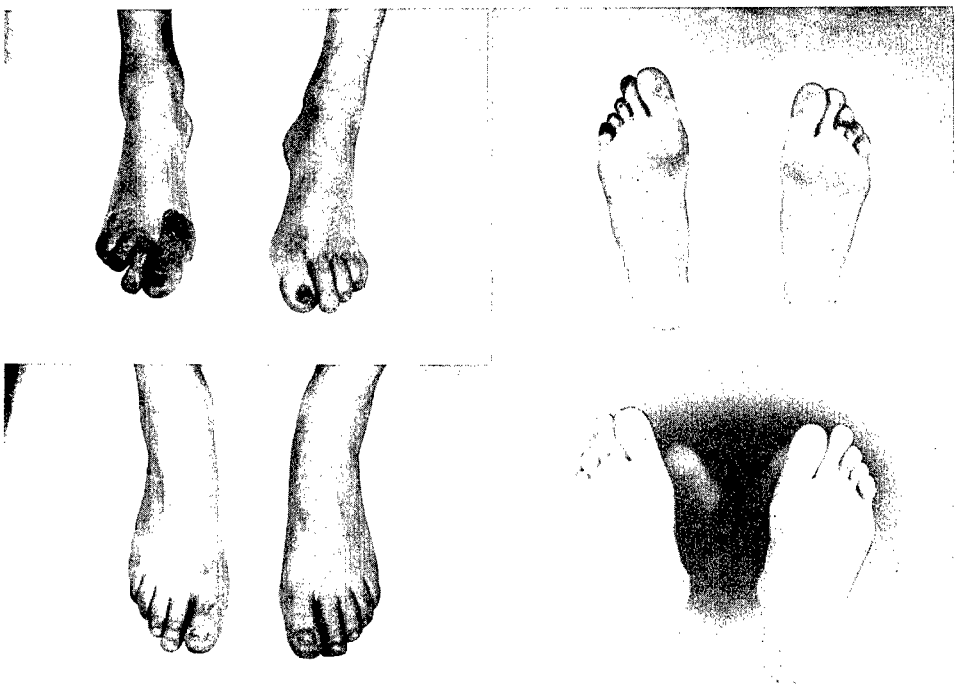

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FIGURE 81.—Superficial gangrene in late trenchfoot. A. Appearance of feet 2 months after injury, when areas of superficial gangrene on the medial aspect of the right foot were becoming demarcated from normal tissue. At this time, the patient complained of stiffness of the toes and tenderness in the sole on the application of pressure. Cyanosis was conspicuous. Pulsations in the peripheral arteries of both feet were normal. B. Plantar view of feet 2 months after injury. Note gangrene of plantar surface of tips of toes of both feet and scaly appearance of skin before desquamation. C. Appearance of feet 2 months later. The superficial areas of gangrene on the medial aspect of the right foot are completely healed, and only areas of pigmentation indicate their sites. A number of nails have been lost. The feet were now less cyanotic, and the toes, less stiff. D. Plantar view of feet at same time as view C. The areas of superficial gangrene on the tips of the toes are completely healed, and the dead epidermis has separated, leaving normal skin.

This patient sustained his injury in France, in October 1944, after 6 days' exposure to cold, wet weather but not to freezing temperatures.

All of the patients with deep gangrene seem to have presented the same general clinical picture in the first stages of their injury as did the men who did not develop gangrene, the only difference being that all their symptoms and signs had apparently been severe. Swelling, cyanosis or pallor, blister formation, severe pain, and numbness of the feet were invariably observed.

Although the gangrene which was present in some cases of cold injury resembled the gangrene present in other vascular disorders, gangrene associated with trenchfoot presented certain features peculiar to the original injury. It

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varied widely in extent. Pain was not associated either with the gangrenous process itself or with the resulting ulceration. Intense vasospasm was a frequent observation. Extensive arterial obliteration proximal to the gangrenous areas was not observed. Finally, the incidence of infection was extremely high.

In the 37 cases of deep gangrene observed at Mayo General Hospital, as in other, similar cases, the process differed from the gangrene observed in thromboangiitis obliterans, arteriosclerosis, and other obliterative vascular diseases, chiefly because the reduction in the circulation of the foot regularly present in those diseases as the result of obliterative vascular changes was generally absent in trenchfoot. Relatively normal circulation was observed in trenchfoot when vasoconstrictor impulses were eliminated, which is contrary to the usual course of events in the obliterative disorders. When the gangrenous process had extended into the dorsum of the foot, the dorsalis pedis pulsation was not palpable, and the pulsation of the posterior tibial artery was likely to be absent also.

Rest pain, which is characteristic of the obliterative diseases, seldom occurred in the late stages of trenchfoot, even when ulceration was present. Initially, rest pain might be very distressing in patients with trenchfoot (p. 271), regardless of whether or not gangrene had developed, but after an interval of weeks or months it usually disappeared completely or almost completely.

Infection does not usually complicate gangrene in the obliterative diseases, but it was frequently in trenchfoot associated with deep gangrene. Skin defects can only occasionally be repaired by grafts in the obliterative vascular diseases, but they could often be successfully covered by this method in cases of deep gangrene following cold injury.

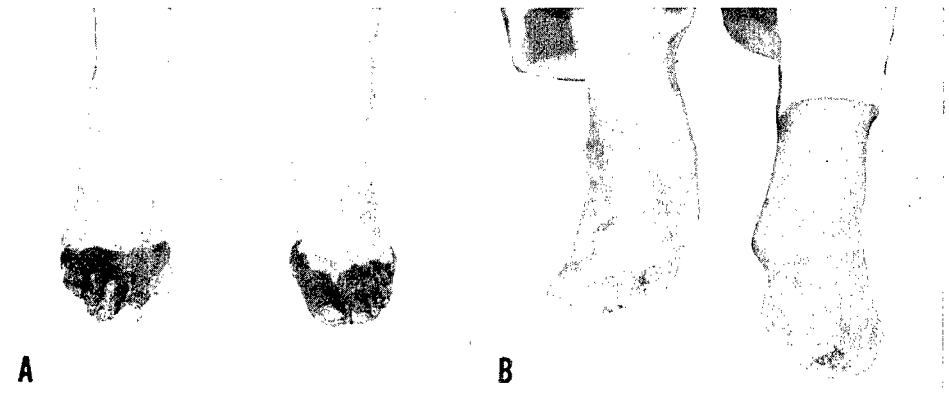
The deep gangrene observed in trenchfoot also differed from that seen in Raynaud's disease and similar disorders, in which the process, even when associated with ulceration, is generally superficial and limited. All of these disorders are alike in that obliterative arterial changes are usually limited to the actual gangrenous areas or, perhaps, to the areas immediately proximal. Patients with Raynaud-like disorders and with frostbite tend to have few symptoms connected with gangrene other than cold sensitivity and hyperhidrosis, which are the rule in the former group of diseases and are very common in frostbite also. In trenchfoot and immersion foot, on the other hand, the most distressing symptoms observed were the result of damage to nerves and muscles in the foot proximal to the area of gangrene. Areas of hypesthesia or hyperesthesia, muscle atrophies, and contractures were relatively common in gangrene associated with trenchfoot. Almost all patients had pain on weight bearing. However, these symptoms, as well as hyperhidrosis, coldness and cyanosis, were also prevalent in patients without gangrene and therefore could not be attributed to postural difficulties resulting from ischemic loss of tissue.

The infection associated with superficial gangrene in cold injury was usually minimal. In deep gangrene, it was usually extensive and therefore

was a serious problem. Though infection was not a part of the primary pathologic process, the circumstances under which cold injury occurred naturally favored its development. The hygiene of the feet was often necessarily neglected under conditions of combat. At the time of exposure, the shoes and socks were often wet and sometimes had not been changed for days or even weeks. Bleb formation, maceration and desquamation of the skin, and loss of the nails were favored by the constant wetness of the feet and the ischemia which resulted from exposure. These lesions, though minor in themselves, served as portals of entry for pathogenic organisms.

When patients with deep gangrene were first seen in Zone of Interior hospitals, the gangrenous parts were often partially separated by a line of demarcation bathed in foul-smelling purulent exudate. Blebs were often present. Sometimes there was evidence of extensive bleb formation throughout all the gangrenous area. The infection was invariably mixed, with penicillin-resistant and sulfonamide-resistant *Bacillus proteus* and *Bacillus pyocyaneus* present in addition to other organisms.

Often, when the gangrene appeared to be of the dry type, removal of the gangrenous tissue at the line of demarcation would reveal underlying pools of purulent exudate (fig. 82). Osteomyelitis was frequently present in this type



AFIP (Mayo GH) 595-1

FIGURE 82.—Deep gangrene of toes of both feet in late stage of trenchfoot. A. Appearance of feet 2 months after injury, when areas of dry gangrene were becoming demarcated from normal tissue. The line of demarcation was bathed in foul-smelling, purulent discharge. At this time, the patient complained of burning, tingling, and numbness of the toes and excessive sweating. There were areas of hypesthesia on the dorsal and medial surfaces of the right foot. Both feet were extremely cyanotic on dependency. Oscillometric readings and pulsations in the peripheral arteries were normal on both sides. B. Appearance of feet 5 months after injury, after bilateral lumbar sympathectomy, amputation of gangrenous toes, and pedicle graft to left foot. The patient was walking well when he was discharged a month later.

This infantryman sustained his injury in Aachen, Germany, in November 1944, after 6 days' exposure to cold, wet weather, with snow.

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of case, as well as in cases of wet gangrene, and showed a tendency to proximal spread, in contrast to soft tissue infection, which showed little tendency to invade adjacent intact soft tissues.

DIAGNOSIS OVERSEAS

Accurate diagnosis in the battalion aid station and other forward installations is of the greatest importance in cold injury. If the soldier is really suffering from cold trauma, unless it is of the mildest and most superficial type, he must be evacuated to a general hospital for definitive treatment, which is usually prolonged. If he is suffering merely from cold feet, a fungous infection, trauma from improperly fitted footgear or some such cause, poor pedal hygiene, or an orthopedic condition, he can usually be treated in the division clearing station or the evacuation hospital, depending upon the evacuation policy in force at the time, and can be promptly returned to his unit. The details of triage are discussed elsewhere (p. 307).

The diagnosis of trenchfoot, when once the possibility of the condition was realized, seldom offered much difficulty in World War II, especially when objective findings were present. It was sometimes a serious problem in cases seen late, in which objective findings had been minimal throughout or in which they had completely disappeared. Patients in the latter group complained of aches and pains in their feet, often to the point of incapacitation, and admitted no relief from any kind of treatment. No satisfactory objective tests were available to aid in diagnosis, and even neuropyschiatric consultation frequently failed to solve the problem. The question of possible malingering was, of course, always a factor in such cases.

Useful points in the diagnosis of cold injury in forward installations included the following considerations:

1. *The history.*—A casualty who had been exposed to cold and wet for a prolonged period of time and who complained of pain or loss of sensation in the feet presumably was suffering from trenchfoot. On the other hand, there was no definite correlation between the length and severity of the exposure and the severity, or even the existence, of cold injury. Seventy-two hours was the average period of incubation, but some men suffered their injuries after an exposure of 12 hours or even less, and some did not begin to complain for many days.

2. *The branch of service.*—Trenchfoot is so predominately a disease of frontline combat infantrymen that many medical officers in World War II thought the diagnosis questionable when it was made in noncombat troops and would not accept it without corroboration of the circumstances of injury.

3. *Symptoms.*—The most constant symptom of cold injury was pain, worse at night. Areas of hypesthesia or true anesthesia were also corroborative. An important differential point, in the absence of objective findings, was that patients suffering from cold injury almost universally stated that they were most comfortable when they were cool and when their feet were exposed

to the air at room temperature. Men whose feet were merely cold, or whose complaints were entirely imaginary, were always eager to warm their feet.

4. *Signs.*—In the forward installations, the appearance of the feet varied, the findings depending upon the timelag between the injury and the first examination by a medical officer. The feet might be red and extremely tender or blanched. Swelling might or might not be present. Blebs might be present or absent. Gangrene and ulceration might already have set in.

One point to be borne in mind in forward installations was the possibility of the occurrence of cold injuries in association with other injuries. It was pointed out at the Paris Conference on Trench Foot in January 1945 (p. 179) that, if a casualty was brought into a field hospital with wounds in the chest or abdomen, it might be a long time before his boots were removed and it was discovered that he was also suffering from trenchfoot. This was a particularly unfortunate error. It was often observed that men with other injuries, particularly abdominal injuries, tolerated cold poorly, and serious damage to the feet might occur while all the attention was concentrated on the battle wound. Ariev [10] pointed out that the cold injury in such cases might be sustained after the other injury, while the man was still lying in the field, or in the course of his transportation to a hospital.

It was also found to be important to examine the feet for possible cold injury before an injury of the extremity was splinted. It was pointed out at the Paris conference that much damage could be done to a man suffering from cold injury as well as from a compound fracture of the femur if a traction strap were put over the instep before the shoe had been removed and the foot examined. The risk of damage of this origin could be avoided by the use in the field of skin traction with adhesive instead of a traction strap.

Differential diagnosis.—The differential diagnosis of trenchfoot and frostbite was not very important. The all-inclusive diagnosis of cold injury would have been better from every standpoint. The differentiation in World War II rested upon the arbitrary distinction that the former occurred when the temperature was above freezing and the latter when the temperature was 32° F. (0° C.) or lower. This distinction was readily made early in the winter, when the temperatures were generally mild, and later in the winter, when they were generally severe. When temperatures were borderline, particularly when they were above freezing during the day and were freezing or lower during the night, there was often considerable confusion. Clinically, the feet looked much the same in both conditions, and about the only subjective distinction possible was that the patient was frequently aware of the precise time that he had been frostbitten, whereas the onset of trenchfoot was always insidious. High-altitude frostbite, for obvious reasons, was not a consideration in forward installations of the Army.

The difficulties of the differential diagnosis of trenchfoot and frostbite and the associated problems which arose in the award of the Purple Heart

[10] Ariev, T. V.: Fundamental Outlines of Present Day Knowledge on Frostbite. Medgiz, Moscow, 1943.

came down, in the end, to purely administrative considerations. They are discussed in detail elsewhere (p. 191).

Special Tests

The development of clinical criteria and of simple objective tests which could be applied under military conditions would be of inestimable value for purposes of triage at various levels of medical care and for determining when the soldier who had been hospitalized with a cold injury could be returned to

TABLE 10.—*Classification and disposition of trenchfoot cases used at the 108th General Hospital, European theater*

Classification	Trenchfoot—mild (first degree)	Trenchfoot—moderate (second degree)	Trenchfoot—severe (third degree)
History	Only mild swelling during hyperemic stage. Could always walk in shoes without much pain.	Could replace shoes and walk with difficulty during hyperemic stage. Edema subsides within 1 week.	Unable to replace shoes or walk in hyperemic stage. Edema persists for more than 1 week.
Physical findings and appearance: Hyperemic stage	Very few or no objective findings. Walking without pain or disability.	Edema less marked. May have small localized areas of ecchymosis.	Marked edema and hyperemia. Usually large areas of intracutaneous ecchymosis with occasional blisters and gangrene rarely.
Posthyperemic stage.	-----do----------	Color of foot slightly changed on dependency. No edema.	May be only characteristic red flush of foot with edema and accentuation of color on dependency.
Motor function of foot.	Walking without pain or disability.	Motor function of toes is fair to good. Walking possible within 10 to 15 days of cessation of edema and with only mild discomfort.	Marked to complete loss of active toe motion. Walking impossible or very difficult up to over 30 days.
Disposition	Hold in ComZ units (ambulatory) for return to duty under 30 days.	U. K. (ambulatory or litter).	ZI (litter).

full or limited duty. No such criteria or tests were developed during World War II. The classification scheme devised during the special study of trenchfoot at the 108th General Hospital in the European theater (table 10) remained about as useful as any.

The special tests employed overseas in World War II did not prove useful. Boland and his associates, who made skin temperature studies in patients seen 1 to 4 weeks after injury, concluded that this method might be of value in determining the severity of injury early in the course of trenchfoot but that it was of little help in later cases associated with cold sensitivity. The ischemic-pain test devised at the 15th General Hospital [11] as a diagnostic and prognostic aid had rather extensive testing, but it proved too variable to be of any value in determining progress of the condition. It also had the basic disadvantage that the results were essentially an interpretation by the patient of his own complaints, which made it a priori of questionable usefulness. Furthermore, as Paddock noted in his studies with it, complaints were likely to become intensified as hospitalization continued. It was found, in fact, that only soldiers of "undeviating character and morale" could resist the temptation, when furnished the opportunity, to enlarge upon their foot troubles. This test did not prove reliable when it was employed in Zone of Interior vascular centers.

NOTE.—The clinical details of high-altitude frostbite are reported elsewhere (p. 13). The tropical type of cold injury experienced on Leyte is also reported elsewhere (p. 211), since it was a unique and limited experience. Finally, as a matter of convenience, all details of recurrent trenchfoot are discussed under the heading of epidemiology (p. 381).

[11] Schecter, A. E., and Ragan, C. A.: Trench Foot: The Diagnostic Value of "Ischemic Pain." Bull. U. S. Army M. Dept. No. 89, pp. 98–100, June 1945.

CHAPTER XI

Therapy and Disposition Overseas

The treatment of trenchfoot has never been really satisfactory. No specific and definitive methods of management were devised in World War II, nor have any been developed since. As was pointed out in the preceding chapter, recovery from cold injury is slow. Rehabilitation is difficult of accomplishment, often psychically as well as physically. Sequelae are frequent and are often permanent.

The final effect of trenchfoot in United States soldiers who fought in World War II has not yet been fully assessed. The residua are now the responsibility of the Veterans' Administration. They are also often encountered by physicians in private practice, whose evaluation of them may be hampered by their unfamiliarity with a condition which has no precise counterpart in civilian life.

In the last year of World War II, the treatment of cold injury was more or less standardized according to the principles set forth in War Department Technical Bulletin (TB MED 81) (appendix A) published 4 August 1944. These principles, which had been formulated chiefly on the basis of the experience in Italy in the winter of 1943–44 [1] were modified as was required by expediency, theater practices, local tactical conditions, and the needs of the special patient. As the experience with trenchfoot increased, numerous methods of management reached the literature or were summarized in official reports. Some of these methods were entirely illogical or even bizarre. Those which were of any value revolved around certain general principles.

EVACUATION AND TRIAGE

In an overseas theater of operations, evacuation and triage are component parts of therapy. Triage, which is the classification of patients according to the type of medical care which their injuries require, is also determined by the point in the chain of evacuation at which medical care, for tactical and other reasons, can be carried out.

The policy eventually developed in World War II, which proved fairly satisfactory, was as follows: When the man with cold injury reached the battalion aid station or clearing station, either by litter carry, by ambulance, or on foot, it was the duty of the first medical officer who saw him to determine

[1] Report, Lt. Col. Fiorindo A. Simeone, MC, to the Surgeon, Fifth U. S. Army, subject: Trenchfoot in the Italian Campaign 1943–45.

that his injuries had been caused by cold. If they were, it was the officer's further duty to determine whether they were of such a degree as to require evacuation farther to the rear. It was necessary to separate casualties who required definitive care from those who, with a little rest and encouragement, a cup of coffee or other stimulant, a cigarette, a change of socks, and similar simple measures, could promptly return to duty. Similar triage was carried out at each subsequent medical installation, so that, at least theoretically, only men who really required definitive treatment were evacuated to the rear as far as an evacuation hospital or a general hospital in the communications zone.

Triage obviously required careful clinical judgment and practical assessment of the need for, and the possibilities of, treatment. It was usually conducted on the simple plan that all men with objective signs (swelling, edema, blisters, discoloration of the feet) were evacuated farther to the rear, eventually to a general hospital. Men without objective signs were frequently sent to a designated medical facility, where they were kept under close observation for 48 hours or a little longer. In the Third U. S. Army, for instance, one or more medical companies of a medical gas-treatment battalion [2] were utilized for this purpose, in addition to an evacuation hospital. If objective changes were going to occur, they occurred, as a rule, within 24 to 48 hours and were unlikely to occur after this time.

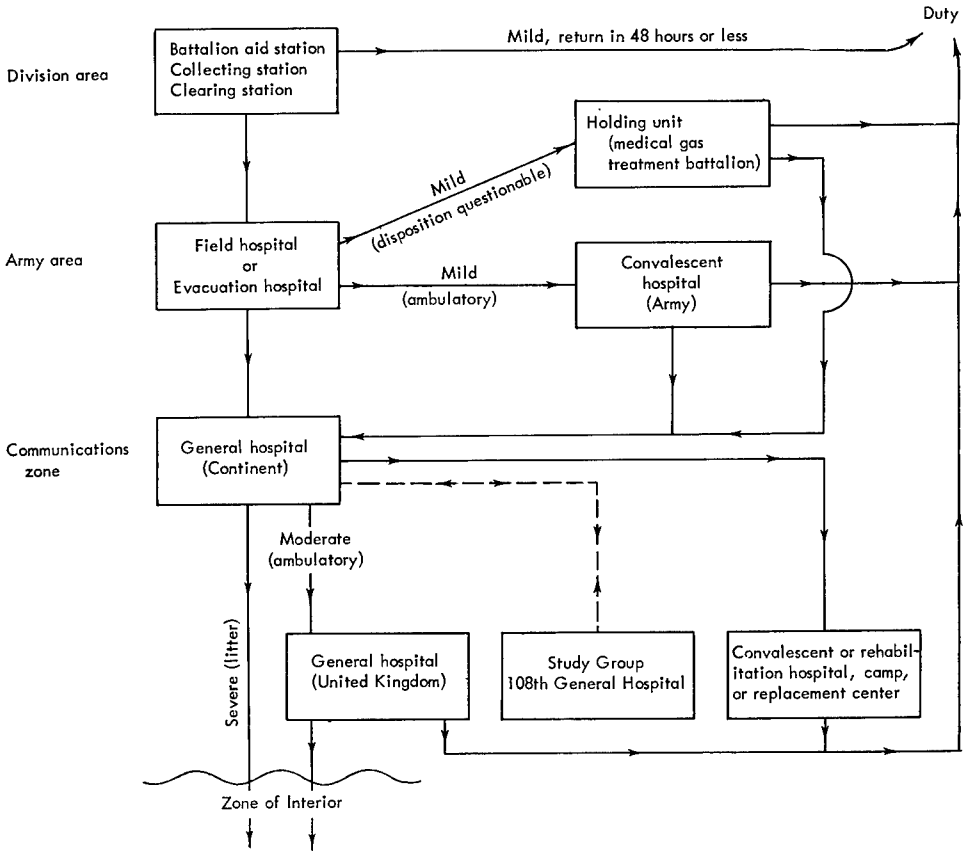
Men who presented objective changes within this period were evacuated to general hospitals. Those who did not were retained in the holding unit, under a 10-day holding policy, after which, if their condition was satisfactory, they were returned to their units. A considerable number of men were thus salvaged who might otherwise have been lost to combat units. On the other hand, it was far better to evacuate a man who might later prove to be suffering merely from cold feet than to return a soldier with an overlooked cold injury to the line, only to have his lesion progress to such a stage that it caused months of disability.

The system of evacuation and triage used in the European Theater of Operations in World War II (chart 5) provided a number of ways in which the individual casualty with trenchfoot who had reached an evacuation or a general hospital could be returned to duty or otherwise disposed of after hospitalization. His disposition, naturally, was related to the severity of his injury.

A man with mild injuries might be sent from an evacuation hospital to a convalescent hospital or a specially designated medical holding unit, such as a medical gas-treatment battalion. If his status after release from the convalescent hospital was still indeterminate, he might be sent to a holding unit for further observation. From this unit, he could either be returned to duty or sent to a general hospital for additional treatment. After treatment at a

[2] The medical gas-treatment battalion was an organization set up for the special treatment of gas casualties in the event that chemical warfare should be employed by the enemy. Since it was well located and was equipped for convalescent and holding medical functions and since it was not needed for the purpose for which it was established, one or more companies were converted to the management of casualties whose cold injuries were minimal and who, it was hoped, could be promptly returned to duty.

CHART 5.—*Flow of cold injury casualties through medical channels, European theater*



general hospital he might be transferred to a rehabilitation hospital or to a camp whence he would be sent directly to duty after reconditioning.

A man with moderately severe injuries might be sent to a convalescent hospital from a general hospital, for further observation. From the convalescent hospital, he might be sent to a rehabilitation hospital or to a camp whence he would eventually be assigned to duty. If, however, his injuries were likely to require relatively long treatment, he would be sent from the general hospital on the Continent to a general hospital in the United Kingdom Base. There his disposition would depend upon the outcome of treatment.

A man with severe injuries, who obviously could not be returned to duty, would be evacuated directly from a general hospital on the Continent to a hospital in the Zone of Interior as soon as he was able to travel.

Effective triage in such a condition as cold injury is necessarily based on some general system of classification. In some areas, the original policy was to send a man with any edema, however slight, to a general hospital but to send a man whose feet were merely white and cold to the medical companies

of a medical gas-treatment battalion. These and similar systems of differentiation were eventually replaced by the classification of injuries into mild, moderate, and severe types (p. 280), according to the criteria devised at the 108th General Hospital in Paris, which served as a special research center. The limitations of this classification, like those of other classifications, were clearly recognized, and it was advised for use with the understanding that it was to serve merely as a guide and was to be interpreted broadly.

THE ALEUTIANS

There was no uniformity of treatment of the cold injuries sustained in the Aleutians campaign either initially or in Zone of Interior hospitals.[3]

Initial Treatment

For all practical purposes, when the soldier on Attu sustained a cold injury, he did whatever seemed to him best for it. Some men simply rested as best they could, using no active measures. Some massaged the feet, sometimes with oil. They had been warned before the invasion not to rub their feet with snow if they became frostbitten, and medical officers had also been cautioned against vigorous massage. Nearly all the men kept their feet elevated when this was possible. Some found greatest relief by keeping the thighs and legs flexed.

Large numbers of casualties, as noted elsewhere (p. 88), were obliged to evacuate themselves by crawling if they could not walk, since litter carries were often impossible.

Immediate treatment on the hospital ships consisted of general warming measures, warm food and drink, morphine for the control of pain, and plasma infusions when they were indicated. All patients were given sulfanilamide by mouth, and sulfanilamide was applied locally, in the form of cream or repeated sprays. The feet were then wrapped in sterile dressings.

In the Aleutians, as in all other theaters, tetanus toxoid was given routinely to all casualties from cold injury, on the ground that it was impossible to predict the cases in which tetanus might be a risk.

Subsequent Treatment

No standardized plan of treatment was in effect in the various hospitals to which these casualties were admitted, and treatment therefore varied in some respects from one institution to another.

183d Station Hospital.—At the 183d Station Hospital at Fort Richardson, Alaska, which received the first casualties, the objective of treatment was the

[3] (1) Annual Report, Surgeon, 183d Station Hospital, 1943. (2) Lesser, A.: Report on Immersion Foot Casualties From the Battle of Attu. Ann. Surg. 121: 257–271, March 1944. (3) Patterson, R. H.: Effect of Prolonged Wet and Cold on the Extremities. Bull. U. S. Army M. Dept. No. 75, April 1944.

control of swelling and transudation and the relief of local heat. This was accomplished by cleansing and elevation of the parts, sterile dressings, and cooling by exposure to temperatures lower than room temperature. Electric fans and icepacks were used in selected cases for the first several days. Lanolin, cocoa butter, or some bland oil was used three times a day to prevent cracking of the skin and subsequent secondary infection. Active and passive exercises were instituted promptly, and walking was resumed as soon as possible.

McCaw General Hospital.—At McCaw General Hospital, Walla Walla, Wash.,[4] the patients fell into two groups, 25 who were received soon after injury and 27 who were received later, by transfer from the Northwest Pacific Area.

The 25 patients received soon after injury included 10 men who went to Attu by submarine (p. 93). All 25 had been among the advance scouts of the invasion. Nine were evacuated primarily for battle wounds but also had cold injuries.

These patients were evacuated by ship to Barnes General Hospital and then, after a stay of about 4 days, were transferred to McCaw General Hospital. All of them were physically exhausted and almost all had lowered red blood cell counts, lowered hemoglobin levels, and moderate to high leukocytosis.

Six patients were transfused. All were placed on iron-vitamin therapy and were given high-caloric diets.

Suppurative and gangrenous areas on 30 of the 50 feet had to be treated by immediate debridement and drainage, the debridement in some instances including removal of affected bone. The great toes were most frequently involved in the gangrenous processes. Local therapy after debridement consisted of dressings of Azochloramid in triacetin, activated zinc peroxide emulsions, or physiologic salt solution. Intact skin in the region of the wounds was covered with a protective coating of compound tincture of benzoin, over which a mixture of zinc oxide ointment and castor oil was applied, to prevent irritation from drainage and from the antiseptic agents used on the wounds. Large, massive, loose dressings were then applied.

Subsequent revision of the wounds, with closure, was carried out in all the cases in which debridement had been performed. Amputation was necessary in 23 of these 30 feet, as follows: Amputation of the first (great) toes alone just proximal or distal to the first metatarsophalangeal joint, in 8 cases; minor partial amputations of the other toes, sometimes alone and sometimes in addition to amputation of the great toes, in 8 cases; amputation and revision through the distal metatarsal area, in 6 cases; tarsometatarsal disarticulation in 1 case. Plastic procedures were also necessary in a number of these cases, and in one instance a pedicle flap from the opposite thigh had to be used to obtain full-thickness skin covering. In two instances, surgery was necessary to straighten rigid, flexed toes, and in another case revision of all the distal phalanges was done for rigid-flexion deformities. Lumbar sympathectomy

[4] See footnote 3 (2), p. 310.

was performed in two cases just before final plastic revision and closure, because of evidence of severe vasomotor disturbances.

When the patients who had been operated on became ambulatory, those who had suffered the loss of distal portions of the feet involving any part of metatarsals were able to walk surprisingly well with the help of prostheses adapted to their special needs. A spring-steel longitudinal strip incorporated in the sole of the shoe, back of the metatarsal heads, proved a very satisfactory substitute for the transverse-arch support usually placed inside the shoe. Pressure points were sought for, and the shoes were modified as necessary to protect them.

All through the period of hospitalization, vascular exercises were conducted three times daily, in organized class fashion. As soon as local conditions permitted, physical therapy was employed, in the form of whirlpool baths, massage, and muscle stimulation.

Soon after they became ambulatory, many of these patients developed dermatophytoses. The condition responded promptly to treatment with potassium permanganate foot soaks and the application of a boric salicylic acid foot powder. Socks and shoes were provided for all the men on the ward.

Two patients had to be separated from service because of their inability to continue infantry duty and their lack of any other training or qualifications for other work. In the other 23 cases in this group, the immediate results were surprisingly good.

The 27 patients received at McCaw General Hospital at intervals of 6 months or more after exposure at Attu had experienced somewhat less severe environmental and battle conditions than the 25 patients admitted soon after injury. Their chief complaints were aching, burning pain in the toes and varying degrees of sweating and clamminess of the feet. Both warmth and cold increased the discomfort. Lumbar sympathetic blocks were performed in all cases, with improvement of the temperature of the feet in all, but with only variable degrees of subjective relief of discomfort.

Fifteen of the twenty-seven patients, whose discomfort was not excessive, could be returned to some form of limited duty, not involving excessive standing or walking, in temperate climates. In three cases, in which lumbar sympathetic block had produced marked relief of symptoms, lumbar sympathectomy was performed. Immediate results were good, but with increasing physical activity, aching of the toes again was experienced, though the feet continued warm and dry. Seven patients were still under observation when the report from McCaw General Hospital was made, and their ultimate disposition is not known.

McCloskey General Hospital.—At McCloskey General Hospital, Temple, Tex., the patients, who were all received late, were divided into three groups for treatment as follows:

1. Patients whose feet were swollen, congested, warm, and painful were treated by bed rest, elevation of the foot of the bed, cleansing, gentle rubbing with cocoa butter to hasten desquamation, and exposure of the feet to room

temperature, with no covering at all. A high-protein, high-vitamin diet was given, with supplemental vitamin therapy. The 28 patients in this group became ambulatory on an average of 2 weeks after admission.

2. Patients whose feet showed moderate blanching on elevation, congestion on dependency, slight edema, reduced temperature, and residual hypesthesia or anesthesia, were treated by essentially the same measures just described, supplemented, in 14 of the 36 cases in the group, by paravertebral block with Metycaine Hydrochloride. In two cases the block was repeated. Two or three of the fourteen men who were treated in this manner felt that there had been some improvement in their condition, but, as a whole, the patients treated by block recovered no more rapidly than those who were treated by general measures only. It was the conclusion of the staff that lumbar sympathetic block is likely to be useful in cold injury only when edema is present and only if it can be performed during the initial stage, a requirement which can scarcely be met in combat conditions. All the patients in the second group of cases became ambulatory in 7 to 10 days.

3. The remaining 47 patients, who were well on the way to recovery when they were admitted, were treated conservatively, were promptly allowed out of bed for graduated periods, and were given systematic exercises.

The experience at McCloskey General Hospital indicated that the essence of treatment in these cases was the rehabilitation of the patients by conservative medical measures, including gradually increasing, carefully supervised muscular activity. It had been originally planned at this hospital to use pavex machines in cold injury, with the objective of preventing gangrene, but the plan was discarded, because of the length of time which had elapsed since the original injury, on the advice of the Surgical Consultants Division, Office of the Surgeon General, after consultation with the inventor of the pavex machine, Louis Herrman, M. D.

Letterman General Hospital.—At Letterman General Hospital, San Francisco, Calif.,[5] treatment was also based upon the classification of the patient according to the degree of his injury, as follows:

1. Patients with first-degree injuries were not hospitalized.

2. Patients with second-degree injuries were kept at bed rest, with the feet slightly elevated, under unheated, hooded, wooden cradles. Lanolin or petrolatum was applied once daily, with light massage. As soon as practical, tepid whirlpool baths and foot exercises, without weight bearing, were instituted. Patients who presented vascular spasm and whose feet were cold and sweaty received one or more lumbar sympathetic blocks with procaine. That these blocks hastened convalescence is doubtful, but they were usually followed by transient improvement, in the form of increased pulsations in the regional arteries, moderate reduction of perspiration, and a lessened tendency toward edema.

3. The patients in this group were eventually given woolen socks and soft shoes and were permitted to be ambulatory while exercises and physical

[5] See footnote 3 (3), p. 310.

therapy were continued. In numerous instances the results of treatment were not satisfactory. As long as 5 months after injury, some of the patients were still complaining of superficial burning and aching and of pains deep within the foot, which were worse on walking.

Patients with third- and fourth-degree injuries were dressed in the operating room, under aseptic precautions, on the day of admission to the hospital. Superficial necrotic tissue was removed to establish free drainage; anesthesia was not required. At the same time, material for aerobic and anaerobic cultures was obtained from moist or infected areas, especially at the line of demarcation. Sulfathiazole powder was sprinkled over all raw areas, which were then covered with petrolatum-impregnated gauze and dry sterile dressings. When trichophytosis was present, as it was in about 80 percent of both these groups, tincture of Merthiolate was applied to the webs of the toes. Padded plaster or Cabot's splints were used to maintain the feet in neutral position. The feet were kept slightly elevated, at room temperature, under hooded wooden cradles. Dressings were changed as infrequently as possible.

Lumbar sympathetic block was carried out in 13 patients who complained of pain, hyperhidrosis, and cold feet. In 10 of the 13 cases, the dorsalis pedis pulsations were diminished or absent. The posterior tibial pulsations were diminished in two cases and absent in one. When the pulsations were present, they varied widely from day to day. Sometimes they were fairly strong, sometimes they were weak, and sometimes they were totally absent. In all cases in which sympathetic block was done, the pulses were thought to improve more rapidly than in the cases in which it was omitted. In one case in which both dorsalis pedis pulses were absent, there was permanent bilateral return of good pulsations after the third block.

Five patients who complained of severe pain were treated by unilateral sympathetic blocks. All stated that pain was less afterward on the treated than on the untreated (control) side. Numbness was also decreased in all five cases. The improvement, however, persisted only for the duration of the block. Four patients with severe hyperhidrosis were transiently benefited by bilateral block, but no permanent results were observed.

Twenty-one patients at Letterman General Hospital were treated by mechanical respiration, produced by alternating in a positive-negative respirator. Oxygen was administered simultaneously, in a further effort to relieve local tissue anoxia. In a nunber of cases, the coloration of the feet was improved and congestion and edema were reduced, but it was concluded that, by the time patients with trenchfoot were received in a general hospital, the optimum time for measures of this kind had already passed. Improved venous drainage and better oxygenation of tissues might, it was thought, have reduced tissue necrosis appreciably if these objectives could have been accomplished immediately after trauma.

Prophylactic X-ray therapy was used locally in all cases in which it was feared that gas bacillus infection might occur. That this treatment played

any part in the absence of this complication seems unlikely. The infection did not occur in other theaters, in none of which X-ray therapy was used.

Amputation was required in 23 cases at Letterman General Hospital, as follows: Both feet, through the lower third of the tibia, in 3 cases; 1 foot, in 2 cases, through the upper and the lower third of the tibia, respectively; half of 1 foot, in 1 case; all the toes of both feet, in 4 cases; 1 to 9 toes, in 13 cases. In none of these cases did gangrene terminate in mummification and a circumscribed line of demarcation. Instead, an edematous and inflammatory zone persisted in the affected area. At the same time, there was a tendency toward slow extension of infection, especially along fascial planes and into neighboring small joints.

All the amputations were performed within 5 to 8 weeks after injury, as soon as a fairly definite zone of demarcation was demonstrable. They could well have been performed even earlier. When the whole foot was involved, and a useful member obviously could not be preserved, much time was saved by performing a guillotine amputation well above the infected demarcating zone. The stump was left open, and compression bandages and skin traction were applied.

Reamputation or plastic revision was carried out later in these cases. Skin grafting was sometimes resorted to, in an attempt to cover exposed areas as promptly as possible. Penicillin solution and Dakin's solution were both tested, but it was eventually found that dressings saturated with physiologic salt solution and changed every 3 or 4 hours provided the simplest and promptest way of preparing granulating areas for skin grafting.

MEDITERRANEAN THEATER OF OPERATIONS

It would serve no useful purpose to describe the various methods of treatment used in the Mediterranean theater during the early months of the trenchfoot experience. As in the experience in the Aleutians, therapy was not standardized. Most of the methods employed were tentative, and many of them were illogical and sometimes actually harmful. Eventually, a routine of treatment, dependent upon the stage at which the casualty was seen, was adopted in all Fifth Army hospitals, the experience in which, as already noted, formed the basis for the official policies on treatment set forth a little later in TB MED 81 (appendix A).

Three considerations of therapy were fundamental:

1. Great care was taken to avoid further trauma and to guard against secondary infection, particularly in the early stages of the injury.

2. Heat was never applied to the feet.

3. The strong psychogenic factor in trenchfoot was recognized early and was dealt with promptly. All patients, with the exception of the few casualties whose injuries were severe enough to suggest that amputation would eventually

be necessary, were impressed from the beginning of treatment with the fact that they were suffering from a curable condition which would permit their return to full duty and that treatment of their injuries was being carried out with this objective in view. Even when it became evident, as it soon did, that only a relatively small number of casualties from trenchfoot could be returned to full duty, this point of view continued to be stressed.

Preinflammatory Stage

In the preinflammatory or ischemic stage of trenchfoot, the patient was transported by litter unless this was absolutely impractical. Special care was taken not to set him down near a stove at any of the halts in the chain of evacuation, though blankets were used under and over the body to keep him comfortably warm. The feet were dried gently and then were kept exposed to cool air, preferably about 65° F. (18.3° C.). They were never rubbed or massaged. Treatment was usually limited to these simple measures until the patient reached an evacuation hospital.

In 13 cases of severe trenchfoot observed by Simeone in a clearing station in Italy, one foot was powdered, the toes were separated by cotton, and uniform pressure dressings were applied (figs. 83 and 84). The untreated feet served as controls. These patients, without exception, stated that discomfort and pain were promptly relieved in the treated feet. Unfortunately, exigencies of evacuation did not permit continued personal direction of treatment and it was learned

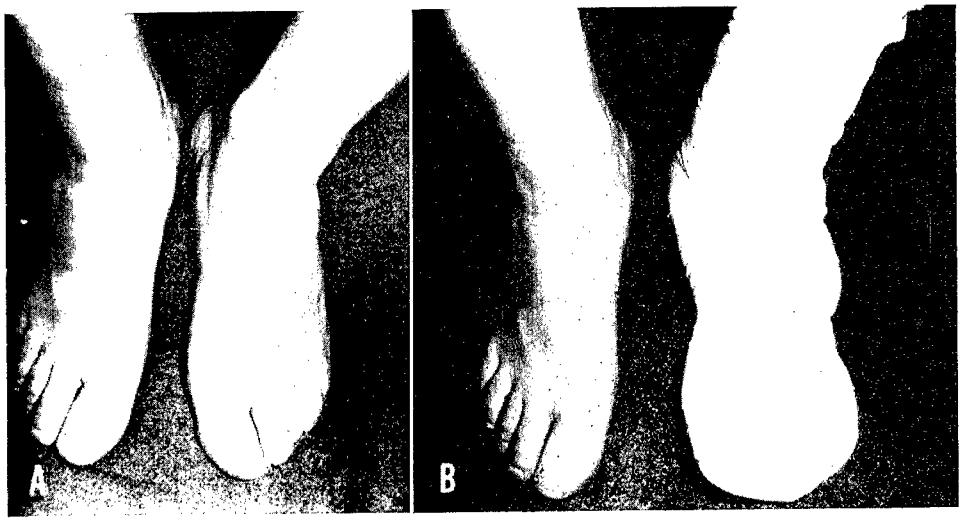


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FIGURE 83.—Management of early inflammatory stage of trenchfoot by application of powder and pressure bandages. A. Trenchfoot observed in clearing station in early inflammatory stage. The feet were warm and dry, but edema had begun to develop. B. Pressure bandage applied to left foot and leg.

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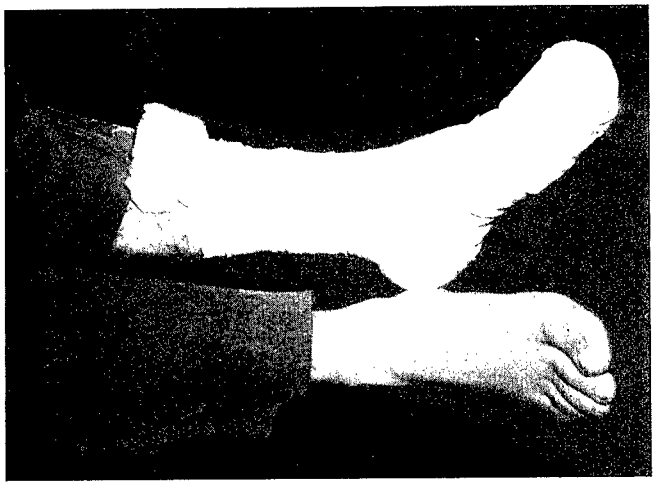

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FIGURE 84.—Application of powder and pressure bandage in early inflammatory stage of trenchfoot.

that the bandages which had been applied were removed as soon as the patients reached the evacuation hospital. The immediate results, however, suggested that this simple method is worthy of a further trial, which it does not seem to have received during World War II.

While there was general agreement, from the beginning of the Mediterranean experience with cold injury, that the direct application of heat to the affected feet was absolutely contraindicated, there was originally some difference of opinion about how rapidly the feet should be allowed to become warm. In the fall of 1944, there were two distinct schools of thought in the Mediterranean theater.

The observers who believed that thawing should be so gradual that the feet never actually became hyperemic were in the minority, and their concept was never generally applied. Their reasoning was as follows: Edema occurs because abnormal metabolic products are liberated after cold injury in very large quantities. The liberation of these substances is thought to proceed at a maximal rate when the temperature is about 59° F. (15° C.). It is therefore desirable that this level be passed as rapidly as possible during the process of thawing, though, as a practical matter, this is possible only on tissue cultures. Any kind of cold applied to the surface of an extremity produces, at best, a gradient of temperature if there is any circulation at all in the part. The temperature in the depth of the part may be 98.6° F. (37° C.) when the surface temperature is 59° F. (15° C.). In the light of these facts, even granting that edema and inflammatory products are injurious to tissues, it still seemed illogical to many observers to keep a limb without circulation, or with minimal circulation, when the duration of ischemia was believed to be an etiologic factor in trenchfoot (p. 266).

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Other observers regarded it as more reasonable to permit a limb to warm itself as long as the warming was accomplished by the return of the circulation to the part, which then would not become excessively warm in proportion to the efficiency of its blood supply. Simeone's experience inclined him to the opinion that, if the circulation did not return spontaneously within 6 hours, efforts should be made to induce vasodilatation, either reflexly or by the use of a vasodilator.

Reflex vasodilatation could be induced by warming the body with blankets or hot water bottles, leaving the feet exposed. In many hospitals, the beds in trenchfoot wards were made up so that blankets and sheets could be rolled back, leaving the distal third of the lower extremities continuously exposed to room air. In addition, the position of the beds was often reversed, in order to keep the feet as far as possible from the stoves in the wards. These practices were in accord with the desires of the patients. Most of them complained of hot feet and wanted no covering at all over them. It was exceptional, in fact, to find a man who did not say that he was more comfrotable when his feet were exposed to cool air.

Whisky was the most generally useful vasodilating agent, but, whatever the agent used, the best results were accomplished if, in the presence of maximal circulation, the tissues were cooled to a point at which vasoconstriction did not occur. It was then certain that the circulation was ample to dispose of products of metabolism and that tissue repair could begin and proceed.[6]

Inflammatory Stage

As a rule, patients were kept at complete bed rest during the inflammatory stage. Those with mild injuries were occasionally permitted mess and latrine privileges shortly after hospitalization, but this was exceptional.

During this stage, as during the previous ischemic stage, the chief objectives of treatment were to prevent trauma and infection and to avoid local heating of the affected part. To achieve the first objectives, strict surgical cleanliness was maintained. The feet were washed daily with warm, soapy water, at 70° F. (21.1° C.), then dried gently and carefully. The toes were kept separated by bits of cotton. Blisters were left undisturbed unless they were sufficiently tense to be painful. Then they were evacuated through a small bore needle. If blisters were already ruptured when the patient was admitted, dead tissue was removed and the area cleansed, after which the foot was wrapped loosely in a sterile towel. The practice of dusting sulfanilamide powder over the lesion was discontinued in the spring of 1944. Feet with gangrenous areas were kept loosely wrapped in sterile towels. Ointments

[6] In an experimental study conducted during the course of the trenchfoot experience, two groups of animals which had been exposed to cold injury by immersion in cold water under identical conditions were treated, respectively, by rapid thawing and by slow thawing. Some animals in the group treated by rapid thawing developed gangrene, but only in the toes, while some in the group treated by slow thawing suffered total loss of tissue up to the level at which the extremities had been immersed. In terms of tissue salvage, the advantage appeared to lie with treatment by rapid thawing. In this group, however, massive fibrosis and induration ultimately occurred.

were avoided unless the skin was excessively dry and wrinkled. Then cottonseed oil or lanolin was applied, but only once daily and always lightly.

The most desirable temperature to which the feet were exposed was thought to be between 60° and 65° F. (15.6° to 18.3° C.). If it proved impossible to maintain this temperature in the ward, or if this environmental temperature was not low enough to keep the feet cool, icecaps were applied. Sterile pledgets of cotton were placed between the toes, and the feet were wrapped in sterile cotton batting and covered with sterile towels before the icecaps were applied. Care was taken not to cool the feet too much and to keep them dry. Equal care was taken to keep the ice bags dry. Wet cold was thought to be actually injurious.

If ice was not available, transient relief was sometimes secured by spraying rubbing alcohol on the feet several times daily. The fan and spray method described by Webster, Woolhouse, and Johnston [7] proved simple and effective. In some hospitals, it was thought that some benefits were accomplished by soaks in cool water and whirlpool baths at 70° F. (21.1° C.) for 20 to 30 minutes daily. Not all patients could tolerate such methods, nor was it thought that they expedited recovery. They were used merely because some patients with hot, swollen, painful feet were temporarily relieved by them and were able to sleep without sedatives and analgesics after one or more of these methods had been employed.

Relief of pain was accomplished by medication only when no other measures were effective. Whatever drug was used was discontinued as promptly as possible. A number of other methods were employed to relieve pain, with variable results or none at all. Polyvitamin therapy, thiamine chloride alone or in combination with other measures, nicotinic acid, pilocarpine, and carbamylcholine chloride gave no better results than were accomplished in cases in which only general measures, which were also employed when these agents were administered, were used exclusively.

Edwards, Shapiro, and Ruffin [8] tested the use of daily intravenous injections of physiologic salt solution, in amounts of 150 to 300 cc. and had variable results. Nineteen patients who had previously had no relief from aspirin or codeine were promptly relieved of pain by the injections but two others, who were bedridden with painful, swollen feet, had no relief at all. No reduction of edema was observed in some cases, but in others it was thought that the swelling disappeared more promptly than usual. Intravenous injections of hypertonic salt solution relieved pains and aches present when the patients were at rest, but relief was transient; the difficulties recurred when the patients became ambulatory. Combined injections of physiologic salt solution and 50-percent glucose in 50-cc. doses were ineffective.

In five cases of severe bilateral cold injury treated at the 23d General Hospital, a snug plaster cast was applied to one foot while the other was left

[7] Webster, D. R., Woolhouse, F. M., and Johnston, J. L.: Immersion Foot. J. Bone & Joint Surg. 24:785–794, October 1942.

[8] Edwards, J. C., Shapiro, M. S., and Ruffin, J. B.: Trenchfoot: Report of 351 Cases. Bull. U. S. Army M. Dept. No. 83, December 1944.

exposed, according to the usual practice. Every patient was convinced that the foot in the cast was less painful than the other, and 4 of the 5 requested that the cast be reapplied when it was removed. Objectively, it was not possible to detect any differences between the treated and control feet. During this period, almost any change in the environment of the foot or in the method of management was likely to produce transient relief, and too much influence therefore could not be attributed to any special therapeutic measure.

The patients were usually most comfortable with the feet level. In a few instances, relief was obtained by elevating them 10 to 12 inches above heart level, but most of the men found this position uncomfortable. If there was considerable edema, the feet were kept elevated most of the time. This position was not practiced in patients with signs of circulatory inefficiency.

As soon as acute pain was relieved, passive vascular exercises were begun. The routine was simple. The feet were elevated at an angle of 45° on a board or a chair, at first for 3 minutes and later for 5 minutes. Then, after the patient had lain with the legs horizontal for 5 minutes, he sat on the edge of the bed, with his feet dangling, at first for 2 minutes and later for 3 minutes. These exercises, which were carried out 3 or 4 times daily, were supplemented by calisthenics in bed, which were conducted each morning by the ward master.

Areas of gangrene were kept under close observation, but in the absence of infection amputation could be safely delayed for 10 to 12 weeks; by this time, the necessity for the operation and the extent of resection required had become absolutely clear cut.

Postinflammatory Stage

The number of therapeutic procedures advised for the management of the postinflammatory stage of trenchfoot was, as always, an index of the lack of effectiveness of any of them. As in the inflammatory stage, any new method of treatment, however irrational it might be, was likely to produce transient relief.

During this stage, management was chiefly symptomatic, the principal objective being to prevent disabling atrophy of the feet. After men had been confined to bed for 5 to 6 weeks or longer, atrophy of the intrinsic muscles of the foot was often evident, and the ligamentous supports of the arches were weakened. Exercise was the best remedy, though it was extremely difficult to make the patients employ it when movement of the feet caused pain and discomfort. Arch supports, while theoretically advisable, were seldom tolerated in the cases in which they were tested. Plaster casts gave unsatisfactory results. Physiotherapy, which was contraindicated during the inflammatory stage, was frequently useful in the postinflammatory stage, but the results were uneven and were usually less good than those the patient accomplished by his own efforts.

The first exercises consisted of gentle passive motion, followed by active motion in the toes and ankles. Walking was begun as soon as possible and was gradually increased until hikes and marches could be attempted. At one re-

conditioning and training unit, an attempt was made to toughen the thin, delicate skin of the feet by having the men exercise barefoot on a beach, but the results were not notable.

Most patients recovering from trenchfoot had aches and pains in the muscles and metatarsophalangeal joints for several weeks after objective signs of damage had disappeared. When ordinary walking had ceased to be uncomfortable, minor aches were common after hikes, but if they were ignored and regular exercise was continued, they usually disappeared.

The morale of men with trenchfoot who required prolonged hospitalization was a serious problem. Opinion was divided concerning the wisdom of segregating groups of patients in the postinflammatory stage. They could be handled more easily, and group exercises could be conducted more efficiently, when they were kept together. On the other hand, symptoms seemed almost contagious, and a new complaint by one patient often meant its prompt appearance in many other men in the same ward. The best solution of the problem was the segregation of patients whose progress was satisfactory and the dispersion of those who presented problems requiring individual attention or who, for one reason or another, made en masse treatment difficult.

The time of bed patients could be occupied by systematic planning, involving reading, writing letters, occupational therapy, supervised exercises, and games and other entertainment. Ambulatory patients required equally careful supervision, but it was less of a problem because outdoor games and exercises were possible.

The establishment of a reconditioning and rehabilitation section in a hospital which treated patients with trenchfoot was always helpful because it took the men out of the ward atmosphere. After medical treatment had been concluded, this atmosphere was highly undesirable. In one hospital in which such a section was established, the men were required to attend formation each morning and retreat each evening. Also, according to their ability, they worked as ward attendants; helped in the post office, Red Cross, and message center; and acted as clerks, telephone operators, and mechanics. In addition, they participated in planned exercises and games and attended lectures on orientation, combat problems, and current events.

Sympathetic Block and Sympathectomy

The value of sympathetic block and sympathectomy was a debatable matter in the Mediterranean theater. There was rather general agreement that very early block, shortly after vasoconstriction had occurred and before ischemia had been present for a considerable length of time, might be useful, but its employment at this time was an obvious impossibility under battle conditions. When the operation was performed later, the results were widely variable. Some observers explained the generally unsatisfactory results by the fact that sympathetic block is a delicate procedure and that many of those who were employing it were not trained in its technique. It is doubtful that

this explanation covers the situation. Dubious or poor results were achieved by many surgeons who had had a large experience in this field.

Simeone reported the results in several series of cases in which sympathetic block was employed:

Early in the winter of 1943–44, this method was used, with the idea of relieving the subjective complaint of pain, on 11 patients seen within 14 days after injury and on 40 others seen in the postinflammatory stage. Immediate effects were good, but no results were permanent.

In another group of 65 patients, seen within 14 days of the injury, it was thought that the blocks performed increased the chances of favorable results when skin grafting was necessary, and possibly shortened the convalescence after the acute or hyperemic stage had passed. There was, however, no significant difference in total hospitalization time for patients treated by this method and those who were treated only by general measures.

Paravertebral block with Novocain relieved the pain of 5 of 17 patients in still another series, but the results were questionable, since comparable relief was experienced in 50 percent of the control group when the needle was merely introduced and no Novocain at all was injected.

Simeone reported only slight relief from the performance of unilateral sympathectomy on 13 patients who had disabling pain; the operation was done at periods varying from the late inflammatory to the late postinflammatory stage. On the other hand, edema disappeared more rapidly than usual in some of these cases, and, in at least one instance of gangrene of the toes, more tissue was salvaged than had originally been thought possible (fig. 85).

Simeone also reported another series of 23 sympathectomies performed in 17 patients who were suffering from such late sequelae of cold injury as vasospasm, hyperhidrosis, bromidrosis, and maceration of the skin. In the only case in which there was no improvement at all, it was found that the operation had been incomplete. Edwards and his associates found unilateral sympathectomy of value in patients with hyperhidrosis; the treated foot improved remarkably in comparison with the untreated foot. Telford's [9] results in five British soldiers were generally good.

The total experience with interruption of the sympathetic-nerve supply in the management of cold injury in the Mediterranean Theater of Operations was uneven and, on the whole, disappointing. As has been pointed out, it was thought that the operation might be of value in cases of obvious circulatory insufficiency (fig. 86), if it could be carried out soon after injury. This would usually be impractical. The procedure seemed of some value late in the course of the injury, for the relief of chronic vasospasm, hyperhidrosis, and the complications of these conditions. It did not seem, however, to have any effect upon subjective complaints of persistent pain in any stage of the condition, nor did it seem to modify the clinical course in any material way.

[9] Telford, E. D.: Sympathectomy in Treatment of the Cryopathies. Brit. M. J. 2:360, 18 Sept. 1943.

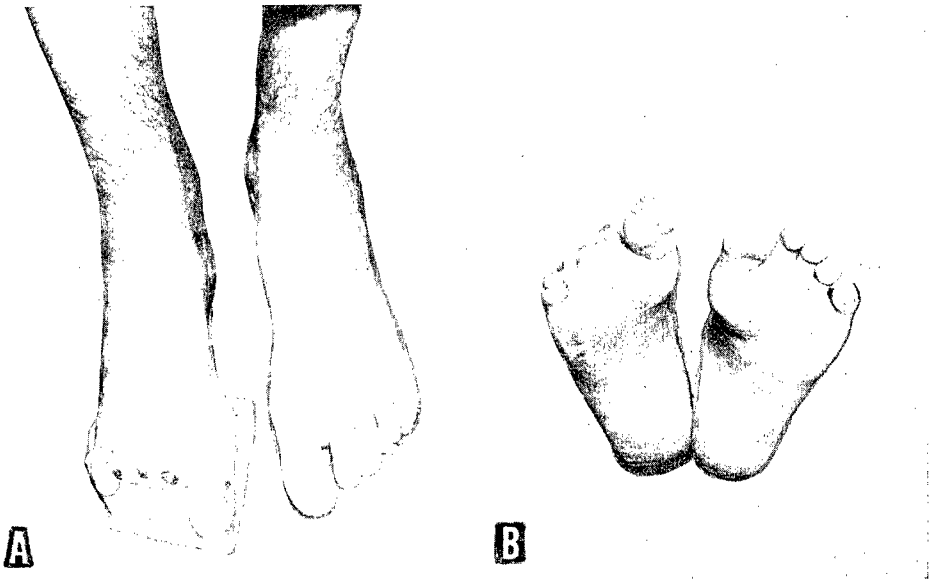

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FIGURE 85.—Effect of sympathectomy in severe trenchfoot. A. Appearance of feet after 3 months of hospitalization and 2 months after right lumbar ganglionectomy. The circulation in the right foot improved considerably after the operation, and more tissue was salvaged than had originally been thought possible. B. Plantar aspect of feet shown in view A.

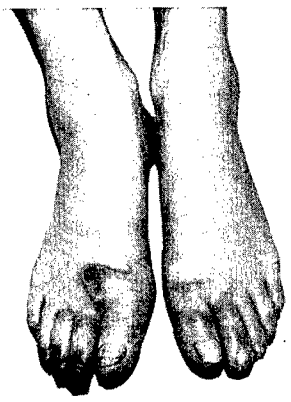

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FIGURE 86.—Inflammatory stage of trenchfoot after 14 days of hospitalization. In this case, the skin cleared distal to the serpentine line at the base of the right great toe after alcohol block of the lumbar sympathetic trunk.

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Amputation

Amputation was always delayed as long as possible, being employed early only for advancing and intractable infection. In such cases, particular care had to be taken to distinguish between an infectious inflammation and the nonbacterial reaction characteristic of the inflammatory stage of trenchfoot.

The practice of delaying amputation as long as possible proved well worthwhile. Circulatory channels were frequently reestablished, and unexpectedly large amounts of tissue were saved. In some of these cases, it was thought that lumbar sympathetic block had increased the salvage. It was repeatedly observed that gangrene, which had seemed deep, was only superficial and that healthy epithelization was present beneath the eschar when it separated spontaneously (p. 296).

EUROPEAN THEATER

In the European Theater of Operations, methods of treatment of cold injury were essentially the same as those finally standardized in the Mediterranean theater. When the European experience occurred, the official policy of management, based on the Mediterranean experience, had already been published in TB MED 81, though its circulation in the theater was later than it should have been to achieve the greatest possible usefulness (p. 164).

General measures.—As the first step, the patient was required to get off his feet. He was transported by litter, and, after his wet clothing had been changed for warm, dry garments, he was kept recumbent. The feet were covered loosely and were protected from further trauma and from infection. No active treatment was undertaken until the evacuation hospital was reached.

Here, the patient was placed at complete bed rest, with the feet on a level with the heart. Care was taken to protect pressure points and to guard against infection. Massage was not practiced, and the feet were handled as little as possible after they had been cleansed when the patient was admitted. The body was kept well covered, but the feet were left exposed, preferably at room temperature of 65° to 70° F. (18.3° to 21.1° C.). Heat was not applied in any form. Artificial cooling was sometimes accomplished by electric fans. If the feet were covered, the covering was elevated by a wooden cradle. The maintenance of minimal tissue metabolism was the objective during the hyperemic stage.

Measures to prevent infection were limited to the use of a careful aseptic technique when the feet had to be handled. The sulfonamides and penicillin were used only when established infection was present. Surgical measures were conservative. Blisters were left intact, and ulcers were treated by simple aseptic methods.

A nutritious diet, high in proteins and vitamins, was provided. The occasional use of vitamin and nicotinic acid therapy was no more successful in European theater hospitals than it had been in the Mediterranean theater.

At the 114th General Hospital, in England, it was noted that 5 patients with streptococcic sore throat, who had had fever of 102° F. (38.9° C.) for 24 hours or more, showed much more rapid improvement than 26 other patients who were admitted at the same time and who had apparently the same degree of cold injury. The possible significance of this observation is not clear.

Vasodilator agents.—Vasodilator drugs were tested in some hospitals, with equivocal results. Whisky was occasionally used but was not generally recommended. It was mentioned at the Paris conference on trenchfoot in January 1945 (p. 179) that the Stars and Stripes had described trenchfoot as the way to get "this nice treatment." The rather enthusiastic early reports from one general hospital on the use of a special negative-pressure respirator were not substantiated when further trials with this method were made.

Sympathetic block and sympathectomy.—The consensus in the European theater was that sympathetic block and sympathectomy did not promote recovery in cold injury. At the Paris conference just mentioned, several observers stated that, while relief of pain was sometimes accomplished and earlier movement of the feet was thus made possible, these results were too infrequent to justify the routine use of this method. Another observer stated that the results were always transient and that some of them were shared by the man in the next bed. An occasional officer thought that sympathetic block or sympathectomy was justified when edema was intractable. In the late stages of cold injury, relief of chronic vasospasm and hyperhidrosis was sometimes secured by these methods.

Amputation.—Superficial gangrene was not uncommon in the European theater, but the necessity for surgical intervention and amputation seldom arose. The only indication regarded as valid for early amputation was intractable advancing infection. Gangrene frequently proved to be only superficial. When the eschar separated, healthy epithelization was present, and rapid regeneration of the tissues was likely to follow. If it did not, skin grafting was performed later.

Orthopedic appliances.—In late stages of cold injury orthopedic appliances or specially fitted or constructed shoes were sometimes used to make walking more comfortable. At the 216th General Hospital, walking was expedited in 8 or 9 cases by injecting the posterior tibial nerve with Novocain and Pontocaine Hydrochloride. Weight bearing was then possible for some hours without pain. This method does not seem to have had any other trial. Physiotherapy was of value in the correction of deformities arising from fibrosis, muscular atrophy, and chronic edema.

Rehabilitation.—On the whole, the best results were accomplished when active muscular exercise was instituted promptly and carried out energetically. This policy was strongly emphasized at the Paris conference on trenchfoot. One particularly aggressive surgeon, it was reported there, supplied his patients with marbles, which they had to transfer from one box to another with their toes. One group of men who were treated by this method were walking 9 and 10 miles within a month after their injuries. It was stressed that medical

officers with a "defeatist attitude," who let their patients merely lie on their backs, "with toes pointed heavenward," had very poor results, including deformities of the toes and feet caused by too prolonged bed rest.

As a general rule, it was the policy to segregate patients with trenchfoot of the same average severity in the same ward. This made it possible to set up a sound program of muscular rehabilitation under the direction of a good noncommissioned officer, or an officer patient, who would see to it that the program was carried out energetically several times a day. As soon as possible, the men were fitted with shoes, in larger sizes than they had previously worn, and were required to be ambulatory.

All patients who could be returned to duty were sent to the rehabilitation service for at least 2 weeks before reassignment to a replacement (reinforcement) depot. During this time, hikes of a minimum of 5 to 6 miles were used to gage their progress. This program was applicable, of course, only in patients with mild to moderate injuries, but even patients with severe injuries, when they became ambulatory, could undertake a modified program of this kind and were improved by it. At the 110th Station Hospital, for instance, it was instituted in 25 cases of trenchfoot of more than average severity, in some instances associated with superficial gangrene. At the end of 5 weeks, 12 of the 25 accomplished a route march of 5 miles. Eleven of the others were ambulatory, and all twenty-three had duties about the ward.

All reconditioning and rehabilitation programs, even if they did not return men to full or limited duty, were successful in the sense that most patients became ambulatory reasonably early and that many were spared neuropsychiatric complications. In addition, hospital beds were conserved, as were the time and effort of medical personnel.

Heparin therapy.—In December 1944, a joint effort was made by the Medical and Surgical Consultants Divisions, Office of the Surgeon General, to set up an investigation of the effect of heparin in the treatment of cold injury, as had been proposed by Lange and Boyd.[10] The rationale of this method of therapy was explained as follows: The primary pathologic process in trenchfoot is tissue injury caused by cold and anoxia. At low temperatures, the tissues release a substance which initiates sterile inflammation. Small blood vessels are injured in this inflammatory process, and transudation of plasma occurs through their thin walls. Because of a combination of factors resulting from arteriolar constriction and diffuse inflammation, clotting of the blood tends to occur in these vessels and is apparently responsible for the most serious damage to the tissues, which in some instances may include gangrene. Whether the associated nerve injury is caused by exudation and anoxia is not yet known. The proposed therapy was the use of an anticoagulant, based on the assumption that thrombosis would thus be halted in its progression if not prevented entirely.

Heparin suspended in Pitkin menstruum was selected for the trial, in

[10] Lange, K., and Boyd, L. J.: The Functional Pathology of Experimental Frostbite and the Prevention of Subsequent Gangrene. Surg., Gynec. & Obst. 80: 346-350, April 1945.

preference to Dicumarol, because of the immediate effectiveness of the former and the lag of 48 to 72 hours before the anticoagulant effect of the latter becomes manifest. Heparin was also better adapted for military use for another reason. When it is used, sufficient control can be maintained by determination of the clotting time by the Lee-White method, which is a relatively simple test. When Dicumarol is used, the prothrombin time must be determined repeatedly by a decidedly more complicated method.

Plans for controlled experimental testing of the technique were carefully worked out and a supply of heparin was sent to the European theater. By the time it arrived and could be distributed, the trenchfoot experience was practically over,[11] and a controlled experiment therefore could not be continued.[12]

RESULTS OF THERAPY—DISPOSITION

As has already been pointed out, the evacuation of casualties within and from a theater of operations is conditioned on the one hand by the continuous necessity of maintaining open beds in forward areas for the reception of battle casualties, and on the other hand by the advisability of keeping as near the frontline as possible all men who might be expected to return to the front within the permitted holding period in this area. Experience in World War II showed that this plan favored the return to duty of the maximum number of nonwounded men within the shortest possible time.

Trenchfoot was managed according to this general plan (p. 307), but the results, from the standpoint of returning men to duty, were far from satisfactory. Crisler stated at the Paris conference on trenchfoot in January 1945 (p. 179) that about 25 percent of all casualties with suspected trenchfoot were sent to the medical gas-treatment battalion centers for trenchfoot. The figure sounds promising, but, when it is broken down into its components, it is found that only one-fifth of these men were ambulatory and able to return to frontline duty at the end of the permitted holding period. The other four-fifths had to be evacuated to general hospitals for definitive treatment. Furthermore, as other observers brought out at this conference, many of those sent back to frontline duty continued to complain of pain in their feet, exactly as many other men in the Zone of Interior had constantly complained of low-back pain.

The disposition of patients with trenchfoot was always a major problem. The disability was of long duration. The results of therapy were discouraging.

[11] Toone, E. C., and William, J. P.: Trenchfoot: Prognosis and Disposition. Bull. U. S. Army M. Dept. 5: 198-210, February 1946.

[12] Heparin seems to have given good results when it was used in Korea. Lt. Col. Kenneth D. Orr, MC, who observed approximately 1,500 cases of cold injury in December 1950, wrote as follows on 14 March 1956: "No agent or procedure was clearly demonstrated to prevent gangrene in 4th degree frostbite. However, in those cases treated with heparin in which treatment was begun less than 36 hours after rewarming, the eventual tissue loss was less than predicted when the patient was first seen. Fifty percent of cases of 4th degree frostbite extending proximal to the web of the toes who received only general supportive measures developed soft, wet, infected gangrene. This same result occurred among patients receiving vasodilators and sympathetic ganglion blocks. Those cases of severe 4th degree frostbite extending proximal to the web of the toes who received heparin all dried and mummified. These heparin-treated cases had asymptomatic, afebrile courses and were transportable after 14 days to the Zone of Interior for definitive surgery."

Only small numbers of men could be returned to full duty, from either forward or rear areas, and additional problems were introduced by the inability of even men returned to limited duty to hold up under any sort of strain.

It was essential for medical officers accustomed to civilian practices to bear in mind that soldiers who were returned to duty, whether full or limited, had to be able to perform all the duties for which they were classified. No arrangements could be made for intermittent or partial performance of assigned tasks. Moreover, the return to duty of soldiers who promptly had to be evacuated again entailed a great waste of valuable time, effort, material, and transportation facilities. A strict disposition policy therefore proved, in the end, to be far wiser than a liberal policy, but, in both the Mediterranean and the European theaters, this had to be learned by experience.

Mediterranean Theater

The experience in the Mediterranean theater, which from the standpoint of disposition was much longer than the experience in the European theater, may be accepted as typical. In general, the criteria of return to full duty were as follows:

1. There must be complete subsidence of swelling and erythema.
2. Vasomotor stability must have been reestablished.
3. Paresthesia and pain must have disappeared entirely unless there was clear evidence that their presence could be explained on psychogenic grounds.
4. There must be no evidence of mechanical strain or arthritic processes.
5. The soldier must have demonstrated, in actual practice, his ability to hike, march, and otherwise stand up under the physical strain of military life.

Criteria for evacuation to the Zone of Interior were as follows: (1) Extensive edema or blister formation; (2) hyperhidrosis or signs of generalized vasomotor instability in either upper or lower extremities; (3) persistence of symptoms after 3 months of adequate treatment; (4) disabling amputations; and (5) associated arthritis, fallen arches, bunions, exostosis, or similar abnormalities.

Of the 50 patients with trenchfoot who formed the material for the first investigation of cold injury in the Mediterranean theater, 8 were returned to duty at the end of a month and 3 more at the end of 6 weeks. At the end of 6 weeks, however, 16 had already been evacuated to hospitals in the Communications Zone, and the remainder were still under treatment in the army area. The duration of edema had proved the best index of the severity of the injury. None of the 11 patients returned to duty within the 6-week period had had edema for more than 9 days.

Although it was not realized at the time, the experience with these 50 patients was to be typical of the whole experience in both the Mediterranean and the European theaters. The duration of treatment was to prove prolonged, and the number of men returned to duty was to be small. Furthermore—as these figures do not show—many of the men returned to duty as

cured were to prove unable to carry out their duties satisfactorily. The following experience, reported by Toone and Williams from an evacuation hospital in Italy, shows very clearly that a liberal disposition policy did not pay.

In all, 1,057 patients with cold injury were disposed of in this hospital between 24 December 1943 and 1 May 1945. During the first month of the survey, the holding period could not exceed 30 days, and 95 percent of the 318 patients with trenchfoot admitted during this time were transferred, as promptly as evacuation facilities permitted, to hospitals in North Africa. Only patients with very mild injuries were retained, because the need for hospital beds in the area was extremely acute.

During the second month of the survey, the holding period was increased to 90 days, and only patients with severe trenchfoot (grades 3 and 4) had to be evacuated. This policy, however, did not prove practical; it resulted in a serious shortage of beds, since the rate of admission for cold injury far outstripped the rate of discharge. It was therefore necessary to transfer some patients to convalescent hospitals in the vicinity and others to other hospitals in the Peninsular Base Section. The establishment of a reconditioning section in each general hospital which received trenchfoot casualties finally solved this special problem.

Between 1 January and 1 June 1944, 249 casualties with trenchfoot were disposed of. Of these, 125 (50.2 percent) were classified for full duty or provisional duty. Seventy-four were reclassified for limited duty and fifty as unfit for duty. At this time, it was thought that the greater number of the men classified for provisional duty could be returned to combat duty after another month of hard reconditioning. It was also thought that many of the men classified for limited assignment could eventually be reclassified for full duty. The 50 patients classified as unfit for any duty were returned to the Zone of Interior. All had had severe initial lesions or, even though their initial lesions had not been severe, had had persistent edema or incapacitating pain.

Between 1 June and 15 October 1944, this evacuation hospital readmitted 99 patients with chronic, persistent, or recurrent trenchfoot, as well as 10 others who had attempted to sweat it out without hospitalization during their primary attacks of trenchfoot. Although only 2 of these 99 patients had originally been treated in this particular hospital, the medical staff was fully aware that their own errors of prognosis were undoubtedly being corrected in other hospitals. The staff also realized that, while they had originally considered their proportion of disposition to duty as too low, actually, because of inexperience with trenchfoot, the proportion had been too high and had proved wasteful rather than conservative. As a result, when these 109 patients were disposed of, only 1 was returned to full duty. Thirty-two were returned to limited duty, and seventy-six were sent to the Zone of Interior.

An analysis of 60 of the 99 patients rehospitalized for trenchfoot made it clear that the new policy was the only sound and practical one. The combined time these 60 patients had been hospitalized and had spent in rehabilitation far

exceeded the time in which they had been able to do any kind of duty after disposition. Furthermore, 46 of these men had spent from 4 to 6 weeks of the duty period in training, and their effective combat time had been at the most, 6 weeks; in some instances, it had not exceeded 2 weeks. The prolonged hospitalization time and the rehabilitation effort expended on them were thus almost entirely wasted. They had had to be withdrawn from combat during a very active campaign and be replaced by men who, for the most part, had not had the benefit of the intensive training which had been wasted on the trenchfoot casualties.

Toone and Williams told in some detail the dismal story of 25 men who had been discharged from various hospitals to full duty. They had been unable to meet duty requirements either in training programs or actual combat. They had to fall out on hikes and marches. They caught rides as best they could on trucks, jeeps, or tanks. If they were fortunate, they finally found assignments as clerks or cooks at headquarters or with a rear echelon group. They were totally unfit for combat. Their disability was a hardship to themselves, it increased administrative difficulties, and it reduced the combat effectiveness of their organizations, which would have been better off if this group of men had never been assigned to them.

The symptoms from which these men suffered all suggested that none of them had recovered completely from the damage resulting from their original exposure to cold, wet weather. All had a history of persistence of one or more of the symptoms of the posthyperemic phase of their original injuries. These symptoms had gradually increased in severity during their brief periods of duty and had been acutely exacerbated by excessive walking or by marching for even short distances. Most of the men also told stories of mild recurrences of the hyperemic phase of the cold injury after minor exposure. In fact, chronic trenchfoot with exacerbation seemed a more appropriate diagnosis in these cases than recurrent trenchfoot.

As a result of this experience, the disposition policies of this particular evacuation hospital were radically altered. Of the 315 men with trenchfoot disposed of between 1 September 1944 and 1 May 1945, only 7 (2.2 percent) were classified for full duty, in sharp contrast to the 50 percent thus classified during the preceding winter. One hundred and twenty-nine (41.0 percent) were reclassified for limited duty, and one hundred seventy-nine (56.8 percent) were returned to the United States. A fairly large number of men with relatively mild trenchfoot were discharged from the hospital when the winter was at its height, and perhaps, had weather conditions been more favorable, 10 to 15 percent of them might have been given a trial at full duty. Even if this had been possible and the trial had been successful, the total number of men returned to full duty would still have been under 10 percent.

It was the conclusion of the staff of this hospital, as it was eventually the conclusion of the staffs of most other hospitals which received trenchfoot casualties, that less than 10 percent of soldiers who suffer attacks of cold injury can be restored to duty as combat infantrymen. It was also their opinion

that prolonged and futile attempts to rehabilitate the other 90 percent should be abandoned as wasteful and impractical. When the men in this group had only moderate injuries, the best plan was to train them for such combat duties as they could perform in tank companies, antiaircraft or field-artillery batteries, or motor-transport units. Men with the most severe injuries should be assigned at once to duties in the rear echelons of combat units or in the more protected environment of the base areas. The rationale of this policy of classification was that, from the standpoint of manpower necessities and losses, hospitalization and rehabilitation in excess of 2 months could accomplish nothing that could not be accomplished better by prompt assignment to a duty status which was likely to be maintained.

The duration of hospitalization, which furnished an index of the severity of the cold injury, was a useful aid in disposition.[13] About 140 patients with trenchfoot were still hospitalized when a study of dispositions was made in the spring of 1945, as part of the continuing theater investigation of this condition. Between 16 September 1944 and 6 April 1945, 1,617 men hospitalized for the ground type of cold injury had already appeared before hospital disposition boards, with the following results:

Six hundred and seventy-one (41 percent of the total number) were discharged to full duty. The average period of hospitalization was known in 618 cases and averaged 26.1 days.

Six hundred and seventy-three (42 percent of the total number) were discharged to limited duty. The average period of hospitalization was known in 504 cases and averaged 56.3 days.

Two hundred and seventy-three (17 percent of the total number) were evacuated to the United States. The average period of hospitalization was known in 210 cases and averaged 63 days.

The average period of hospitalization for the whole group in which these data were known was 43.4 days. Seventeen percent were lost from an active theater of operations after they had occupied hospital beds on an average of 2 months each, and only 42 percent, less than half, were returned to full duty. If allowance is made for the undoubted recurrences in the group returned to full duty, the picture is even more discouraging.

Over the period in which these 1,607 patients were disposed of, 2 patients with cold injury of the hand appeared before disposition boards in the Mediterranean theater. One man was returned to full duty after 15 days of hospitalization and the other to limited duty after 31 days.

[13] See footnote 1, p. 307.

CHAPTER XII

Therapy and Disposition in Zone of Interior [1]

Casualties from cold injury who did not complete their recovery overseas were evacuated to the Zone of Interior, where they were treated at the special vascular centers established at Ashford General Hospital, White Sulphur Springs, W. Va., DeWitt General Hospital, Auburn, Calif., and Mayo General Hospital, Galesburg, Ill., at the United States Army General Hospital at Camp Carson, Colo., or in other convalescent centers. Camp Carson, which had been an Army Service Forces Convalescent Hospital, was designated as a general and convalescent hospital, chiefly for the treatment of frostbite and trenchfoot, in February 1945.

Triage at the ports of debarkation was carried out on two general principles:

1. All casualties who had suffered any loss of tissue or who presented gangrene of the toes or other parts of the foot and all patients who had severe complaints or who were unable to walk were sent to vascular centers.

2. All other patients were sent to convalescent centers, preferably in a mild climate.

During the 18-month period ending in October 1945, 2,027 soldiers who had suffered from cold injury were treated in the three vascular centers. During the 4-month period of its operation as a special trenchfoot center, 4,892 soldiers with cold injuries were admitted to the general hospital at Camp Carson.

An analysis of the clinical records of 1,275 of the 2,027 patients with cold injury treated at the three vascular centers forms the background for the general statements made and the conclusions reached in the following pages. Actual figures and percentages are chiefly derived from 656 cases studied intensively at the Mayo General Hospital Vascular Center.

PREVIOUS (OVERSEAS) TREATMENT

From a study of the records of patients with trenchfoot observed at vascular centers in the Zone of Interior, it was not possible to determine with any degree of accuracy the precise methods of management which had been employed in hospitals overseas. Many of the men had apparently been transported to the rear in well-heated ambulances, but thereafter a heated environment was usually avoided. Eleven patients at Mayo General Hospital furnished a striking exception; all had been treated by the application of moderate heat

[1] The reports and analyses upon which most of the material in this chapter is based were prepared by Lt. Col. Harris B. Shumacker, Jr., MC, formerly Chief of Surgery, Mayo General Hospital.

to the feet. In another instance, in which bilateral gangrene subsequently developed, the feet had been exposed to a hot stove.

For the most part, treatment of patients without gangrene had consisted of continuous exposure of the feet, with or without elevation, at room temperature. Electric fans and icepacks were sometimes used. In all but mild cases, complete bed rest was maintained for 2 to 3 months. In a few instances, alternate hot and cold soaks were used, and Buerger's exercises were also used in some cases. Penicillin and the sulfonamides were occasionally administered to combat secondary infection.

Forty-seven patients without gangrene, who were treated at Mayo General Hospital, had had paravertebral lumbar sympathetic blocks overseas. The feet had always become warm, dry, and pink immediately afterward, but in every instance the response was transient. Two other patients had been treated by sympathectomy. In neither instance was there any relief of the aching sensation of which the patients complained, but it was thought that healing had been accelerated in a foot that showed an area of apparent deep gangrene.

The initial therapy overseas in patients who were admitted with apparent deep gangrene to the vascular centers in the United States had been directed toward combating secondary infection by the use of penicillin and the sulfonamides. Sedatives and narcotics had been employed as necessary. Conservative therapy had been the rule. Early amputation of the toes or of part of the foot had been carried out in only 1 of 37 patients with deep gangrene received at Mayo General Hospital, and only 17 of the 1,275 patients treated at all three centers had had any kind of surgery overseas.

THERAPY (MEDICAL PHASE)

The patients were told from the day of admission that their complete recovery depended upon their own efforts. It was emphasized that exercise and ambulation would expedite recovery, and they were told that they would be given every chance to improve on conservative management before surgical measures were considered.

Massage and lubrication.—Treatment at the vascular centers began with cleansing the feet of accumulated dirt and dead and desquamating skin. This was best accomplished by soaking the feet and by the liberal use of soap. Desquamation was further expedited by rubbing the feet with lanolin ointment containing 4 percent salicylic acid. The patient carried out this massage himself, at regular, scheduled intervals, after demonstration by, and under the supervision of, the physical therapist. In addition to the practical considerations of removing dead epidermis, which was usually thick and unsightly, and stimulating the circulation by massage, this procedure kept the patient occupied and aided his morale by permitting him to share in his own treatment.

When desquamation was complete, lanolin ointment was replaced by a preparation of mineral oil and a dilute solution of alcohol, which was rubbed

into the skin of the feet at least twice daily, for 30 minutes each time. The patient worked on his own feet or on the feet of the man in the bed next to him, as was most convenient. Much emphasis was placed on active manipulation of the toes, to counteract stiffness, contractures, and the atrophy of disuse.

Exercise and ambulation.—Patients with residua of trenchfoot had usually been at complete bed rest, without even latrine privileges, on an average of 9 weeks (the range being from 1 to 20 weeks) when they arrived at the vascular centers in the Zone of Interior. The first objective of therapy was therefore to make them ambulatory. In many instances, it required considerable persuasion by the ward officers to overcome the inhibitions which had developed during the long periods of complete bed rest. Even when there was no real reason why they should not become ambulatory at once, the men often objected to getting out of bed. In other instances, the resumption of walking was really difficult and uncomfortable because of pain, swelling, and tenderness in the sole of the foot.

When the toes were notably stiff, contracted, and atrophied, the daily routine of massage by the patient was supplemented by active and passive manipulations by the physical therapist. This treatment, supplemented by what the patient did for himself, freed up adhesions about tendon sheaths and joint capsules and loosened up fibrotic toes. The opinion was that the routine employment of these simple measures saved many toes which otherwise might have required amputation.

Group exercises were conducted for all the patients by trained ward personnel. They consisted of active foot and ankle exercises designed to prevent contracture of the Achilles' tendon and the gastrocnemius-soleus muscle group, as well as to prevent talipes equinus and pes cavus.

When the patients began to walk, they were fitted with low quarter shoes, which were more satisfactory than garrison shoes because of their light weight. Also, since less of the foot was covered, there was better provision for evaporation of perspiration. If hyperhidrosis was a prominent symptom, the shoes were perforated in numerous sites.

Almost a third of the patients without gangrene treated at the Mayo General Hospital Vascular Center complained of tenderness over the distal portion of the foot on the plantar surface, and, to protect this area, shifted the weight of the body to the heel (fig. 87) or to the lateral edge of the foot. To correct the resulting unnatural gait and the subsequent undesirable alterations in the dynamics of the foot and the spine, either a thick piece of leather or a second rubber heel was attached to the under surface of the shoe, in front of the regular heel (fig. 88). The patient thus walked on two heels and experienced almost no pressure on the sensitive portion of the foot. As ambulation was continued, the anterior heel, which received most of the wear, gradually wore down until, eventually, pressure was applied to the entire sole of the shoe. By this time, the sensitivity originally complained of had usually disappeared or had so greatly diminished that the additional heel could be entirely

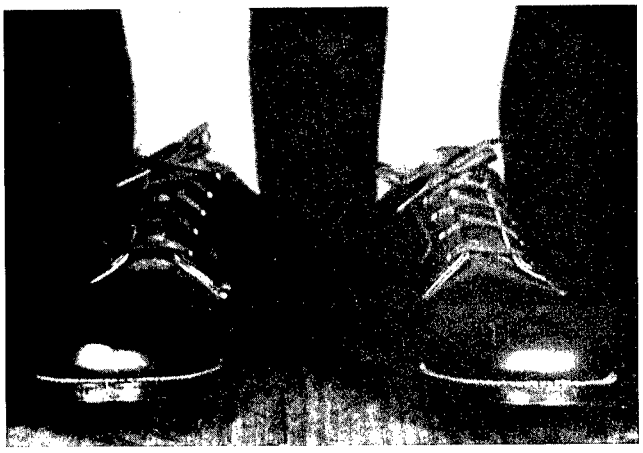

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FIGURE 87.—Typical heelwalker, who shifts pressure to heel to remove weight from sensitive sole of foot in later stages of trenchfoot.

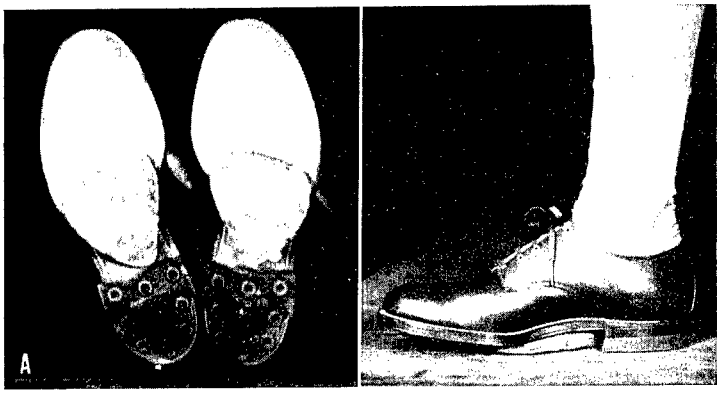

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FIGURE 88.—Correction of heelwalking by application of second heel anteriorly, to remove pressure from sole of foot. A. Plantar view. B. Lateral view. Note present stance of patient, with sole of shoe off ground.

dispensed with. In the occasional case in which the patient complained of sensitivity to pressure in the heel, the front of the shoe was built up with leather beyond the level of the heel, which was thus protected from trauma.

By these and other simple devices, patients who were fearful of leaving their beds were persuaded to become ambulatory, and a vicious circle was broken which, if it had been permitted to continue unchecked, would have led eventually to invalidism.

Lumbar sympathetic block.—A number of patients in the vascular centers were treated by paravertebral lumbar sympathetic block, partly to establish

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that their complaints of cyanosis, coldness, and hyperhidrosis were caused by excessive sympathetic activity, and partly to assess the therapeutic effects of this measure. In some instances, the only effect of the procedure was to bring about, for a short time, good coloration, warmth, and dryness of the foot. In other instances, there was transient alleviation of the sensitivity of the sole of the foot, which has just been described. Sympathectomy was later performed in several cases in both these groups. Hyperhidrosis and vasoconstriction both disappeared, but the results in respect to relief of pain on weight bearing were only indifferent.

Typhoid vaccine therapy.—Some of the first patients with trenchfoot received at Mayo General Hospital were treated intravenously with typhoid vaccine, always after preliminary testing. The initial small dosage was gradually increased to the point at which a single injection was followed by a rise in body temperature to approximately 102° F. (38.9° C.). The course of treatment consisted of 10 to 15 intravenous injections at 2-day intervals.

All of the first patients given this treatment had been chosen at random and with no selection. When the results in these cases were analyzed, it was found that the only significant change in the clinical picture after treatment was that some patients showed a considerable reduction in edema. Thereafter, the use of this method was limited to patients whose chief complaint was edema. In 6 of the 16 cases in which typhoid vaccine was used on this special indication, there were no evident results. The other 10 patients showed rapid improvement after the first or second injection; thereafter, their improvement, while it continued, was considerably less striking. At the end of the course, however, all 10 patients, who had previously spent most of their time in bed and whose edema had not been improved by 3 weeks of complete bed rest, were fully ambulatory. This method of treatment therefore seems to hold out some promise and seems worthy of further trial in late cases of trenchfoot in which swelling is prominent. Whether or not it will be effective in any given case can be determined after the first 2 or 3 injections.

Control of hyperhidrosis.—Hyperhidrosis was a common and sometimes incapacitating complaint, which was relieved only moderately, if at all, by the use of low-cut, ventilated shoes, daily foot baths, frequent changes of socks, and foot powders. Frei's method of applying formalin by means of electrophoresis was tested in 121 patients with this complaint, on the ground that formalin baths are often used by dermatologists in the management of hyperhidrosis and that the therapeutic effect might be accentuated by forcing the formalin into the skin by means of a galvanic current.

This method was never employed until the patients had been tested for sensitivity. The precaution proved essential, as well over a quarter of the men for whom the treatment was considered were found sensitive to formalin. Treatment consisted of placing the large negative electrode of an ordinary galvanic-current machine in close contact with the abdomen while the positive electrode was immersed in a bakelite container filled with 1-percent formalin solution in sufficient quantity to reach above the ankles. A course of treat-

ment consisted of six daily applications of 10 to 12 milliamperes of current for 20-minute periods.

Results were variable. In 29 of the 121 cases in which the method was used, treatment could not be continued beyond the second or third application because of mild dermatitis or the development of fissures between the toes. Thirty-seven of seventy-four patients who had one course of treatment showed almost immediate cessation of sweating, twenty-one had a fair response, and the others had no benefit at all. At the end of a 4-week followup period, the therapeutic effect was still excellent in 7 patients and good in 32, but it was only fair in 16 and was poor in 19. Eighteen patients were given two courses of treatment, at an average interval of 39 days. In this group, the results were good in 6 cases, fair in 8, and poor in 4. At the end of a 2-month period of observation, hyperhidrosis had returned in most cases, regardless of the original results, but it was less severe, and it was concluded that this mode of treatment has a definite, if transient, beneficial effect in the late stages of trenchfoot. Patients with hyperhidrosis treated by sympathectomy had, of course, complete and lasting relief (p. 342).

Other measures.—A certain number of other therapeutic methods were tested at the vascular centers, not because there was any real expectation that they would prove effective but to give the patients the benefit of all possible techniques and to rule out, in the future management of trenchfoot, those techniques which were entirely useless. As expected, the results were for the most part unsatisfactory, and the data (all from Mayo General Hospital) are presented merely for the record.

Four patients with prominent signs of excessive sympathetic activity were treated by electrophoresis with a 0.2-percent aqueous solution of Mecholyl Chloride (acetyl-beta-methylcholine chloride). Six daily applications were made, by the technique described for the similar application of formalin. The local vasodilating properties of Mecholyl furnished the rationale for this procedure, the objective of which was to counteract vasospasm. The feet were always transiently warmer after each treatment, but there was always a prompt reversion to the original cold, blue state, and, at the end of the period of observation, there was no permanent improvement in vasomotor tone in any instance.

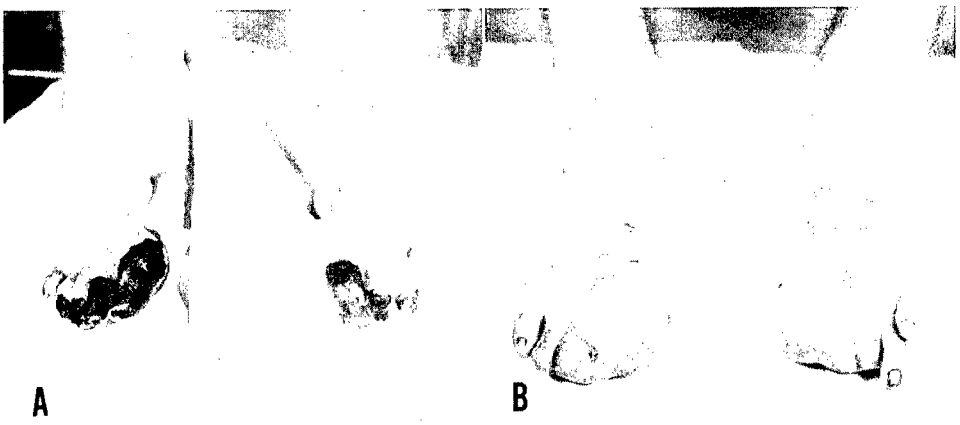
Eleven patients with complaints referable to the peripheral nervous system were given daily intravenous injections of thiamin chloride (100 mg.) for an average of 14 days. No untoward effects were noted, but there was also no alteration of symptoms. The patients continued to complain of paresthesias, aching, burning, and sensitivity in the soles of the feet. It was concluded that this form of therapy was of no value in the relief of neurologic complaints in the later stages of trenchfoot.

Eight patients were treated in Sanders beds and by Buerger's exercises. There was no reduction in the severity of their complaints, and cyanosis, coldness, and hyperhidrosis remained unaffected.

THERAPY (SURGICAL PHASE)

Sympathectomy.—Since vasoconstriction is a fundamental factor in the pathogenesis of trenchfoot, as well as one of the most constant sequelae, it was natural that sympathectomy should be regarded as a rational procedure in the last stages, whether or not other procedures were necessary. Sixty-six lumbar sympathectomies were performed on forty-nine patients at the Mayo General Hospital, by excision of the second and third lumbar sympathetic ganglia, together with the intervening chain. The operations were performed through an anterior extraperitoneal approach, under spinal analgesia. There were no complications in any case. The distribution of cases according to indications was as follows:

1. *Deep gangrene.*—There were 38 operations performed on 30 patients. Exposure had occurred in these cases on an average of 2 months earlier. From 1 to 5 toes were affected (figs. 89, 90, and 91). Evidences of vasoconstriction were conspicuous. The feet sweated profusely and were frequently cold and cyanotic. Secondary infection was present in 29 of the 30 cases. Local heat was originally present, as the result of the inflammatory reaction, in all of these cases, but cooling of the feet was observed as the infection cleared. Occasionally, the feet were warm, and sweating was almost completely absent.



AFIP (Mayo GH) 578-1, 578-2

FIGURE 89.—Extensive gangrene of both feet in late stage of trenchfoot. A. Appearance of feet before operation. B. Appearance of feet after bilateral lumbar sympathectomy and amputation through line of demarcation. Healing was satisfactory, and the patient was discharged with useful feet.

Satisfactory and reasonably prompt healing occurred in all 30 cases (figs. 89, 90, and 91), though at times, when the metatarsal bones were exposed, tube transfer grafts were necessary before healing was complete (figs. 90 and 91).

Since no control series was run, it cannot be said positively that the rate of healing was expedited by sympathectomy, but there is some evidence, as

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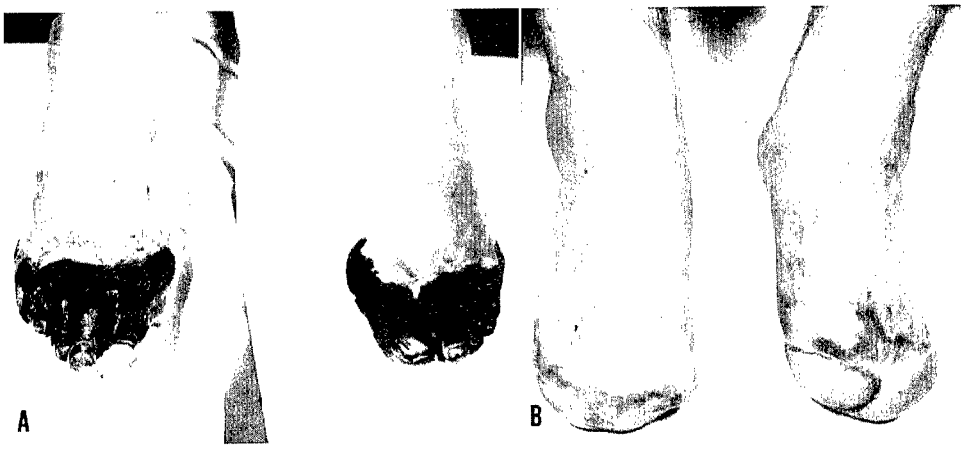
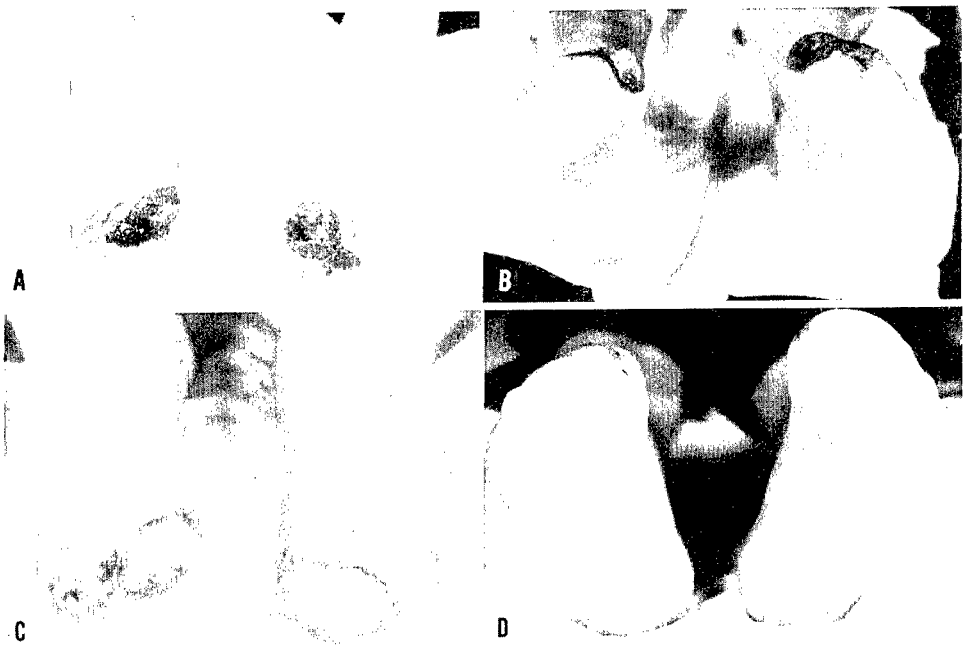


AFIP (Mayo GH) 595-7, 595-1

FIGURE 90.—Extensive gangrene of both feet in late stage of trenchfoot. A. Appearpearance of feet before operation. B. Appearance of feet after bilateral lumbar sympathectomy, amputation, and tube transfer graft to left foot.



AFIP (Mayo GH) 687-1, 687-2, 687-9, 687-10

FIGURE 91.—Extensive gangrene of both feet in late stage of trenchfoot. A. Appearance of feet after sympathectomy and amputation. Dorsal view. B. Plantar view. C and D. Dorsal and plantar views showing appearance of feet after bilateral application of tube transfer grafts and removal of part of head of right first metatarsal.

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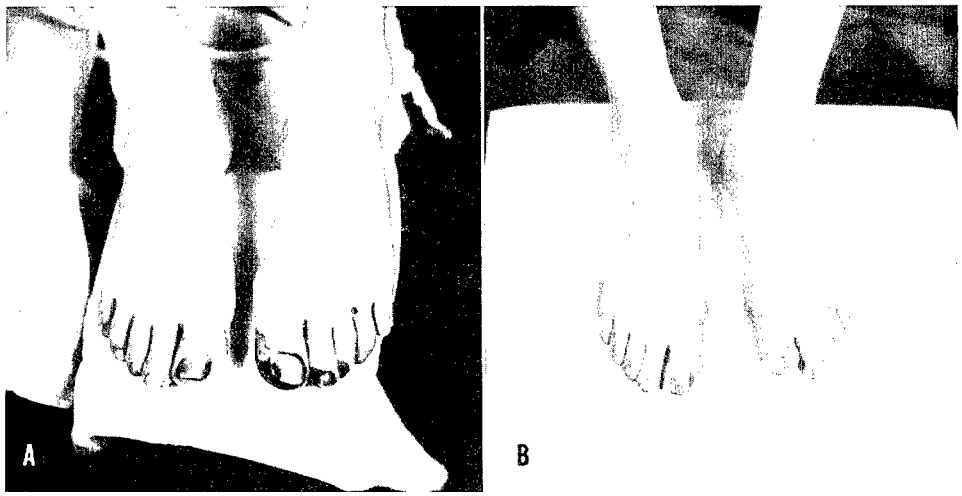
case 1 indicates, that the increase in circulation following the operation had a beneficial effect on lesions associated with significant vasospasm.

Case 1.—This patient was first seen after the first four toes on one foot had been amputated. The stumps were granulating and infected. After the infection had been treated for 4 months, small, deep grafts were applied, with poor results; the grafts did not take and little or no epithelization followed. Sympathectomy was then performed because the foot was cold, wet, and cyanotic. Complete healing occurred within a few days. The stump was subsequently revised because the skin over the distal end was thin and delicate.

The contrast of rapid epithelization of raw areas following sympathectomy and the slow healing in cases in which it had not been performed was particularly evident when vasospasm was present. After operation, the feet were warm and had a healthy color, and sweating was no longer a problem. If the skin was excessively dry, lanolin was applied daily.

When small split-thickness grafts were attempted after sympathectomy, it was not always possible to secure takes (figs. 92 and 93), but tube grafts were transferred as readily as to normal limbs.



AFIP (Mayo GH) 700-1, 700-4

FIGURE 92.—Gangrene of both feet in late stage of trenchfoot. A. Appearance of feet before operation. B. Appearance of feet after unilateral sympathectomy, amputation of gangrenous area of left great toe, application of split-thickness skin graft, which failed to take, and lateral amputation of distal phalanx of toe and revision of stump.

In 17 patients on whom unilateral sympathectomy had been performed, the skin temperature of the toes or stumps averaged 78.4° F. (25.8° C.) in the untreated limb and 91.8° F. (33.2° C.) in the sympathectomized limb. Oscillometry at the ankle averaged 2.6 on the untreated side and 4.6 on the sympathectomized side. After sympathectomy, dorsalis pedis and posterior tibial pulsations were generally present and full, and there was nothing to suggest any extensive obliterative change in the arteries of the feet, although there

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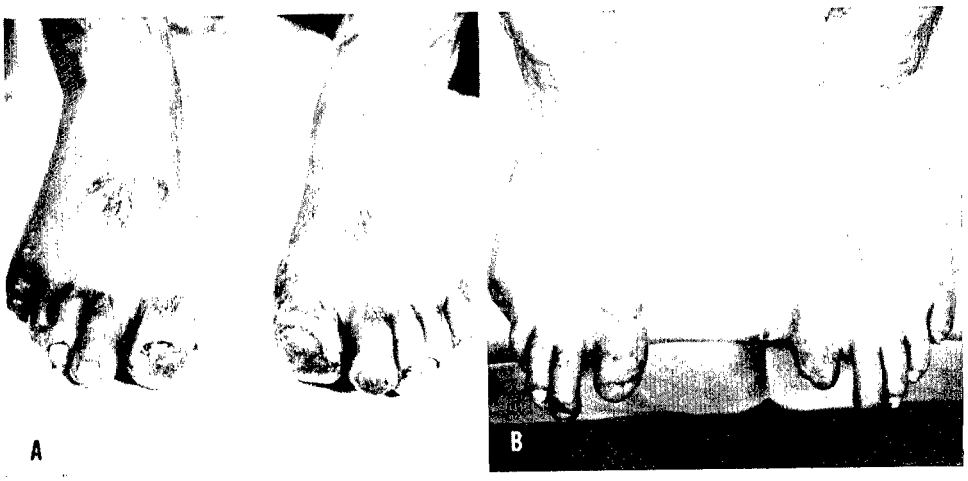


AFIP (Mayo GH) 680-2, 680-5

FIGURE 93.—Gangrene of both feet in late stage of trenchfoot. A. Appearance of feet after excision of gangrenous parts and bilateral sympathectomy. A split-thickness skin graft applied to the left great toe failed to heal, because of infection. B. Appearance of feet after revision of stumps of both great toes, because of osteomyelitis, and amputation of right fifth toe for same reason.

may have been thromboses of the digital artery or of small branches in the stump immediately adjacent to the line of demarcation.

2. *Cold sensitivity.*—There were 13 operations on 9 patients. Four patients in this group suffered from sweating to such a degree that their socks were almost constantly wet. In two cases, maceration of the skin had occurred, followed by secondary infection. These 4 patients, as well as the other 5, whose chief symptom was cold sensitivity, all complained of pain on exposure, with a distressing sense of numbness. In every case, the feet became warm and dry and the coloration normal after sympathectomy. The abnormal response to cold, and the associated discomfort, were diminished or reduced in degree, and the infection present in two patients with hyperhidrosis promptly cleared up.

3. *Pain on weight bearing.*—There were 15 operations on 10 patients. All the patients in this group had fairly well-marked vasospasm, which was completely relieved by the operation. Two patients who complained of pain in the heels had complete relief of pain, as did three of the eight who complained of pain in the metatarsal region. Two other patients with metatarsal pain secured moderate relief, but there was no improvement in the remaining cases.

In the light of these results, it was concluded that sympathectomy (1) is useful in minimizing tissue loss and in accelerating healing in patients with gangrene associated with vasospasm; (2) is of value when hyperhidrosis is a prominent symptom, particularly when maceration of the skin, local infection, and cold sensitivity are associated; and (3) is of questionable value in the

relief of pain on weight bearing and in mild vasoconstriction in the absence of severe associated manifestations.

General measures.—Of all measures instituted to control infection, before gangrenous areas were excised, the most useful was the application of warm sterile compresses saturated with physiologic salt solution. It was frequently necessary to use in addition some ointment, such as zinc oxide, to protect the intact skin against maceration, the tendency toward which seemed greater than in normal limbs. Perhaps the explanation was the very recent epithelization of large areas of skin following extensive desquamation. Another possible explanation was the extensive hyperhidrosis from which so many patients suffered.

Most of the patients were treated either with sulfadiazine or penicillin or both. If streptomycin had been available, the results might have been better, since some of the organisms which were present are sensitive to this antibiotic. Chemotherapy and antibiotic therapy were possibly effective in preventing the spread of infection, but neither method had any evident effect on the local infection. Aqueous Mercurochrome solution proved more efficacious than dilute acetic acid in clearing up infection caused by *Bacillus pyocyaneus*.

In a number of instances of apparently superficial dry gangrene, an active infection, which led to osteomyelitis, was present under the crust. Amputation was often necessary in these cases. In order to prevent such an outcome, the practice eventually developed of using compresses in all cases in which areas of superficial gangrene failed to separate promptly, in an effort to hasten separation and subsequent epithelization. The prompt removal of all well-demarcated, gangrenous tissue was found to be an important step in the management of these cases.

Even when infection cleared grossly under treatment, it was often still present deep in the tissues. The surgeon was therefore greatly handicapped in the use of split-thickness and other types of skin grafts.

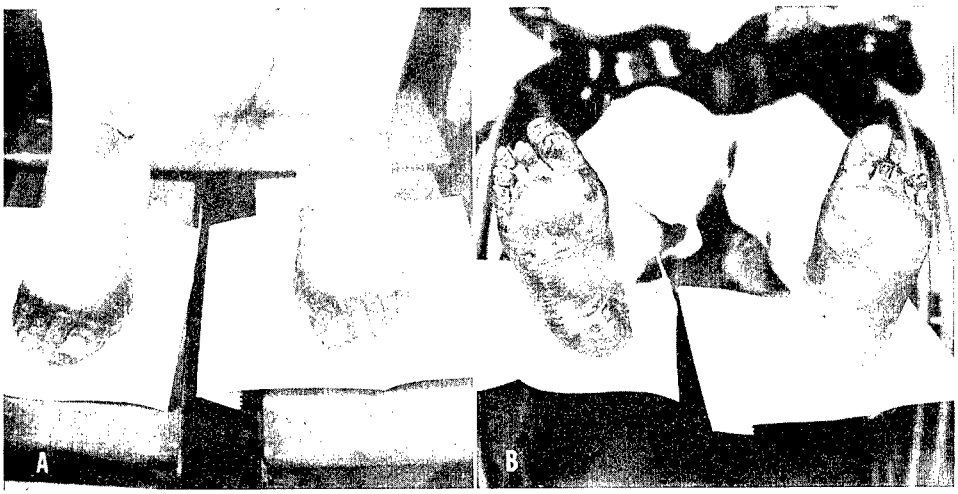
Amputation.—Gangrenous plaques and digits were, as a rule, amputated through the line of demarcation as soon as possible after the patients were received in the vascular centers. Sympathectomy was performed at the same time in selected cases. The prevalence of infection, as already noted, permitted closed amputations in very few cases.

The extent of the amputation depended upon the degree of the gangrene. The policy of conservation of all tissue that could be salvaged was strictly adhered to.

In some of the 37 patients with deep gangrene treated at Mayo General Hospital, only a single toe was affected. In other cases, the process was limited to the distal, or the distal and middle, phalanges. In still others, all the toes were completely gangrenous. In 13 cases the gangrene was so extensive that the heads of the metatarsals were left exposed after operation, and in 7 cases it was necessary to remove portions of the metatarsal bones. Protruding stumps of bone were often left in situ because infection made complete revision inadvisable at the time. Later, the stumps were further revised, and the pro-

truding phalanges were rongeured off. Disarticulation was performed in several cases. The operation was technically simple, and it was thought that osteomyelitis of the proximal stump was less common after this procedure than after amputation through the phalanges.

Amputation of a portion of the foot or leg was necessary in only two instances. One patient, who had gangrene of both feet (fig. 94) was transferred to an amputation center for amputation of the leg. The other patient (fig. 95), who had previously undergone amputation (partly tarsal-metatarsal and partly through the proximal portion of the metatarsals), had been left with a painful, unstable and entirely unsatisfactory stump. He was transferred to an amputation center for a Syme's operation



AFIP (Mayo GH) 596-1, 596-2

FIGURE 94.—Extensive gangrene in late stage of trenchfoot, for which amputation through leg was eventually necessary. A. Dorsal view. B. Plantar view.

Contractures of the toes and stiffness of the joints and muscles were rather frequent in patients who had sustained loss of tissue from gangrene, as well as in other cases. Stiffness could usually be relieved by physiotherapy and exercise, but contractures did not always respond to these methods or to the use of metatarsal bars. The commonest deformity resulted from extensor contractures. Flexion contractures were less common. Both types were more likely to occur in stumps than in intact toes. In a few instances, the contracture was so severe and disabling that amputation seemed wiser than continued attempts to remedy the situation by conservative methods (fig. 96).

Skin grafts and plastic revision.—Skin grafting was unnecessary in most patients, even those with deep gangrene (figs. 89, 97, and 98), the majority of whom were discharged with useful feet after amputation. When the toes had been amputated through the phalanges, epithelization usually occurred promptly, and the new skin was usually strong enough to withstand the trauma of walking.

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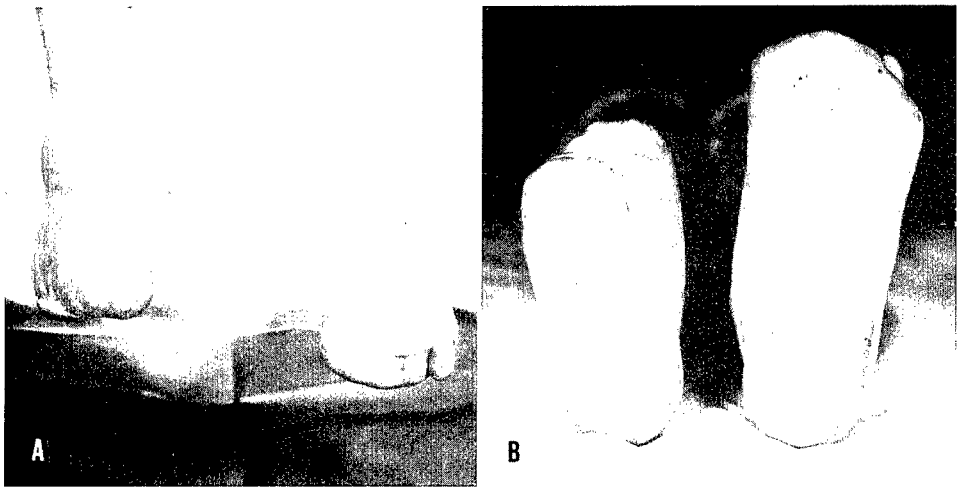
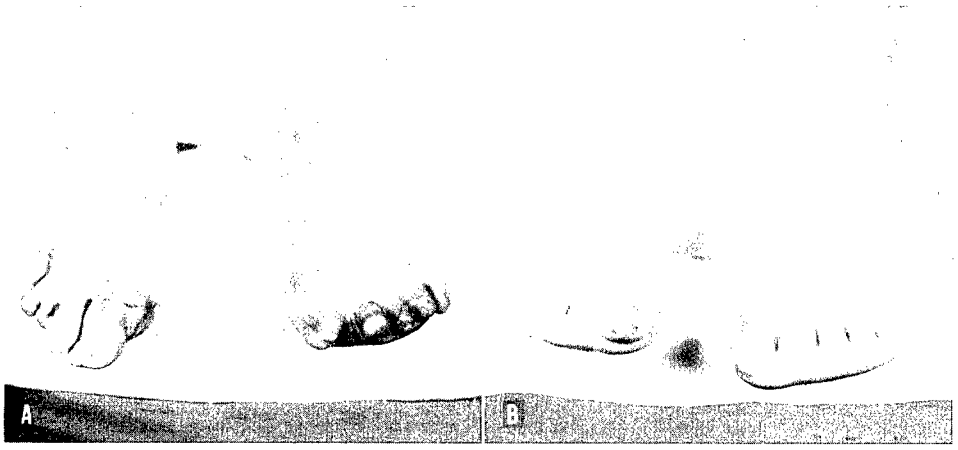


AFIP (Mayo GH) 1222-1, 1222-2

FIGURE 95. Appearance of feet after amputation (partly tarsal-metatarsal and partly through proximal portion of metatarsals) for extensive gangrene in late stage of trenchfoot. The resulting stumps were painful, unstable, and highly unsatisfactory. This patient was eventually transferred to an amputation center for a Syme operation. A. Dorsal view. B. Plantar view.



AFIP (Mayo GH) 1265-1, 1265-3

FIGURE 96. Contractures of toes in late trenchfoot, requiring amputation for relief. A. Contractures before operation. B. Appearance of feet after amputation and revision of stumps. The patient was left with comfortable feet.

In a few cases in which thin skin was adherent to the bone, revision with primary closure was carried out. If the defect was large, and particularly if an entire toe or several toes had been lost, it was often desirable to employ a split-thickness graft as a temporary procedure even if a full-thickness graft later had to be used. In some cases, split-thickness grafts were satisfactory

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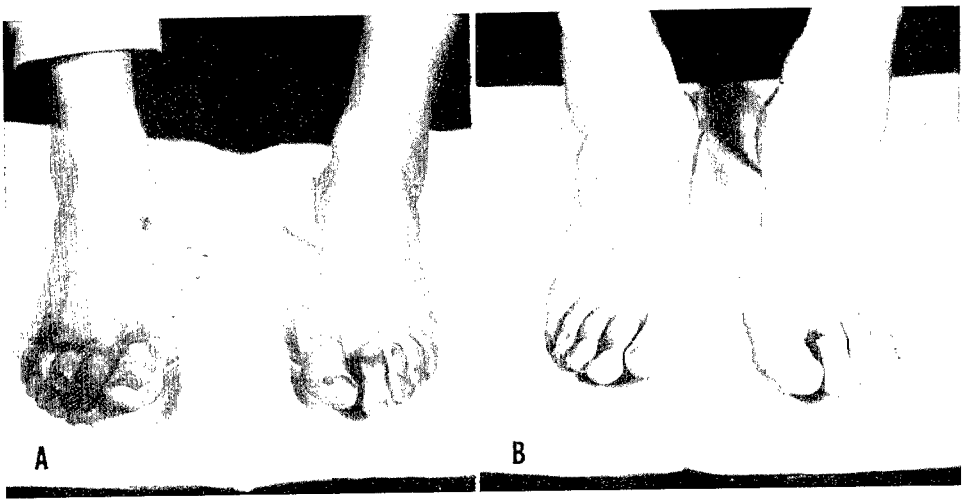
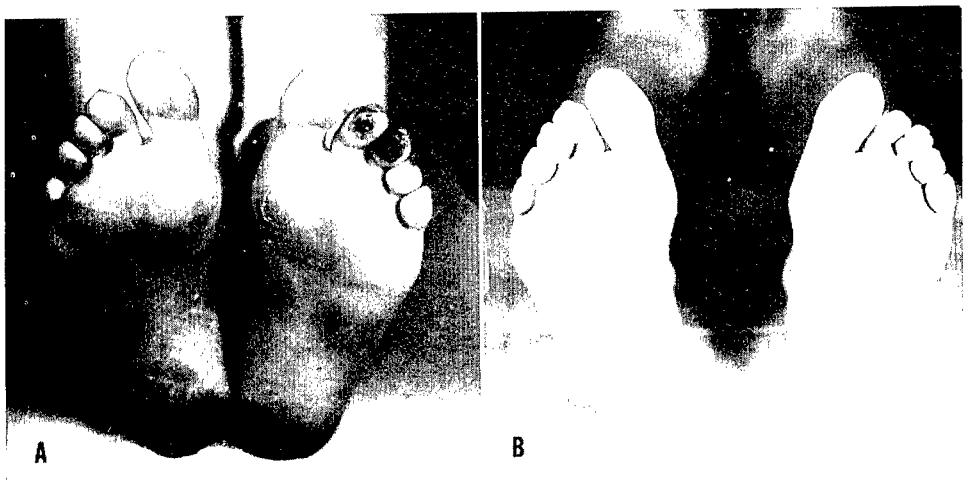


AFIP (Mayo GH) 583-2

FIGURE 97.—Deep gangrene of feet, extending to bone, in late stage of trenchfoot. A. Appearance of feet before sympathectomy. B. Appearance of feet after unilateral sympathectomy and excision of gangrenous parts. Healing was prompt and satisfactory, without additional surgery. In this case, an area of gangrene on the sole of the right foot also healed promptly.



AFIP (Mayo GH) 581-2, 581-1

FIGURE 98.—Deep gangrene of feet, extending to bone, in late stage of trenchfoot. A. Appearance of feet before unilateral sympathectomy. B. Appearance of feet after unilateral sympathectomy and excision of gangrenous parts. Healing was prompt and satisfactory, without additional surgery.

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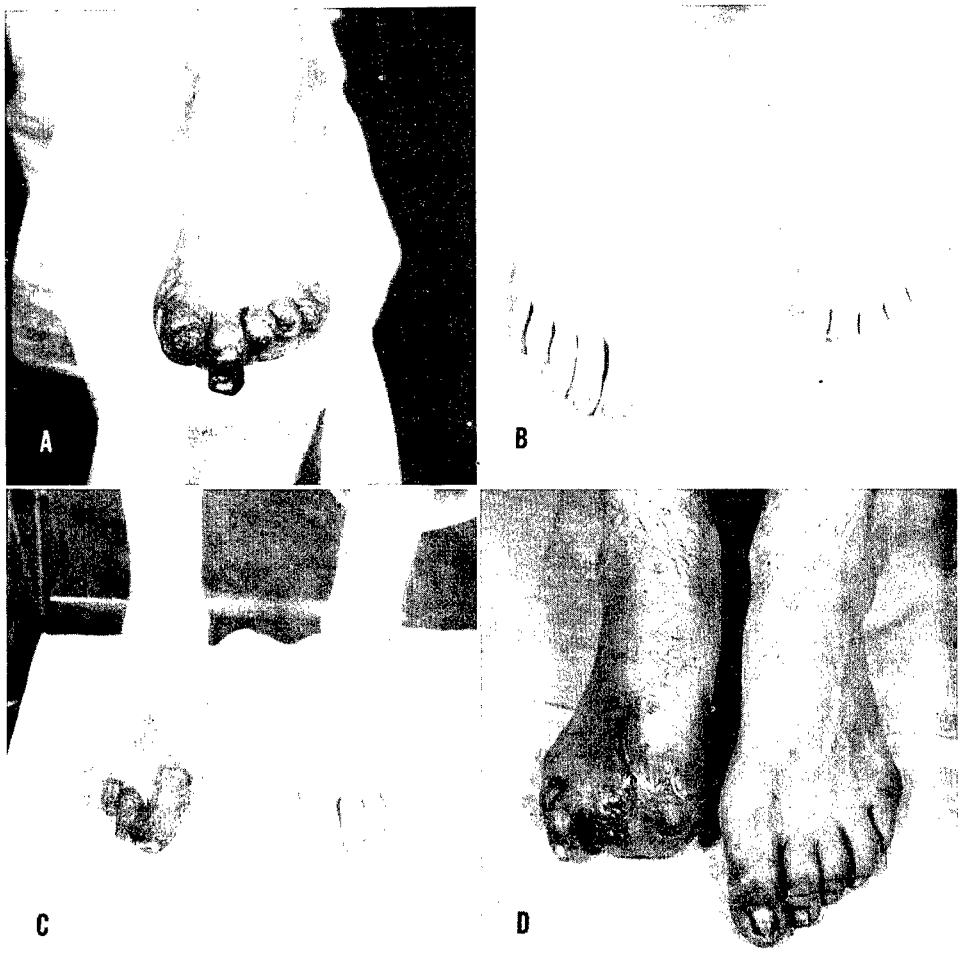
(fig. 99), but in general they were not (figs. 92 and 93) probably because of infection rather than because of poor circulation in the stump.

Tube grafts (figs. 90, 91, 100, 101, and 102) had to be used in five cases, in all of which amputation left the metatarsal heads exposed. The skin of the sole was, fortunately, intact in these cases, so that the graft did not have to be placed on a weight-bearing surface.



AFIP (Mayo GH) 585-1, 585-2, 598-2, 598-3

FIGURE 99.—Gangrene of feet in late stage of trenchfoot. Application of split-thickness skin grafts, followed by good healing, minimal loss of tissue, and good functional results. A. Appearance of left foot before operation. B. Appearance of foot shown in view A after unilateral sympathectomy and coverage of stumps of first, third, and fourth toes with split-thickness skin grafts. C. Appearance of feet before operation. D. Appearance of feet shown in view C after unilateral sympathectomy and coverage of ulcerated area over right metatarsal ends with split-thickness skin grafts.

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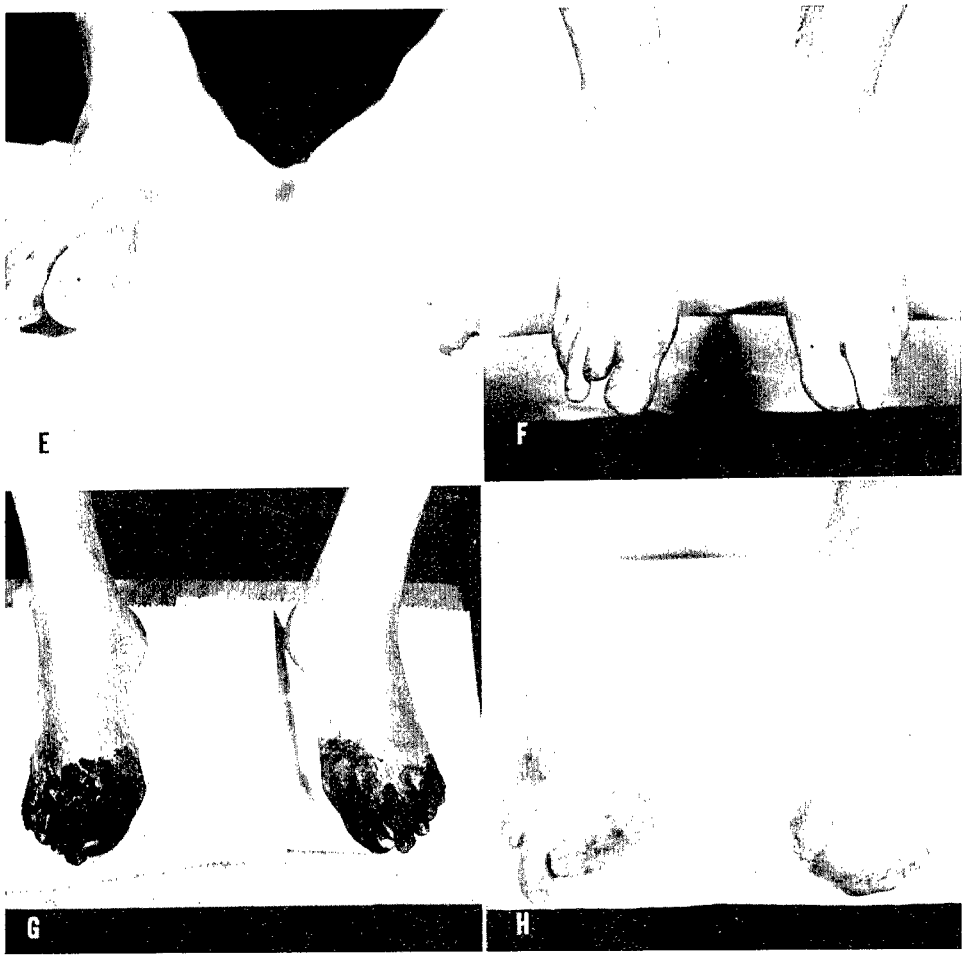

AFIP (Mayo GH) 630-1, 630-3, 677-1, 677-5

FIGURE 99.—Continued. E. Appearance of feet before operation. F. Appearance of feet shown in view E after unilateral sympathectomy and coverage of defect along dorsomesial aspect of toes of right foot with split-thickness skin grafts. G. Appearance of feet before operation. H. Appearance of feet shown in view G after bilateral sympathectomy and coverage of ulcers over stumps of both first toes with split-thickness skin grafts.

When the first of these five patients was operated on, a double pedicle graft was elevated from the opposite leg, a split-thickness graft was placed beneath the pedicle graft, and the pedicle graft was then transferred to the defect in the foot. It was found at this stage of the procedure that sufficient atrophy had occurred to permit primary closure of the skin beneath the pedicle, which was then converted into a tube. Three weeks later, the tube was divided at the lower end and sutured to the defect of the foot, the limbs being held in place with plaster of paris. The same technique was employed in the four other cases in which transfer grafts were necessary.

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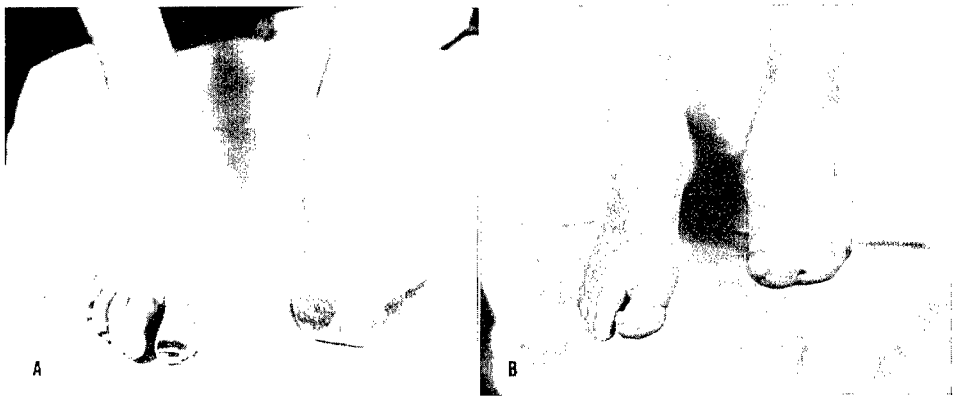

AFIP (Mayo GH) 682-4, 682-5

FIGURE 100.—Deep gangrene of feet in late stage of trenchfoot. Utilization of tube transfer grafts with bilateral sympathectomy after amputation. The functional result was excellent. A. Appearance of left foot after bilateral sympathectomy and amputation of toes. B. Appearance of foot shown in view A after application of tube transfer graft.

The operation was performed as follows: Two parallel incisions were made on the posteromedial aspect of the contralateral leg, the width and length of the pedicle depending upon the size of the area to be covered. The anterior incision was placed just posterior to the saphenous vein; care was taken to avoid injury to the saphenous nerve. The skin between the incisions, together with the underlying subcutaneous fat, was elevated. The pedicle was gently retracted and the skin margins were sufficiently reflected both anteriorly and posteriorly to permit closure without tension. Approximation of the skin edges with interrupted sutures of fine cotton converted the pedicle into a tube (fig. 103). Between the second and third weeks after operation, the circulation in the tube was tested by the application of a rubber tourniquet about the distal end. In all five cases in which this method was used, good circulation was maintained during the period of tentative constriction.

At the second operation, the tube was divided at the lower end and the resulting defect in the leg was closed by suture. The tube was then opened and sutured in place about the ulcerated area, the skin edges of which had been freshly mobilized. Proper position was maintained with a plaster cast applied to both lower extremities (fig. 104). The patients seldom complained of this position. Three weeks later, the cast was removed, the proximal end of the tube was divided, and the free end of the graft was sutured in place.

In 3 of the 5 cases in which this technique was used, healing occurred without complications of any kind. In the fourth case, about 10 percent of the distal end of the graft was lost, but the small ulcer which resulted healed promptly. In the remaining case, a small draining sinus persisted in the suture line and did not respond to compresses, curetting, or excision of the margins with secondary closure. Exploration revealed a small sequestrum from the

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AFIP (Mayo GH) 595-1, 595-7, 595-8

FIGURE 101.—Deep gangrene of feet in late stage of trenchfoot. Utilization of tube transfer grafts with bilateral sympathectomy after amputation. The functional result was excellent. A. Appearance of feet before operation. B. Appearance of feet after bilateral sympathectomy and amputation. Note exposure of first and third left metatarsals and first through fourth right metatarsals. C. Appearance of feet on dorsal aspect after transfer of full-thickness skin to both feet by means of tube grafts. D. Plantar view.

head of a metatarsal bone. Its removal was followed by prompt healing, but the patient's hospital stay had meantime been considerably prolonged.

When gangrene was limited to a portion of a toe and revision of the stump was necessary because of osteomyelitis or because the skin was thin and adherent, the sacrifice of a small amount of tissue did not affect the result. When, however, the heads of the metatarsal bones formed the stump, they were usually preserved. Good function was sometimes obtained by simple revision (fig. 105), but in such cases, as a rule, a more comfortable and more useful foot was obtained when the metatarsal heads were left in situ and were covered by a skin graft.

Prostheses.—The majority of patients with deep gangrene following trenchfoot had useful feet when they were discharged, though in some instances

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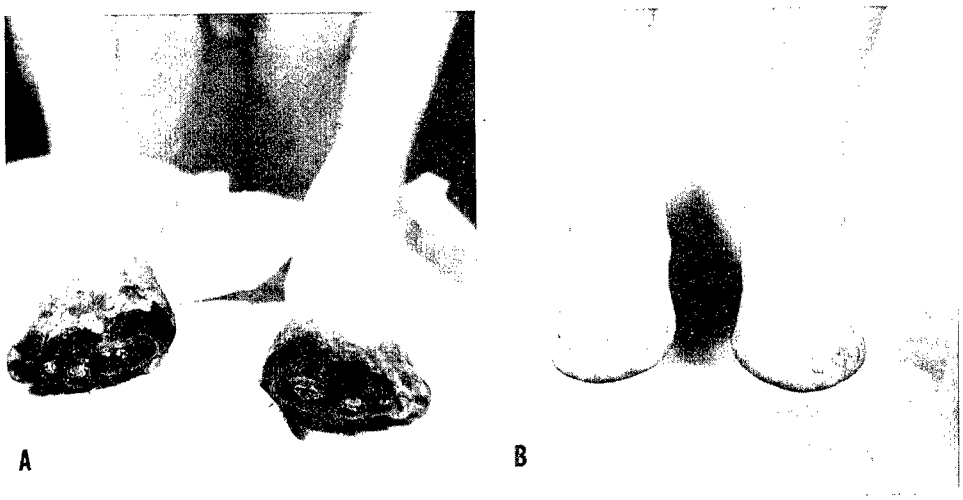

AFIP (Mayo GH) 580-2, 580-8

FIGURE 102.—Deep gangrene of feet in late stage of trenchfoot. Utilization of tube transfer graft with bilateral sympathectomy after amputation. The functional result was excellent. A. Appearance of feet before operation. B. Appearance of feet shown in view A after amputation of toes, bilateral sympathectomy, and application of tube transfer graft. The fourth and fifth toes were originally preserved in this case but were subsequently amputated because of stiffness and discomfort.

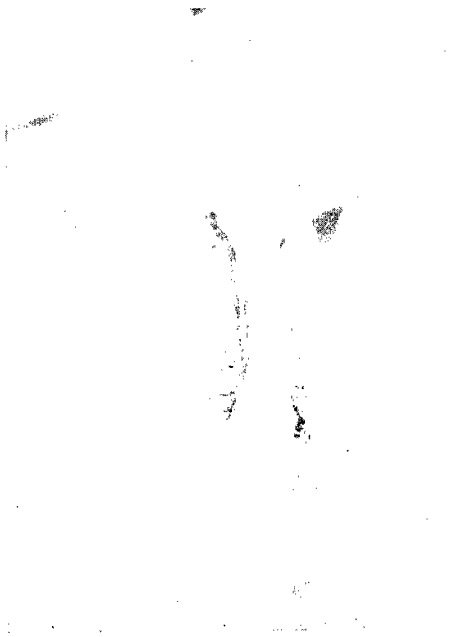

FIGURE 103.—Technique of tube transfer graft. Pedicle has been converted into tube by approximation of skin edges with interrupted sutures of fine cotton.

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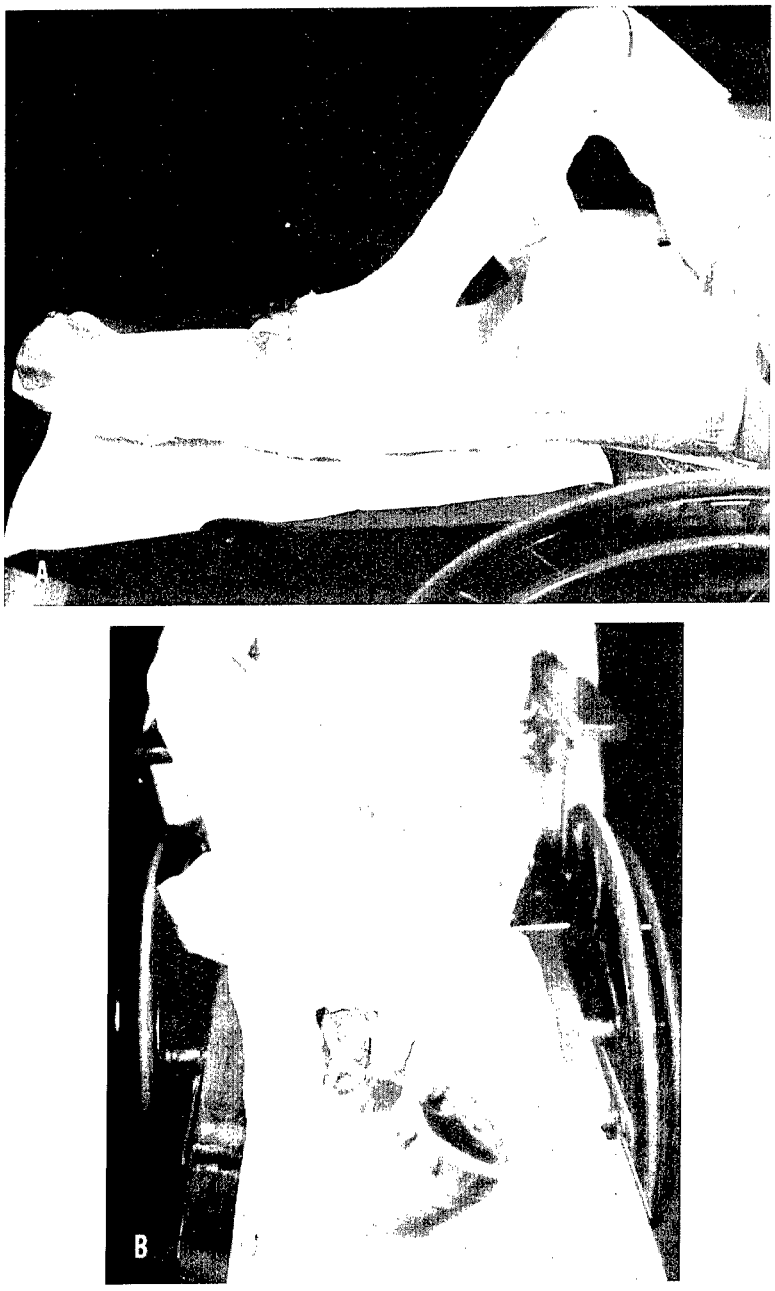

AFIP (Mayo GH) 595-2, 595-3

FIGURE 104. -A and B. Technique of plaster immobilization after tube transfer graft.

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AFIP (Mayo GH) 543-2

FIGURE 105. Appearance of right foot after loss of toes. Healing occurred after sympathectomy, but the stump was covered with thin, adherent skin and was not satisfactory. Revision was accomplished by sacrificing most of the heads of the first and second metatarsals. Though this patient was left with a satisfactory stump, a better result would probably have been obtained if a tube transfer graft had been used instead of a reamputation operation.

prostheses were necessary. When all the toes had been amputated, a sponge-rubber or cotton pad was used in the toe of the shoe to prevent the foot from sliding forward. In an occasional case in which the second and third toes had been amputated and the great toe left in situ, a pad of chamois-covered sponge rubber, inserted between the toes and kept in position with the sock, helped to prevent hallux valgus. Some patients with relaxed feet, who experienced discomfort on walking, found resilient arch supports helpful. In general, there was little complaint on either standing or walking except for slight to moderate discomfort in the metatarsal area. This type of discomfort, however, was complained of just as frequently by patients who had not developed gangrene and had not undergone amputation. Relief was frequently obtained by the use of a metatarsal bar or of a second heel in front of the regular heel of the shoe (p. 335).

RECONDITIONING

Although reconditioning of men with trenchfoot was a most important and essential phase of their treatment in the Zone of Interior hospital, almost nothing was available on the subject in the literature, and it was necessary to set up what amounted to a new program. During the period since exposure and injury, most of the patients received in the United States had been at complete bed rest and they were reluctant to get up (p. 324). Men hospitalized in England had had Buerger's exercises as part of their regular treatment, but, as a rule, reconditioning had been on a voluntary basis since their arrival in the Zone of Interior, and most of them had not participated. Their morale was poor. They had no concept of the nature of their injuries, and their fear of complete future invalidism was combined with disbelief in the efficacy of any treatment. Many of them were in poor physical condition and were convinced that they could do nothing active. The reconditioning program, as it was set

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up at the vascular centers, Camp Carson and elsewhere, had to overcome psychologic as well as physical difficulties.

The following reconditioning program, which was carried out at Mayo General Hospital, differs only in details from the programs carried out elsewhere.

Initial Phase

Bedridden patients.—A special type of program was necessary for men who could not become ambulatory as soon as they were admitted to the Zone of Interior hospital, either because of gangrenous lesions or because the soles of the feet were too sensitive to permit weight bearing. The routine, which was conducted under the supervision of the ward officer and ward master, consisted of corrective exercises in bed in the morning, with games, tournaments, and various tests for physical fitness in the afternoon.

Ambulatory patients.—As soon as the patients were able to walk around the ward without too much difficulty and discomfort and were able to go to the mess hall for their meals, they were transferred to special barracks, set aside for trenchfoot patients, and were placed on an ambulatory reconditioning program. Although they were still regarded as hospital patients, they were at once given all the pass privileges of soldiers in the command, with the objective of encouraging walking.

The program was graduated. For the first 4 weeks, the exercises, although they were carried out in the gymnasium, were of such a character that only a small portion of the time was spent on the feet. Volleyball, shot-putting contests, and various exercises designed to strengthen the muscles of the upper portion of the body were performed sitting down. At the end of 4 weeks, a number of exercises performed on the feet were added to the program. Then mild weight-bearing exercises and games were substituted for some of the exercises and games which had been performed sitting down. The amount of exercise performed on the feet was gradually increased until the desired level of activity was reached. This took from 1 to 3 months, depending upon the rate of progress of the individual patient. At this time, the patients also engaged in occupational therapy requiring the use of the muscles of the feet and legs, to counteract the stiffness and atrophy which were the residua of trenchfoot.

Water calisthenics formed an important part of the program for ambulatory patients. It was thought that the buoyancy of the water in the pool would enhance the recovery of a sense of balance and permit more vigorous use of the muscles of the feet, with less pain. At first, the men merely sat on the edge of the pool and kicked their feet in the water. It was often necessary to overcome their reluctance to do even this, for fear that wetting the feet would make their condition worse. As a matter of fact, a few men with more severe degrees of trenchfoot did respond badly to this part of the program. Some complaints were intensified. Sometimes hot, prickly sensations were experienced. In some instances, a dermatitis appeared, perhaps because of

the effect of the chlorine in the water on the sensitive skin. Patients who had any untoward effects from immersion of the feet were excused from this part of the reconditioning program, but all patients who could tolerate immersion were encouraged to carry it out.

After a few days of merely kicking the feet in the water, various types of water calisthenics were undertaken. Then the patients walked in the water, first on the toes, and later on the feet. Finally, water games were engaged in. Weight-bearing exercises that could not be tolerated in the gymnasium often proved feasible in the pool, in which, by regulating the depth of the water, it was possible to regulate the weight borne by the feet.

With the few exceptions noted, all patients, no matter how severe their condition, could engage in the scheduled exercises in water up to the shoulder. Patients with milder injuries could perform them in water up to the waist. The depth of the water was gradually reduced for each individual, so that more and more weight could be borne on the feet, which could thus be conditioned, without much discomfort, to normal weight bearing and body balance.

For the first week after exercises in the pool were begun, there were frequent complaints of soreness and stiffness in the muscles of the legs and thighs, probably because of the unaccustomed movements. If the exercises were persisted in, these gradually disappeared. Some patients ceased to suffer from hyperhidrosis, though others found it increased. Most of the men felt that the water had a relaxing effect on the muscles of the feet and permitted greater freedom of movement. Both patients and staff, in fact, agreed that water calisthenics constituted perhaps the most effective part of the reconditioning program.

All of the patients, as soon as their condition permitted, were assigned, as already mentioned, to different departments in the command, such as the motor pool, electrical shop, post office, and communications center, as well as to the educational reconditioning program. Their own preference, as far as possible, served as the basis for the assignment. Other men furnished work details for different parts of the hospital. Although all of these assignments required walking and standing, sometimes for considerable periods of time, the men were usually interested in what they were doing, as well as in their own progress, and there were few fresh complaints.

Second Phase

Outdoor activities were begun at the end of 8 weeks of the reconditioning program, with hiking and bicycle riding occupying most of the time allotted for them. Group walking at a leisurely pace was continued all during the program, the short distances at first attempted being gradually increased to 1 or 2 miles. A definite goal was set for each hike, but it was made clear that men who were in distress from pain or cold could drop out at any time without penalty. At first, most of the walking was done on asphalt roads. Later, as tolerance increased, irregularly surfaced roads were no longer bypassed.

A marching cadence was required only at Retreat, which was conducted three times a week.

At first, there were numerous complaints, particularly when walking was begun over uneven ground. Burning and aching were chiefly complained of, not when the men were walking but afterward when they were at rest. Later, as the skin of the sole hardened, all complaints became fewer. Since there were general complaints of the discomfort produced by socks wet with perspiration, dry cotton socks were always put on before the hike and were changed as soon as it was over. Care was taken to keep the feet as dry as possible outdoors, since exposure to cold in wet socks always resulted in an exacerbation of symptoms.

If the outdoor reconditioning program had to be carried out in winter, when the environmental temperature was low and the ground was often covered with snow, four-buckle arctic galoshes were provided, for wear over the ordinary low quarter shoes. However, so many of the patients complained of burning, swelling, and excessive sweating when galoshes were worn that their use was eventually made entirely voluntary.

After bicycle riding was begun, the level of the seat was gradually raised, so that more and more strain was placed on the small muscles of the foot. The distance ridden was also gradually increased. At the end of the period of reconditioning, most of the patients could ride 3 to 4 miles without difficulty, though some continued to have pain in the small muscles of the foot. Since this symptom did not materially improve with graded increases in the distance ridden, men who experienced it were excused from this type of exercise.

Immediate Results

The first and most obvious therapeutic effect of the reconditioning program at Mayo General Hospital was a rapid change in the mental outlook of the patients. For the previous weeks or months, they had led lives of bedridden invalidism, and they saw little beyond it. Then they suddenly found themselves part of a program of gradually increasing physical activity. They began to do things which they had thought they could never do again, and they saw others doing them. Their self-confidence returned as their general physical condition and capacity improved. Furthermore, continuing participation in competitive sports had a wholesome effect on their outlook toward future duties and responsibilities.

The reconditioning program, which was begun on 24 November 1944, for 35 enlisted men, eventually included 550 enlisted men and 17 officers. It developed by trial and error. When it was started, it was not clear how much physical activity could be undertaken without ill effects. The patients in the first groups, realizing that the program was still experimental and that their reactions would govern the content of the program in the future, entered into it with great enthusiasm and supplied much helpful comment on the various phases. Future programs were modified in the light of these first reactions.

As time passed and disposition in larger and larger numbers became necessary, the mental outlook of the patients became very different, particularly as the war drew to a close. Many of them were no longer interested, and the spirit of cooperation which had played so vital a part in the success of the early courses began to disappear. Emphasis was now shifted to disposition and compensation for injuries, and complete restoration of the feet to normal became a secondary objective.

DISPOSITION

When it was thought that a patient with trenchfoot had obtained the maximal possible benefit from the reconditioning program with respect to his general health and that his feet were sufficiently recovered to allow participation in a fairly normal program of daily activity, he was brought before the hospital disposition board. At the vascular centers, this board consisted of the chief or the assistant chief of the medical section, the chief of the medical vascular section, and the ward officer in closest contact with the patient during his period of hospitalization. The procedure consisted of the reading of a summary of the case history, the examination of the patient by members of the board, including a survey of his gait without shoes, and a discussion of the findings. All information obtained during a board proceeding was placed on a special sheet.

The following considerations governed the disposition of patients: (1) The rate of progress in the hospital, (2) the duration of hospitalization, (3) the severity of persisting signs and symptoms, (4) the degree of hyperhidrosis, (5) the amount of atrophy in the small muscles of the feet, (6) the actual loss of tissue as a result of gangrene, (7) the tendency to blister formation and fissures, (8) the condition of the skin on the soles of the feet, (9) the type of persistent symptoms, such as neuritic pains, (10) the gait, (11) the distance that could be walked without difficulty, (12) other defects, and (13) the mental outlook.

Enlisted Men

Final disposition was made on 1,042 of the enlisted men with trenchfoot treated at the three vascular centers. They were (1) sent to duty, with a "3" or "4" (indicating disability of the lower extremities) in their profiles, or (2) sent to convalescent centers or other hospitals for additional treatment, or (3) given a Certificate of Disability Discharge. In about two-thirds of the cases, there was no difficulty at all in arriving at a decision. The patients clearly fell into one category or another. In the remaining third, there was a good deal of difficulty, and, in numerous instances, the decision was not unanimous. There seems little doubt that in many cases disposition might have been different if the matter had been brought up again or had been brought up before another board of medical officers.

Of the 1,042 enlisted men on whom disposition was made at the vascular centers, 332 (31.9 percent) were returned to duty. All had shown fairly rapid progress. None of them had any other medical or surgical disability. All had normal gaits. All could stand on their toes. Most of them could walk without difficulty for at least a mile. Cyanosis was minimal, and none presented signs of excessive sweating, coldness, atrophy of the small muscles of the feet, or stiffness of the toes. Very few complained of neuritic pains, numbness of the toes, or tenderness of the soles of the feet on weight bearing and walking.

Three hundred and ninety-four enlisted men (37.8 percent of the total number) were discharged from the hospital to civilian life. About a third of those discharged presented an associated condition which in itself might not have been disabling but which, when combined with moderate residua of trenchfoot, was sufficient to warrant discharge from the Army. These conditions included plantar warts, various orthopedic disabilities of the feet, partially disabling wounds of the lower extremities, and mild to moderate psychoneurosis.

Men given medical discharges because of trenchfoot residua usually presented findings indicative of excessive sympathetic activity, such as cold and cyanotic feet and hyperhidrosis, which was sometimes incapacitating and might require changes of socks two or three times daily. Increase of symptoms, particularly hyperhidrosis and swelling, was frequent during hot weather. Hypesthesia on the plantar surfaces of the toes and the adjacent portion of the foot was still present. Some men complained of a neuritic type of pain while they were at rest, as well as of numbness of one or more toes. Usually, the skin on the sole of the foot was delicate, perhaps because the patients, to avoid the pain caused by ambulation, walked very little. The gait was likely to be abnormal. They walked chiefly on the heel or the lateral edges of the foot or failed to push off properly with the toes.

Most of the patients with a history of deep gangrene and subsequent loss of tissue were discharged to civilian life. Most of them had had severe attacks of trenchfoot, and at the time of discharge, in addition to having lost toes or portions of the feet, they had such sequelae as hyperhidrosis, extreme coldness and cyanosis of the feet, and neuritic symptoms and signs.

As a general rule, the men returned to civilian life had little desire to remain in the Army. Attempts had been made, during the entire period of their hospitalization, to alter their point of view. Weekly group conferences, conducted by the psychiatrist, had given them opportunities to present their problems and discuss the reasons for their discontent, but these efforts had failed. They all felt that they had done their share of fighting. There was no actual proof, but there seems little doubt that the symptoms complained of by at least some of the men in this group were exaggerated. Some men frankly admitted that they were making the most of their complaints, but they justified themselves by saying that they felt that they could no longer be of use to the Army.

The remaining 316 patients, 30.3 percent of the total number disposed of, were thought to need further reconditioning, and were sent to convalescent centers. Most of them had been transferred from hospitals in which reconditioning programs for trenchfoot had not been pursued vigorously. Their disposition on discharge from the convalescent centers is not known.

Followup.—Eighty-six replies were received from a letter and questionnaire sent, 3 months after they had left the hospital, to the first one hundred and twenty-five enlisted men discharged to civilian life from the Mayo General Hospital Vascular Center. More than two-thirds had obtained work within a little over a month after discharge, and well over half of these held their original jobs. Six percent were enrolled in technical schools and colleges. About a quarter were not working; the questionnaire, unfortunately, failed to inquire specifically whether work had been sought and had not been secured.

Most of the men who were working held jobs which required physical activity. Although they spent an average of 4 hours daily on their feet, most of them felt that they were able to do their work with as little difficulty as fellow workmen without a history of physical disability from cold injury.

In spite of the generally good working record of these 86 men, two-thirds of them complained of burning sensations in the feet, tenderness of the soles, and hyperhidrosis. More than half said that their feet swelled. A few complained of blister formation and trichophytosis. Less than half could walk a mile or more without difficulty. Twelve percent had noted moderate to marked improvement in the condition of their feet since they had returned to civilian life, but 41 percent reported no improvement at all.

Officers

Disposition of officers with trenchfoot, as exemplified by the 17 observed at Mayo General Hospital, differed in a number of respects from the disposition of enlisted men. Only one of these officers was brought before a retirement board. He had had a severe attack of cold injury, and his feet were in bad condition when he was admitted. Although his progress was satisfactory, at the time of disposition he still had numerous residua, such as tenderness in the soles of the feet on walking, marked cyanosis, coldness, hyperhidrosis, and some swelling.

The other 16 officers, all of whom had had moderately severe degrees of trenchfoot, showed rapid improvement after hospitalization in the United States. They took part in the reconditioning program with enthusiasm and showed the benefits of it very quickly. As compared with enlisted men with practically the same amount of exposure and practically the same objective findings, they had far fewer complaints. Their relatively higher morale undoubtedly accounted for their generally better response to treatment and reconditioning.

All 16 officers were assigned to limited duty when they left Mayo General Hospital, with the understanding that they were to be reexamined in one of the vascular centers at the end of 6 months, to determine whether they could then be returned to full duty. At the end of 3 months, it was learned that several of them had already had to be rehospitalized because of aggravation of their symptoms.

One officer could not do even office work because of burning and swelling of the feet. He had been assigned to a post in the South and attributed his difficulties to the high environmental temperature.

Another officer had been able to work with only slight discomfort in California, but, 2 months after his transfer to a camp in Texas, where the environmental temperature was high, he began to suffer from aching sensations in the soles of the foot, followed by paresthesia in the toes. His work as an instructor, which necessitated his being on his feet a great deal, caused an increase of all his symptoms. When transferred to desk work, he continued to experience aching and pain in the arch of the foot, so severe as to require hospitalization at the station hospital to which he was assigned and eventual return to the Mayo General Hospital Vascular Center. At this time, he complained of a throbbing sensation in the soles of both feet after walking about three blocks. He walked on the edges of his feet, to reduce the amount of weight on the soles. This gait had not been present when he was originally a patient at the vascular center. Examination of the feet was entirely negative except for some cyanosis when they were dependent. This officer's story closely resembles the stories of at least four other officers who had to be rehospitalized at other institutions within 2 or 3 months after leaving Mayo General Hospital.

In contrast to the preceding histories are the results in four officers with trenchfoot who were assigned to Mayo General Hospital and who could be closely watched. For the most part, these four performed their assigned duties with few complaints. They also indulged in sports, such as baseball and golf, without ill effects. There were almost no objective findings when their feet were examined periodically.

The morale of the four officers assigned to the hospital was very high. They were doing work for which they were well suited and which was exactly what they wanted to do. The officers with recurrent symptoms, on the other hand, were all dissatisfied with their assignments and all felt that, because they were likely to be returned to the hospital within 6 months, no real effort had been made to assign them according to their ability. None of them was kept especially busy, and all had time to concentrate upon the state of their feet. Under the circumstances, they had excellent opportunities to exaggerate their complaints in their own minds.

PREDICTIVE TESTS

In the Zone of Interior, as well as overseas, the patient with residual complaints from cold injury, who had few objective signs or none at all, presented serious diagnostic problems. Burch and his associates,[2] working under the Office of Scientific Research and Development, devised for this kind of patient what they called an activity index, predicated upon changes in the skin temperature before, during, and after occlusion of the vessels of the leg. In this test, the degree of inflammatory activity in a part injured by cold and moisture is determined by three observations: (1) The initial stabilization temperature of the affected part, (2) the fall in temperature after 15 minutes of occlusion, and (3) the rise in temperature during the hyperemic period after release of the occlusion.

The investigation, which was carried out on 46 men who had suffered from trenchfoot, was carefully controlled, the controls including both normal subjects and psychoneurotic subjects without organic disease of any kind. All observations were made in a constant-temperature room, and all other environmental circumstances were also carefully controlled.

Under the conditions of this study, Burch and his associates, while recognizing the necessity for further investigation and evaluation of this test, regarded the following observations as justified:

1. If the temperature of a toe at the end of 15 minutes' stay in a constant-temperature room at 68° F. (20° C.) is above 84.2° F. (29° C.), the chances are almost 100 percent that the toe is not normal. If the temperature is above 80.6° F. (27° C.), the chances of abnormality are about 75 percent.

2. If, at the end of the whole study (approximately an hour), the rate of refilling is less than 8.0 seconds, the chances are almost 100 percent that the part is not normal. At the end of 2 minutes', and of 15 minutes', stay in the observation room, the rate of refilling of the skin vessels which had been emptied by pressure was essentially the same for the control subjects and the subjects with previous cold injury.

3. If the temperature of the big toe falls more than 9° F. (5° C.) during the period of occlusion and if there is a maximum rise of 9° F. (5° C.) or more above the control value during the period of reactive hyperemia, the chances of abnormality are about 90 percent. If the fall is greater than 5.4° F. (3° C.) and the rise after the release of the circulation is greater than 5.4° F (3° C.), the chances of abnormality are about 75 percent. In fact, with a fall of 3.6° F. (2° C.) during occlusion and a rise on the same order during release, the chances of abnormality are more than 50 percent.

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[2] Burch, G. H., Myers, H. L., Porter, R. R., and Schaffer, N.: Objective Studies of Some Physiologic Responses in Mild Chronic Trench Foot. Bull. Johns Hopkins Hosp. 80: 1-70, January 1947.

4. When all three of the phenomena just described are clearly abnormal, the chances that the part is diseased approach 100 percent, and the observations, naturally, are more conclusive than if only one of the reactions is suggestively abnormal. The availability of two separate objective phenomena and one quasi-objective phenomenon obviously makes for greater accuracy. The accuracy of the test can be further insured by making observations on both limbs simultaneously, one part serving as a control for the other.

Burch and his associates, as already noted, recognized both the limits of this activity index and the need for further research on it. The index, nonetheless, is practical and should prove useful in the evaluation of the numerous late cases of cold injury which are characterized by subjective complaints and by a total, or almost total, absence of objective findings.[3]

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[3] The long-term story of trenchfoot, as has been intimated elsewhere, remains to be told. It may eventually be told by the Veterans' Administration. Redisch, in an article entitled "Chronic Trench Foot.—A Problem in the Care of World War II Veterans," which appeared in the *Military Surgeon* for December 1947, stated that the Veterans' Administration Regional Office in Newark, N. J., had seen 54 men with chronic trenchfoot in a single 12-day period in 1946. He expected that, by the end of 1947, from 50,000 to 100,000 veterans would have claimed disability from this type of injury. It is significant that sufferers from chronic cold injury were continuing to seek medical care from the Veterans' Administration late in 1946, almost 2 years after the last cold injuries had been sustained in combat.

Information personally secured from the Veterans' Administration showed that, in 1948, 161 patients with cold injury (trenchfoot or immersion foot) were discharged from Veterans' Administration medical facilities; in 58 of these cases, cold injury was the principal diagnosis. Comparable information for 1949 showed 115 patients discharged, 50 of them with the principal diagnosis of cold injury. These figures give no indication of the number of patients with cold injury still under medical supervision, but they do emphasize the chronicity of this type of injury and the long-term medical cost.

It is interesting and highly significant that, as late as 1949, some veterans who had sustained their cold injuries in World War I were still under the care of the Administration. Five such patients were discharged in 1946, and four more were observed in 1949.

A followup study of men with previous cold injury has been under way as a research project in the Veterans' Administration since 1950. The information secured will make it possible to determine the permanent residua (or lack of residua) in men discharged to civilian life after their injuries.

Another followup study of 100 cold injury patients, made 4 years after occurrence of the injury in Korea was published by Blair, Schatzi, and Orr in the *Journal of the American Medical Association*, 6 April 1957.

CHAPTER XIII

The Epidemiology of Cold Injury

GENERAL CONSIDERATIONS

Studies made in ETOUSA (European Theater of Operation, United States Army) during the winter of 1944–45 clearly showed that cold injury is a component of mass trauma and that is behaves in accordance with epidemiologic laws. It was thus demonstrated again that the biologic principles that govern disease as a community problem hold equally well for trauma, including trauma caused by cold.

Before cold injury is discussed from this point of view, certain general facts concerning epidemiology must be stated, as follows:

Epidemiology, according to Gordon,[1] may be defined as medical ecology and may be interpreted as the influence of the total environment upon the reactions of living things. By this concept, health is the equilibrium of all the factors which come into play to influence disease or injury in man. Agent, host, and environmental factors make up the total epidemiologic potential, and their equilibrium, or their lack of equilibrium, determines the presence or absence of disease or trauma in any given community.

The agent is the specific cause of trauma or disease. The host, man, has many inherent qualities which predispose him to, or which protect him against, injury or disease. The environment in all its aspects, physical, biologic, and socioeconomic, constitutes the medium through which agent and host are brought together to cause injury or disease. Man's equilibrium in health may become a lack, or absence, of equilibrium in trauma or disease through (1) actions of the agent, (2) reactions of the host, (3) functions of the environment, or (4) the interactions of any two, or of all three, of these epidemiologic potentials.

With the acceptance of this concept, the causation of disease or injury is not limited to any specific micro-organism, or to any single agent, such as cold. Multiple factors are always involved. Epidemiology embraces both multiple causation and the multiple mechanisms through which multiple causative factors interact. An understanding of the effect of the interactions of causative factors is essential to a comprehension of the whole epidemiologic problem. Epidemiologic analysis of total cause and effect is the only sound basis from

[1] Gordon, J. E.: The Strategic and Tactical Influence of Disease in World War II (Preventive Medicine and Epidemiology). Am. J. M. Sc. 215: 311-326, March 1948.

which a clear picture of the total situation can be derived; it is also the only sound basis upon which an effective program of prevention and control can be built.

Application of Epidemiologic Principles to Cold Injury

All of these generalizations are applicable to cold injury. The specific causative agent is cold, or cold in association with wet. A number of host factors determine the susceptibility of the soldier to these agents. The interplay of agent and host factors is governed by a number of environmental factors.

The total causation of cold injury is complex. This is not so much because any single factor involved is complex but because of the interrelation of the multiple factors which come into play to make up the mechanism of cold injury under variable circumstances. It is not at all difficult to classify these several factors according to agent, host, or environment. What *is* difficult, in the analysis of the over-all problem, is to determine the relative weight which should be assigned to each single factor.

Interpretation of World War II experience of cold injury.—The interpretation of the cold injury experience of World War II may be approached in several ways, as follows:

1. The first approach is an endeavor to interpret this experience from the point of view of broad causality. It has been established historically, both by experiment and experience, that cold and wet, singly or associated, are the preeminent causal factors in cold injury. They are the conditions which must be present if it is to occur. Historically, mass cold injury has occurred only in time of war, only then in the cold or wet-cold season, and only then under circumstances of military stress that bring about unusual exposure of the soldier. Exposure has two components, degree and duration. Time, or duration, thus becomes an additional component of broad causation.

With these fundamental concepts established, it is possible to investigate how the several modifying factors of agent, host, and environment impinge upon the core of causation. The chronicle of cold injury in World War I and the field investigations of cold injury carried out in World War II were along these lines and pointed toward the determination of the factors which made up total causation.

2. In view of the constancy of the basic causative factors of cold injury, that is, cold and wet, a second approach toward the problem is logically directed toward the study of modifying factors. This particular study is limited to individual factors or to circumscribed groups of the several causative components of cold injury. The effect of cold injury is readily measured in terms of numbers of cases and time lost as a result. It is difficult to count and measure the modifying factors which may chiefly determine the prevalence of the injury. Many of them are intangible host factors, such as fatigue, nutritional status, or the effect of a previous cold injury. Environmental factors such as command leadership, discipline, and training are even more difficult to measure precisely.

It would have been fairly simple to measure the agent factors of cold and wet in World War II if detailed records of temperature fluctuations and precipitation had been made a part of the record of each division. They were not. Average weather data were recorded by army areas, but in no theater do records exist of the detailed day-by-day fluctuations within division areas.

3. A theoretical method of approach is to assign relative values to each of the factors implicated in cold injury and to study the trenchfoot record in each division in the light of these values. This method permits a composite evaluation of the circumstances which are favorable and unfavorable to trenchfoot. As a practical matter, when this method was used, low ratings generally were associated with good division records for cold injury, but the distinctions were not drawn finely enough to establish reliable quantitative multiple-factor relationships.

Twenty-one infantry divisions in the European theater were rated by this method for the months of November and December 1944 according to type of combat action, clothing supply, rotation, training and experience, shelter, and terrain, in addition to the basic factors of cold and wet. Details of this study are recorded elsewhere (p. 366). In general, it may be said that the selection of qualitatively significant factors by multiple correlation techniques was restricted by lack of precise measurements for factors presumed to be important on the basis of previous experience. Significant correlation could be established between the cold injury experience and the degree of combat, as well as cold injury and shelter. Significant correlation could also be established, though to a lesser extent, for rotation as well as terrain. Had more precise data been available, multiple regression studies of these factors might have made possible the assessment of relative factor weights.

However, in spite of its limitations, this study bore out, in general, the ratings already established for the various divisions in relation to their cold injury records. It also confirmed the feasibility of evaluating the modifying factors in cold injury for which precise quantitative measurements are not available.

4. In the absence of data ample enough and precise enough to permit statistical measurement of the influence of such factors of concern to the individual soldier as leadership, training, clothing, fatigue, or foot discipline, some other method had to be found to assess the role of these and other factors involved in cold injury in World War II. None presented itself except the epidemiologic approach of studying organizations ranging in size from battalions to divisions by the selection of periods of time and situations in which only one factor seemed to vary in comparison with other organizations of similar size operating under identical or almost identical conditions.[2] This method, which is applicable to agent, host, and environmental factors alike, has been utilized in this chapter to study the modifying agents of cold injury. All possible factors

[2] All data concerning the various divisions and other organizations used for unit case histories and other studies in this chapter were obtained from the appropriate records on file in the Office of the Surgeon General of the Army.

have been evaluated by this method. In addition, the influence of certain of them has been assessed in part by the rating method and statistical procedures already mentioned.

ANALYSIS OF SELECTED DIVISIONS BY CORRELATION STUDIES

The experiences of 21 divisions on the Western Front in November and December 1944 were studied, by the technique already described in the light of six factors of environment, in an attempt to weigh the impact of these factors on the incidence of trenchfoot. These factors, namely, combat action, rotation policies, weather, shelter, terrain, and troop experience, constitute the independent variables among which interaction may take place. The dependent variable is the incidence of trenchfoot.

Since none of these factors are susceptible of quantitative grading, a subjective scoring of their intensity was set up (see footnote 1, table 11), ranging from (1) least predisposing to (4) most predisposing. Each division was then rated separately for November and December, and the data were recorded, together with the actual numbers of cases of cold injury each had experienced (tables 11 and 12).

Data concerning temperature and precipitation could not be weighed in relation to other factors because, as already noted, they are available only as means for whole army areas and thus do not fluctuate by division. Similarly, criteria for measuring training and experience are gross and thus do not vary significantly between the divisions or between the 2 months covered by the analysis.

Clothing supply was a theater problem. All divisions were affected to some extent. No division was without supplies, but no division was fully equipped. Variations between divisions in this respect were not great, and the moderate improvement which occurred in December affected them all. The influence of this factor can therefore be judged only by isolated circumstances, such as were created, for instance, when overshoes were left behind by order.

Before a statistical analysis of these data was undertaken, it was necessary to find a linear function of the incidence which was roughly related to the independent variables. The logarithm of the incidence was found to fulfill this requirement. Next, the usual procedure of computing correlation coefficients was applied for each of the six independent variables and the dependent variable (table 13). The coefficients of combat action and shelter were found highly significant. Those of terrain and rotation were of borderline significance. The paradoxical finding that the coefficient of weather, which is a basic factor, was entirely insignificant could be explained only by the nature of the data. As pointed out earlier in this chapter, these data were general and incomplete. During the period chosen for the study, the weather seems

TABLE 11.—*Scores of 21 infantry divisions, European theater, by cold injury modifying factor, November 1944*

Infantry divisions	Cases (number)	Combat action			Scoring criteria [1] for clothing supply	Scoring criteria [1] for rotation	Cold and wet			Scoring criteria [1] for training and combat experience	Shelter			Scoring criteria [1] for terrain	Sum of weighted scores
		Duration by scoring criteria (days)	Scoring criteria [1]	Weighted average of scores			Duration by scoring criteria (days)	Scoring criteria [1]	Weighted average of scores		Duration by scoring criteria (days)	Scoring criteria [1]	Weighted average of scores		
1st	267	17 13	2 4	2.9	2	1	22 8	3 4	3.3	2	10 20	1 4	3.0	2	16.2
2d	37	-------	3	3.0	2	2	22 8	3 4	3.3	3	-------	3	3.0	2	18.3
3d	498	-------	4	4.0	2	2	-------	4	4.0	1	-------	4	4.0	2	19.0
5th	857	20 10	4 1	3.0	3	2	-------	3	3.0	1	19 11	4 1	2.9	3	17.9
8th	109	20 2 8	3 1 4	3.1	2	2	-------	3	3.0	2	-------	2	2.0	2	16.1
9th	118	18 12	1 4	2.2	2	3	22 8	3 4	3.3	1	3 12 15	2 4 2	2.8	3	17.3
26th	1,679	-------	4	4.0	3	4	22 8	3 4	3.3	4	23 7	4 1	3.3	4	25.6
29th	97	15 15	3 4	3.5	2	2	22 8	3 4	3.3	2	-------	2	2.0	3	17.8
30th	16	15 15	2 3	2.5	2	2	22 8	3 4	3.3	2	-------	1	1.0	3	15.8
35th	504	11 19	4 3	3.4	[2] 3 [2] 2	2	15 15	3 4	3.5	2	11 19	4 3	3.4	4	21.0
36th	380	-------	3	3.0	2	4	17 13	3 4	3.4	1	-------	2	2.0	[3] 3 [3] 2	17.9

See footnotes on p. 369.

TABLE 11.—*Scores of 21 infantry divisions, European theater, by cold injury modifying factor, November 1944*—Continued

Infantry divisions	Cases (number)	Combat action			Scoring criteria [1] for clothing supply	Scoring criteria [1] for rotation	Cold and wet			Scoring criteria for training and combat experience	Shelter			Scoring criteria [1] for terrain	Sum of weighted scores
		Duration by scoring criteria (days)	Scoring criteria [1]	Weighted average of scores			Duration by scoring criteria (days)	Scoring criteria [1]	Weighted average of scores		Duration by scoring criteria (days)	Scoring criteria [1]	Weighted average of scores		
44th	310	13 5 12	2 4 3	2.7	2	3	17 13	3 4	3.4	2	-------	4	4.0	3	20.1
45th	113	-------	4	4.0	3	3	-------	3	3.0	1	13 17	4 2	2.9	2	18.9
80th	928	-------	4	4.0	[4] 3	3	17 13	3 4	3.4	2	-------	4	4.0	3	22.4
83d	9	-------	2	2.0	2	3	22 8	3 4	3.3	2	-------	1	1.0	2	15.3
84th	450	10 20	1 4	3.0	2	3	22 8	3 4	3.3	3	10 20	2 4	3.3	3	20.6
90th	307	7 19 4	2 4 1	3.1	2	3	17 13	3 4	3.4	2	26 4	4 2	3.7	4	21.2
95th	229	20 10	3 4	3.3	2	3	17 13	3 4	3.4	2	8 10 12	2 4 1	2.3	3	19.0
99th	496	8 22	1 2	1.7	2	3	22 8	3 4	3.3	4	-------	3	3.0	2	19.0
102d	78	27 3	2 4	2.2	2	1	22 8	3 4	3.3	4	-------	4	4.0	3	19.5
104th	350	7 23	4 2	2.5	2	3	22 8	3 4	3.3	3	7 23	4 2	2.5	2	18.3

[1] Scoring criteria for modifying factors in cold injury, based on favorability to cold injury (from 1, least predisposing, to 4, most predisposing):

Combat action:
1. Movement unopposed; reserve; rest.
2. Static defense, patrolling; static defense, line holding.
3. Active defense, minor fighting.
4. Active offense, major fighting; active defense, with attack.

Shelter:
1. Buildings.
2. Tents, dugouts, bunkers.
3. Foxholes, improved.
4. Foxholes, unimproved, wet.

Terrain:
1. Dry, hilly, or mountainous; frozen snow underfoot.
2. Hilly or mountainous, forested; moderate mud.
3. Flat to rolling, muddy, wet.
4. Marshy, flooded, streams.

Rotation:
1. Excellent; rotation by units and within units at regular intervals; rest and bathing facilities.
2. Good; rotation by unit and within units when situation permits; limitation on numbers of men rotated; limited facilities.
3. Fair; no definite division rotation policy; small unit rotation when opportunity exists.
4. Poor; no specified policy or facilities.

Training and combat experience:
1. MTO, ETO, active campaigning.
2. ETO throughout, battlewise, no trenchfoot experience.
3. Entered ETO September or October 1944 without battle or trenchfoot experience.
4. New division, no experience; began combat in cold weather November or December 1944.

Clothing supply:
1. Completely supplied, overshoes or shoepacs.
2. Shortage of overshoes or shoepacs; socks and clothing completely supplied.
3. Shortage of overshoes and socks; socks with ration poor.
4. Shortage of overshoes or shoepacs, socks, and clothing.

Cold and wet:
1. Above 50° F. (10° C.), with or without rain.
2. Below 32° F. (0° C.), with or without precipitation.
3. 40° F.-50° F. (4.5° C.-10° C.), with rain.
4. 32° F.-40° F. (0° C.-4.5° C.), with rain.

[2] The duration of scoring criterion 3 was 20 days and for scoring criterion 2 was 10 days; the average weighted score was 2.7.

[3] The duration of scoring criteria 2 and 3 was 15 days each; the average weighted score was 2.5.

[4] Overshoes left behind by order.

TABLE 12.—*Scores of 21 infantry divisions, European theater, by cold injury modifying factor, December 1944*

Infantry divisions	Cases (number)	Combat action			Scoring criteria [1] for clothing supply	Scoring criteria [1] for rotation	Cold and wet			Scoring criteria [1] for training and combat experience	Shelter			Scoring criteria [1] for terrain	Sum of weighted scores
		Duration of scoring criteria (days)	Scoring criteria [1]	Weighted average of scores			Duration of scoring criteria (days)	Scoring criteria [1]	Weighted average of scores		Duration of scoring criteria (days)	Scoring criteria [1]	Weighted average of scores		
1st	126	8 8 6 9	4 1 3 2	2.5	1	1	19 4 8	3 4 2	2.9	2	8 16 6	4 1 2	2.0	2	13.4
2d	204	11 1 10 9	3 1 4 3	3.3	2	2	19 4 8	3 4 2	2.9	3	12 4 15	3 4 3	3.1	2	18.3
3d	222	-------	4	4.0	1	3	-------	4	4.0	1	-------	1	1.0	2	16.0
5th	154	21 10	3 4	3.3	2	2	21 10	4 2	3.4	1	20 11	3 2	2.6	2	16.3
8th	339	6 25	4 3	3.2	2	2	8 15 8	3 4 2	3.2	2	-------	2	2.0	3	17.4
9th	143	6 9 16	1 4 2	2.4	2	3	8 15 8	3 4 2	3.2	1	6 9 16	2 4 3	3.1	[2] 3 [2] 2 [2] 2	16.9
26th	333	24 7	4 1	3.3	2	4	12 10 9	3 4 2	3.0	4	13 7 11	2 1 4	2.5	[3] 3 [3] 2	21.3
29th	57	15 16	4 3	3.5	1	2	15 9 7	3 4 2	3.1	2	15 16	3 2	2.5	3	17.1
30th	112	12 5 14	3 1 4	3.1	2	2	11 11 9	3 4 2	3.1	2	18 13	2 3	2.4	[4] 3 [4] 2	17.2

35th	115	23	3	2.5	2	2	11	3	2.9	2	26	2	2.2	[5] 3	16.2
		7	1				9	4			5	3		[5] 2	
							11	2							
36th	200	-------	3	3.0	2	4	12	3	3.3	1	-------	2	2.0	2	17.3
							14	4							
							5	2							
44th	320	-------	3	3.0	2	3	17	4	3.1	2	-------	4	4.0	3	20.1
							13	2							
45th	300	-------	4	4.0	1	3	17	4	3.1	1	-------	4	4.0	3	19.1
							13	2							
80th	236	16	4	3.3	2	3	19	3	2.9	2	-------	2	2.0	2	17.2
		4	1				4	4							
		11	3				8	2							
83d	291	4	2	3.5	[6] 2	3	19	3	2.9	2	28	4	3.8	2	18.7
		24	4		[6] 1		4	4			3	2			
		3	1				8	2							
84th	210	20	3	2.7	2	[7] 2	19	3	2.9	2	20	4	3.3	[8] 3	17.0
		10	2			[7] 1	4	4			10	2		[8] 1	
							8	2							
90th	369	24	4	3.5	2	3	19	3	2.9	2	-------	4	4.0	3	20.4
		7	2				4	4							
							8	2							
95th	72	12	4	2.8	2	3	19	3	2.9	2	-------	2	2.0	3	17.7
		19	2				4	4							
							8	2							
99th	733	12	2	3.1	2	2	19	3	2.9	4	15	3	3.5	2	19.5
		16	4				4	4			16	4			
		3	3				8	2							
102d	203	3	4	2.2	2	1	14	3	3.1	4	3	4	1.3	2	15.6
		28	2				10	4			28	1			
							7	2							
104th	92	-------	2	2.0	2	3	19	3	2.9	3	-------	1	1.0	2	15.9
							4	4							
							8	2							

See footnotes on p. 372.

[1] Scoring criteria for modifying factors in cold injury, based on favorability to cold injury (from 1, least predisposing, to 4, most predisposing):

Combat action:
1. Movement unopposed; reserve; rest.
2. Static defense, patrolling; static defense, line holding.
3. Active defense, minor fighting.
4. Active offense, major fighting; active defense, with attack.

Shelter:
1. Buildings.
2. Tents, dugouts, bunkers.
3. Foxholes, improved.
4. Foxholes, unimproved, wet.

Terrain:
1. Dry, hilly, or mountainous; frozen snow underfoot.
2. Hilly or mountainous, forested; moderate mud.
3. Flat to rolling, muddy, wet.
4. Marshy, flooded, streams.

Rotation:
1. Excellent: rotation by units and within units at regular intervals; rest and bathing facilities.
2. Good; rotation by unit and within units when situation permits; limitation on numbers of men rotated; limited facilities.
3. Fair; no definite division rotation policy; small unit rotation when opportunity exists.
4. Poor; no specified policy or facilities.

Training and combat experience:
1. MTO, ETO, active campaigning.
2. ETO throughout, battlewise, no trenchfoot experience.
3. Entered ETO September or October 1944 without battle or trenchfoot experience.
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Clothing supply:
1. Completely supplied, overshoes or shoepacs.
2. Shortage of overshoes or shoepacs; socks and clothing completely supplied.
3. Shortage of overshoes and socks; socks with ration poor.
4. Shortage of overshoes or shoepacs, socks, and clothing.

Cold and wet:
1. Above 50° F. (10° C.), with or without rain.
2. Below 32° F. (0° C.), with or without precipitation.
3. 40° F.–50° F. (4.5° C.–10° C.), with rain.
4. 32° F.–40° F. (0° C.–4.5° C.), with rain.

[2] The duration of scoring criterion 3 was 6 days, for scoring criterion 2 was 9 and 16 days, respectively; the average weighted score was 2.2.
[3] The duration of scoring criterion 3 was 10 days and for scoring criterion 2 was 11 days; the average weighted score was 2.5.
[4] The duration of scoring criterion 3 was 18 days and for scoring criterion 2 was 13 days; the average weighted score was 2.6.
[5] The duration of scoring criterion 3 was 20 days and for scoring criterion 2 was 11 days; the average weighted score was 2.6.
[6] The duration of scoring criteria 2 and 1 was 15 days each; the average weighted score was 1.5.
[7] The duration of scoring criterion 2 was 26 days and for scoring criterion 1 was 5 days; the average weighted score was 1.8.
[8] The duration of scoring criterion 3 was 20 days and for scoring criterion 1 was 10 days; the average weighted score was 2.3.

to have held fairly constant, so that it could not greatly influence variations in the trenchfoot incidence. The correlation coefficient for training and experience versus incidence can be disregarded, since it was rather low.

TABLE 13.—*Cases of trenchfoot in 21 infantry divisions, European theater, November and December 1944, in relation to ratings of several predisposing factors*

[Relationship between variables expressed by coefficient of correlation; logarithms of incidence of cold injury were used in computing the coefficients]

Independent variables	Dependent variable	Interacting independent variables		
		Combat action	Shelter	Rotation
Combat action	*0. 419*			
Rotation	. 271	0. 283	0. 017	
Shelter	*. 547*	. 268		
Terrain	. 262	. 234	*. 322*	0. 172
Weather	. 021	(1)	(1)	(1)
Training and experience	. 120	(1)	(1)	(1)
Shelter-terrain [2]	*. 532*	*. 350*		—. 029

[1] Data not computed. [2] Mean score.

NOTE.—The figures in italic are significant correlation coefficients. Those above 0.304 are significant at the 5-percent level; those above 0.393 are significant at the 1-percent level.

Of the four apparently significant factors left after those just discussed are eliminated, shelter and terrain appear to be of the same nature, both being determined by the topography of the area. It is therefore feasible to combine them in one score by simply averaging the individual scores. With the combined score, a significant correlation is found with trenchfoot. The weighting of each of the three factors, rotation, combat action, and shelter-terrain, is possible, by means of multiple regression analysis. However, this complicated procedure would scarcely be profitable, since it would reflect only the relative weight within this particular situation, while other relative weights might be applicable to other situations, in another area of combat, for instance, or in another season. The relative importance of the three factors cannot be evaluated, but some interrelation can be found by the first order of correlation coefficients between their independent variables. There is a certain interaction between combat action and rotation (table 13) but no correlation between rotation and shelter. A third significant correlation between combat action and shelter adds further uncertainty to their evaluation.

The result of this analysis can therefore be summarized as follows: In an area with relatively bad weather, factors of the military environment were of more importance than weather in determining trenchfoot. Among these, combat action and shelter seemed to be of highest importance. Rotation policy was less influential. No relation between trenchfoot and troop training and experience could be found. Thus, within the broad causation of trenchfoot, certain factors of environment were found to influence incidence

when the weather was highly favorable for the occurrence of this special type of cold injury.

This analysis of cold injury in 21 divisions on the Western Front in November and December 1944 does not entirely bear out the epidemiologic findings of detailed unit surveys presented later in this chapter, especially in regard to such factors as the influence of weather, training and experience, clothing supplies, and rotation. The discrepancy, in itself, emphasizes the need for much more detailed data by units if, in the future, a valid statistical analysis is to clarify the roles of the several modifying factors in the causation of cold injury.

Interaction of combat action and season.—The statistical analysis just recorded was limited to a short period of the winter in Europe which was highly conducive to the occurrence of trenchfoot. Data on the incidence of trenchfoot among United States and British troops in Italy from October 1944 through March 1945 throw a different light upon certain factors. Trenchfoot was more frequent among United States troops, as is shown by the rate by months (chart 6, table 14). Combat action, however, varied for the two forces, as shown by battle-casualty rates. It is possible to correct the trenchfoot incidence for combat action by relating the rate of trenchfoot to that of battle casualties. When the rates thus obtained are plotted against the months of occurrence, two facts emerge. The first is that there is a distinct seasonal effect, with the peak in January and February. The second is that the apparent difference between British and United States troops seems to be without significance (chart 7, table 14). The interesting point in these data is that the seasonal

CHART 6.—*Trenchfoot incidence rates, United States and British forces in Italy, October 1944 through March 1945*

[Rate expressed as number per annum per 1,000 average strength]

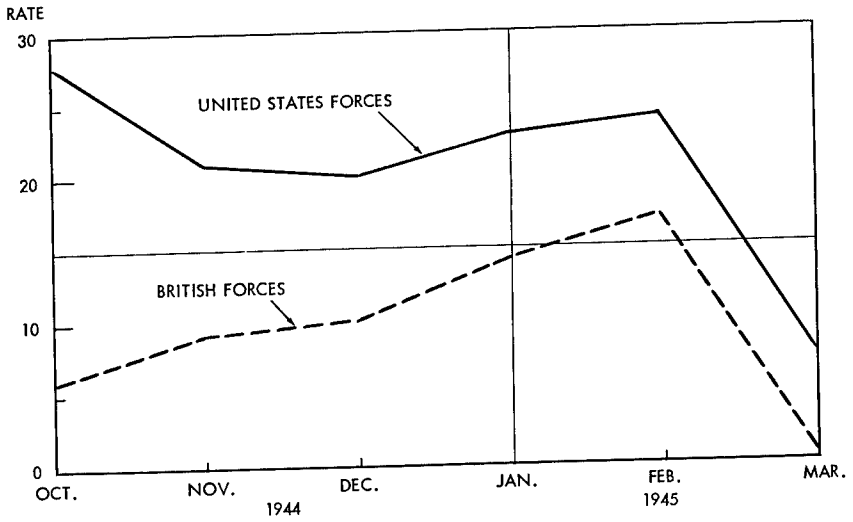

CHART 7.—*Comparison of ratios of trenchfoot to battle casualties in United States and British forces in Italy, October 1944 through March 1945*

[Ratio of trenchfoot to battle casualties expressed as a percentage]

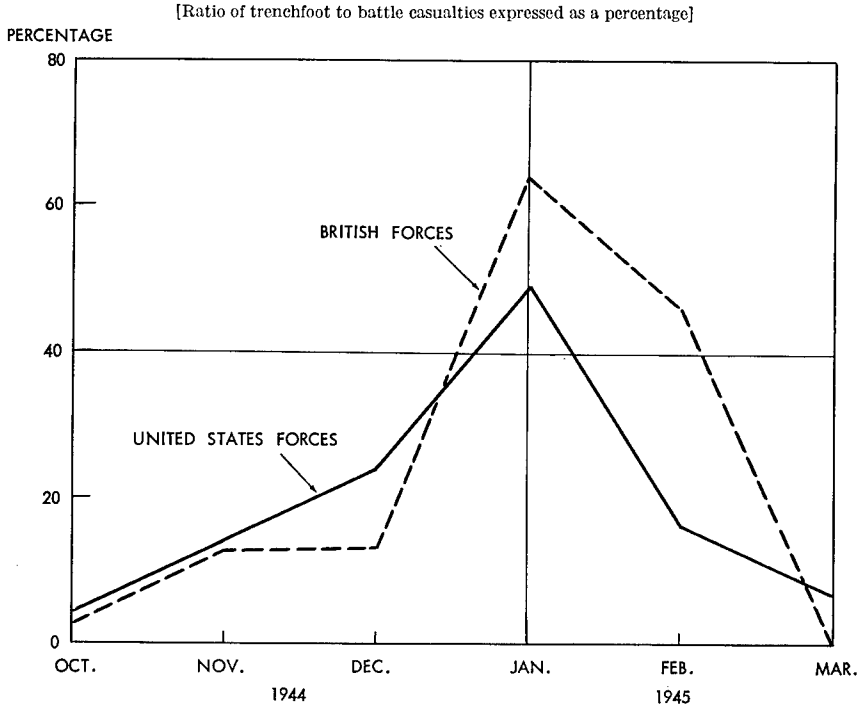

TABLE 14.—*Comparative incidence rates for trenchfoot cases and battle casualties, United States and British forces in Italy, October 1944 through March 1945*

[Rate expressed as number per annum per 1,000 average strength]

Month and year	U. S. Army			British forces		
	Trenchfoot (rate)	Battle casualties (rate)	Ratio of trenchfoot to battle casualties	Trenchfoot (rate)	Battle casualties (rate)	Ratio of trenchfoot to battle casualties
1944						
October	28	647	4. 32:100	6	236	2. 54:100
November	21	153	13. 72:100	9	75	12. 00:100
December	20	85	23. 52:100	10	80	12. 50:100
1945						
January	23	47	48. 93:100	14	22	63. 63:100
February	24	154	15. 58:100	17	37	45. 94:100
March	7	113	6. 19:100	0	6	0

factor was originally hidden by interaction with the military operation. The severest combat action took place during the months when the temperature was highest, but the trenchfoot incidence was apparently the same throughout the whole period. When the interaction of combat action and season was dissolved, however, the relatively higher incidence of trenchfoot in the colder months became evident, and it was then possible to explain the differences in the incidence of trenchfoot in the two forces by differences in their exposure.

EPIDEMIOLOGIC ANALYSIS OF AGENT, HOST, AND ENVIRONMENTAL FACTORS

Agent Factors

Cold.—Cold is the predominant agent in the production of cold injury, just as it is also the immediate exciting cause of tissue damage, irrespective of the influence of extraneous modifying factors. If the effect of cold is described as loss of body heat, the role of wetness as one of the modifying factors in cold injury is more easily comprehended. Experimental studies, the experience of armies in previous wars, and the experience of Arctic explorers and of the inhabitants of cold countries leave no doubt of the part cold plays in the production of cold injury.

The role of cold and the mechanism of the production of cold injury have been described in detail elsewhere (pp. 404 and 235).

Man is a tropical animal and is therefore highly susceptible to the effects of cold. The temperature of the human body and, to a lesser extent, that of the feet is kept independent of the temperature of the environment by two mechanisms. The first is natural means, such as metabolism and the circulation. Metabolic heat is distributed to the periphery by way of the circulation, upon which the hands and feet are particularly dependent for the maintenance of a temperature independent of that of the environment. Any factor that tends to impede the circulation (p. 390) would therefore be expected to render the hands and feet more susceptible to the action of cold.

The second means by which the temperature of the body is kept independent of that of the environment is artificial, the use of clothing. When man is reasonably well clothed, he is not greatly affected by dry cold above the freezing point. This was clearly established by the experience of British troops in World War I. Losses from trenchfoot were promptly and markedly reduced by the simple expedients of using trenchboards and wearing gum boots, which allowed the men to reach the trenches dry-shod. After these measures had been adopted, exposure to moderate degrees of cold (from above freezing to 50° F. (10° C.)) did not cause significant cold injury.

The evaluation of cold as an agent factor in the production of cold injury would be simple if the effects were in direct proportion to temperature. Then a simple relation between temperature and duration of exposure could easily

be expressed. The situation is not so simple. The effect of cold as an agent in cold injury is, as already indicated, best described as a loss of body heat, a concept which serves to explain the role of wetness as a modifying factor. Since loss of body heat is the important consideration, the relation of cold and of several other factors becomes complex. Heat loss may be much greater at temperatures above freezing than it is at temperatures below this level if wetness or other factors expedite the process. The loss may be much less at temperatures below freezing if the soldier is properly insulated with clothing and can keep dry. Under these circumstances, it is both expedient and advisable to regard cold as an agent in cold injury which acts in the same manner in which a bacterium acts as the agent in an infectious disease. Similarly, it is well to view the modifying factors that determine the extent and seriousness of cold injury in the same way in which various circumstances may influence the invasiveness of micro-organisms.

Wet.—In the causation of cold injuries that occur in the range of temperatures above freezing, the synergistic relation that wet bears to cold may again be compared to the synergistic relations of certain micro-organisms to each other in the causation of infectious disease. Because of the physical properties of water, wetness enhances the effect of cold. Body heat is readily conducted to the outside atmosphere from the feet and other parts of the body through wet stocks, shoes, gloves, and other articles of clothing. Evaporation of water in wet clothing occurs with substantial additional cooling effects, even when the outside atmosphere is cold and humid.

Wetness has other undesirable effects. It causes clothing to cling closely to the skin and thus eliminates the insulating layer of air ordinarily present between the skin and the clothing. Air spaces between layers of clothing and air in the interstices of the clothing are also lost when the clothing is wet. Dry, intact skin, because of its horny layer, has inherent insulating properties that are destroyed by wetness. Finally, water or wet clothing in contact with the skin for long periods may cause maceration, which in turn increases the likelihood of trauma and infection.

The synergistic effect of wetness is highly important because many military operations conducted in winter take place at temperatures at which wetness combines with cold to produce cold injury. Since cold, as temperature, and wetness, as precipitation, are components of weather, and in this capacity are also environmental factors, both will be discussed in greater detail under the latter heading (p. 404).

Host Factors

The host factors responsible for cold injury are inextricably interwoven with the same human attributes that cause soldiers to perform well or poorly in battle, that build up high morale or result in indifference, and that motivate men to fight to the bitter end on one hand and to desert on the other. These are human attitudes, traits, and resources. They are, at one and the same time, physical, mental, and emotional. No precise standards of measurement are

available for them, but a full understanding of them is the essence of leadership and command function.

Leadership and personnel have been accorded a vast amount of study in the past, and extensive research on human action, attitude, and motivation are currently under way. In some of these studies, great emphasis has been placed upon the psychology of war and on leadership, while in others the chief attention has been given to physical attributes. There is considerable doubt, however, whether all of these studies, and the knowledge derived from them, have been utilized to the best advantage. It has been proposed that the Armed Forces might, with full justification, establish and support research to study man as a whole and to evaluate influences of all kinds, physical, mental, emotional, environmental, and all others that combine to cause men to react and perform as they do. Until this or some similar approach to the measurement of human host factors can be accomplished, it will be impossible to evaluate thoroughly the factors that influence cold injury, combat trauma, neuropsychiatric conditions, and disease.

Because of the absence of satisfactory methods of measurement, the evaluation of host factors is necessarily imperfect. It is based on observations made in wartime, opinions, and such crude measurements as are possible. Nonetheless, by these methods, the important role of host factors is made clear, as is the need for greater understanding of them and for precise methods of measuring them. In spite of these lacks, the crude methods necessarily used in World War II made clear the important role of host factors. The questionnaire submitted to 1,018 trenchfoot casualties and to an adequate control group toward the end of the war (p. 400) furnished material that, together with unit observations, demonstrated both host and environmental influences.

Age.—No conclusive evidence exists that age, per se, influences individual susceptibility to cold injury in the age range of military combat soldiers; that is, 18 to 35 years (table 15). Observations on shipwrecked mariners and passengers suggest that persons below the age of 17 and above the age of 40 years may be more susceptible than those in the years between. These phenomena can be explained by the instability of the cardiovascular system, its inability to adjust to stress in the younger group, and the generally lowered adaptability of the circulatory system in those in middle age and older.

In 1,018 trenchfoot casualties surveyed in Zone of Interior hospitals in 1945 (p. 400), age distribution bore no relationship at all to cold injury (table 15). These were chiefly combat troops, and the age range was narrow. Age seemed similarly without influence in the 144 patients with trenchfoot who were surveyed by Berson and Angelucci [3] in hospitals in Italy and who were compared with 877 soldiers hospitalized for other reasons.

In one sense, age does play a role in the susceptibility to trenchfoot. Observations made at the 1st Arctic Aeromedical Laboratory and reported by

[3] Berson, R. C., and Angelucci, R. J.: Trench Foot. Bull. U. S. Army M. Dept. No. 77, pp. 91–99, June 1944.

Miller [4] emphasize the importance of physical fitness in withstanding the stress of cold. Since physical fitness is, as a rule, likely to be less in older age groups, an increased individual susceptibility probably could be shown in them. In combat units, however, this would not hold, since the physically unfit are screened out by intent at the time of induction and by the exigencies of battle experience if they have passed the initial screening.

TABLE 15.—*Age at last birthday of 1,018 patients with trenchfoot, hospitalized in Zone of Interior*

Age	Cases (number)	Percent
18 and 19	122	12
20 to 24	234	23
25 to 29	448	44
30 to 34	143	14
35 and over	41	4
Unknown	30	3
Total	1, 018	100

Sex.—No data came out of World War II to justify the consideration of sex as a host factor in susceptibility to cold injury. This might be expected because of the military circumstances. Members of the Women's Army Corps were not exposed to conditions conducive to cold injury. They were utilized in the larger headquarters and in hospitals and, in both locations, had shelter, food, and ample clothing. Nurses were assigned as far forward as evacuation or field hospitals in army areas, but the installations were always under canvas or in other sheltered locations. The hospital sites, it is true, often became quagmires, but exposure was not great, and adequate clothing, including galoshes, was provided. Furthermore, the nature of their work kept the nurses, for the most part, in heated shelters.

Race and geographic origin.—The role of race and geographic origin as host factors in cold injury is not well clarified by data recorded for either of the World Wars.

Gilcreest [5] recorded the unusual prevalence of trenchfoot among American Negroes in World War I with a great deal of humor, but his comments concerning cold injury among men of this race in combat are neither convincing nor informative. In World War II, observations in training areas in the United States, as well as in Italy and on the Western Front, furnished no indications that United States Negroes or other soldiers native to Southern States

[4] Miller, A. J.: Physical Fitness for Strenuous Work in Relation to the Survival Situation in a Cold Environment. Report of Project XIV, 1st Artic Aeromedical Laboratory, Ladd Air Force Base, Alaska, 1948.

[5] Brownrigg, E. M.: Frostbite in Shipwrecked Mariners. Am. J. Surg. 59: 232-247, February 1943. [Includes discussion by Edgar L. Gilcreest, pp. 245-246.]

were any more or any less susceptible to cold injuries than were other troops. Combat comparisons are not valid because a large proportion of Negro troops were assigned to service organizations and did not suffer much exposure.

Such combat records as do exist, however, suggest a possible racial susceptibility to cold. The 92d Infantry Division, a Negro combat unit, was exposed to cold in Italy, in the winter of 1944–45, when protection was far better understood and clothing far more adequate than in the previous winter. Although the total incidence of trenchfoot in the Mediterranean theater was greatly reduced for these reasons, this particular division supplied one out of every three cold casualties reported. A possible explanation is that the unit was new to combat and lacked the battle training and experience with cold which other Fifth U. S. Army divisions possessed in the second winter of fighting in Italy.[6]

It was also observed that trenchfoot was relatively more frequent in Japanese-American soldiers than in other United States troops.[7] The rate was high in the 100th Infantry Battalion (Separate), composed of Japanese-American soldiers, although it was attached to a regiment (the 133d Infantry) in which the rate was low because foot discipline was excellent. The explanation offered by the commanding officer of the regiment was that Japanese-American soldiers were peculiarly susceptible to cold injury because of the delicate construction of their feet. The regimental surgeon was of the same opinion.

Not a great deal of information exists about other troops. In World War I, the French used Senegalese troops on the Western Front in 1917 and had a high incidence of "frozen feet" in the middle of April, when cold injury was negligible among other French forces. Brazilian and Hawaiian troops fighting in Italy in the winter of 1944–45 had a high incidence of trenchfoot.[8] The original injuries were thought to be more severe than in North American troops, and recurrences were unusually frequent. Inexperience and newness to combat probably accounted for a part of this record, as in the Negro division just mentioned, but racial susceptibility cannot be entirely discounted.

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[6] Later studies confirm the Mediterranean experience concerning cold injury in the Negro. In the winter of 1951–52, a special cold injury research team, commanded by Lt. Col. Kenneth D. Orr, MC, made an extended study of the etiologic, pathologic, epidemiologic, clinical, and therapeutic aspects of these injuries. The report of the work of this team was published on 1 April 1953 (Summary of Activities, Cold Injury Research Team Korea, 1951–52, Report No. 113, Army Medical Research Laboratory, Fort Knox, Ky.). This report (p. 418) stated that Negro soldiers proved to be a significantly greater risk for attack by frostbite (6 times) than other soldiers when all environmental conditions were equalized. At the regimental level, the Negro rate was 35.9 per 1,000, compared to 5.8 per 1,000 for white soldiers. Negroes also showed more severe injuries than white soldiers. Differences in tissue susceptibility were neither proved nor disproved.

Additional confirmation of the apparently greater Negro susceptibility to cold injury is also found in a report by Maj. Gen. Alvin L. Gorby, in Essential Technical Medical Data for January–March 1956, United States Army, Europe. During February 1956, the number of reported cases of cold injury exceeded the total reported for the cold injury season of 1954–55. While cold injury was the outstanding morbidity problem during this month, it was considered remarkable that the incidence was not higher and the severity not greater, since the winter of 1955–56 was the most severe in Europe in the past century. On the other hand, while the incidence of cold injury was not inordinately high, a large proportion of the cases occurred in Negro troops, which indicates, as previous studies have indicated, that race is a predisposing factor in this condition.

[7] Annual Report, Surgeon, VI Corps, Seventh U. S. Army, 1944.

[8] Toone, E. C., and Williams, J. P.: Trench Foot: Prognosis and Disposition. Bull. U. S. Army M. Dept. 5: 198–210, February 1946.

The evidence of racial susceptibility to cold is thus fragmentary. It is certainly not sufficiently convincing to prevent the employment of presumably susceptible races in winter operations, such as those in Europe in World War II, although better knowledge of this host factor might strengthen the decision to use certain racial groups in service echelons or in light holding defense operations pending a long period of acclimatization. As a matter of fact, acclimatization and adaptation to climatic environment are difficult to separate from purely inherent racial susceptibility or lack of susceptibility. All races can acclimatize to cold, to some extent, at least, and can learn to do the things necessary for survival in the cold.

The Eskimos furnish the outstanding illustration of this ability. The white man can acclimatize to the arctic cold, but he never develops inherent protective mechanisms equal to those of the Eskimos, who, as the result of long development, undoubtedly possess a racial tolerance to cold. Eskimo babies wear no clothes. They are carried in pouches on their mothers' backs, in skin-to-skin contact, and they are removed stark naked, in weather far below zero, for excretion, feeding, and other care, without apparent harm. The Eskimos, furthermore, know the value of protective clothing and of special care of the feet. All their clothing is layered and loosely fitted. The inner layer, of caribou skin, is worn with the fur to the wearer's skin; a second, outer skin is worn with the fur outside. For footgear, Eskimos wear sealskin mukluks, which are loosely fitted, changed frequently, and discarded when it is no longer possible to chew them into pliability.

Previous cold injury experience.—There seems no doubt that previous cold injury predisposes the soldier who has experienced it to further trauma from cold. The degree of predisposition varies in proportion to the severity of the original injury, recurrence being most frequent when the previous injury has been moderate to severe.

It was thought that some of the cases of cold injury which occurred on Kiska were early recurrences of the injuries which had been sustained on Attu, though the possibility of recrudescence rather than recurrence could not, of course, be completely dismissed (p. 99). In Italy and in Europe, however, there was no doubt of the seriousness of recurrent cold injury.

Lt. Col. (later Col.) Fiorindo A. Simeone, who made a special investigation of trenchfoot in the Mediterranean theater in the winter of 1943–44 and in the following winter (p. 101), estimated that 15 percent of all casualties from this cause who were returned to duty might be expected to have recurrences. He also expressed the opinion that a man who had suffered a cold injury would be particularly susceptible to the effects of cold if he were exposed again within a few weeks or a few months. The course of events substantiated his opinion. Although only 2 percent of the personnel of all divisions of the Fifth U. S. Army suffered from trenchfoot, 18 percent of all patients hospitalized for this cause had previously been hospitalized for it. Twenty-two percent of the cases observed in December 1944 were instances of recurrence (8 percent from the winter of 1944–45 and 14 percent from the previous winter), and, in January

1945, 23 percent of the cases were recurrent (18 percent from the winter of 1944–45 and 5 percent from the previous winter). The conclusion of Berson and Angelucci, that previous exposure is not an important factor in susceptibility to cold injury, is not in accord with the conclusions of others. The explanation probably is that their studies were made before the factor of previous exposure had begun to exert its heaviest influence.

Recurrent trenchfoot in the European theater was first encountered in the Seventh U. S. Army, many of whose components had fought in Italy the previous winter. On 30 November 1944, an officer from the Preventive Medicine Division, Office of the Chief Surgeon, ETOUSA, noted in a memorandum on trenchfoot in the Third and Seventh U. S. Armies that, between 1 October and 18 November, 1,441 cases had been reported in the Seventh U. S. Army and that about 50 percent of these were instances of recurrence. The experienced divisions from which most of these recurrences came had few new cases except among Japanese-American troops. These troops had suffered heavily from this cause in Italy and had the same experience in France. Other estimates of recurrent trenchfoot in soldiers who had sustained cold injury in Italy the previous winter ranged from 30 to 35 percent.

When investigators from the Office of the Chief Surgeon, ETOUSA, questioned the surgeons from various combat divisions concerning recurrent cases of trenchfoot and their opinion of the susceptibility to subsequent cold injury of those who had previously experienced it, it was the consensus that men with prior injuries were more susceptible to subsequent injury. The following endorsement forwarded by the Surgeon, 45th Infantry Division, to the Surgeon, Seventh U. S. Army, was based on the opinions of all surgeons in the division and was representative of the opinion in the whole theater:

> a. Trench foot in Italy, especially if of such a degree as to be classified as moderate, *did* render the men susceptible to vascular disturbances in the feet between the period of landing in Southern France and the onset of weather cold enough to actually precipitate trench foot.
>
> b. Persons who have had trench foot will *not* tolerate well intensive marching, even though the weather is warm.

Incidentally, the surgeon of the 2d Infantry Division recorded that men who had suffered from frozen feet in Michigan during winter maneuvers 2 years earlier were the first to succumb to cold trauma in the 1944–45 campaign on the Western Front.

The situation with respect to recurrence is excellently summed up in a report from the 23d General Hospital covering data from 5 November to 1 December 1944 and included in Essential Technical Medical Data, ETOUSA, for November 1944:

> Of 122 so-called recurrent cases, 58 patients had received previous hospital care for cold injury. They had spent a total of 3,788 days (10.3 years) in hospitals, and 749 additional days in reconditioning. Many of them had been returned to A (full) duty, and had remained on full duty for several weeks, but closer analysis showed their activities to have been of a limited nature. These men were really a burden to their commands because of frequent sick calls, the periods they spent in quarters, their constant complaints of foot pain on walking and in wet, cold weather, and the necessity of transporting them in vehicles when

the troops advanced. Return to combat conditions frequently caused prompt relapses, especially in men who had sustained their first cold injuries in France. Patients with recurrent cold injury did not have a more severe grade of injury than those primarily affected, but their tolerance to wet and cold was definitely less.

Medical officers responsible for the management of trenchfoot did not at first comprehend the ready susceptibility to subsequent cold injury of men who had previously sustained such injuries. They soon learned the lesson. In the winter of 1943–44, for instance, 50 percent of all men with trenchfoot treated at the 45th General Hospital in Italy were returned to full duty.[9] In the second winter, when the risk of retraumatization by cold had become more clearly understood, only 2.1 percent were returned to full duty.

Experiences in the European theater also showed that the usefulness to the Army of a man who had sustained a cold injury was likely to be limited. On 1 December 1944, the Commanding General, Third U. S. Army, wrote to the Theater Chief Surgeon that serious consideration must be given to the rapid replacement of able-bodied soldiers in the rear by men who had suffered from trenchfoot and who could do duty as military police or truck drivers or who could work in other posts in which they would not again be exposed to wet and cold.

During the week ending 24 February 1945, the Office of the Surgeon, United Kingdom Base, surveyed one general hospital chosen at random from each of six hospital centers in respect to the trenchfoot situation. The disposition of the patients indicated that the lesson of recurrent cold injury had been learned. There had been 1,828 dispositions in a total of 3,769 admissions for cold injury in these six hospitals up to and including 21 February 1945. Of this number, 192 men had been returned to general duty (11 percent); 672 had been returned to limited duty (37 percent); 443 had been sent to convalescent hospitals (24 percent); and 520 had been evacuated to the Zone of Interior (28 percent). In short, and assuming that the men returned to full duty had been able to stand up under it, which is a highly unlikely assumption, 89 percent of 1,828 combat troops had been lost from combat duty because of cold injury. The results were somewhat better in the hospitals which had stressed early, active exercise and had conducted special classes in rehabilitation.

These dispositions were far from the optimistic predictions advanced early in the winter. In the 1944 report of the 108th General Hospital in Paris, in which 150 beds had been set aside for the investigation of cold injury, the estimate was that only 10 percent of the casualties from this cause would have severe enough injuries to require evacuation to the Zone of Interior and that 37 percent would have injuries mild enough to permit their return to duty within 60 to 90 days. As a matter of fact, about a third of all patients admitted with cold injury as the primary diagnosis had to be evacuated to the Zone of Interior and 18 percent received Certificate of Disability discharges.

One reason why it was thought that recurrence would not be a factor of major importance in field forces on the Western Front was that the evacuation

[9] See footnote 8, p. 380.

policy encouraged the removal to rear echelon medical installations of men with even mild injuries if their symptoms lasted more than 2 or 3 days.[10] With a triage and evacuation policy of such strictness, opinions were expressed as late as January 1945 that recurrent trenchfoot would not be great in combat soldiers. Recurrence did take place, however, when many casualties originally evacuated with apparently mild injuries were returned to combat duty; the importance of previous cold injury as a host factor in the causation of this type of trauma thus was proved again.

When the weather became warmer, many hospitals began to send larger proportions of their patients with cold injury back to full duty, or to limited duty, on the ground that they would not be exposed again to extreme cold or wet cold. This policy was also not successful. Men returned to even limited assignments did not usually hold up well under their duties, and many of them eventually had to be evacuated to the Zone of Interior.

The evidence collected in Italy and in the European theater thus left no doubt that the wisest plan of disposition was to return all casualties with cold injuries, unless they were very mild (first degree), to the Zone of Interior for possible assignment to a theater where the climate was more moderate and their services could be better utilized. The loss of time was enormous when they were returned to full or even limited duty in a cold climate. It would have been wiser to retain in the theater in which they had sustained their injuries only those who had some special talent for the war effort. Even when this plan is followed, the residua of cold injury (p. 284) will often make these soldiers a burden rather than an asset to their organizations.

Because so many men with recurrent cold injuries lacked any objective evidence of the disease, their management was particularly difficult. When there was obvious tissue damage, the decision was simple, but no test was available by which physiologic disturbances could be demonstrated, and, in the absence of sound proof to the contrary, complaints had to be accepted at their face value. At that, malingering was suspected in a surprisingly small number of cases.[11]

Inherent constitutional factors.—Lewis, in his discussion of chilblains and in his reports on cold in general (p. 235), has shown that the individual response to cold varies greatly from person to person. This fact is generally accepted, though the inherent constitutional reasons for the variability are not readily apparent. The Raynaud and Buerger syndromes are well known and easily recognizable clinically, but the abnormal physiologic processes upon which they are based have not been satisfactorily explained. It is not at all clear why moderate cold should act as a trigger mechanism in one person, setting off the typical response to cold, including blanching and even blue coloration

[10] Minutes, Trenchfoot Conference, Office of the Chief Surgeon, ETOUSA, Paris, 24 Jan. 1945.

[11] Another interesting feature of the report of the research team which studied cold injury in Korea during the winter of 1951–52 (p. 380) was its confirmation of the experiences in the Mediterranean and European theaters concerning the effects of previous cold injury. A previous injury was shown incontrovertibly to predispose to a second attack (p. 417). The attack rate among soldiers who had had no previous injuries was 2.6 per thousand, compared to 5.0 per thousand for men who had previously sustained cold injuries.

of the skin, while in other persons under the same conditions of exposure sensitivity is very much less marked.

Lange and his associates,[12] who accept the thesis that sensitivity to cold varies widely from person to person, take the position that susceptibility is rather constant in the same subject. They subjected volunteers to spot-freezing, applying to an area 5 cm. in diameter a metal capsule at 3.6° F. (−15.8° C.) for 30 minutes. Exposures that consistently produced extensive gangrene in the total exposed area in some volunteers did not cause tissue breakdown in others, in spite of repeated tests. Lange and his group believe that by means of standard test procedures to be developed from investigations such as these it may be possible, eventually, to screen persons with an unusually high sensitivity to cold.

German students of cold injury have repeatedly emphasized the importance of individual susceptibility to cold. Block,[13] for instance, concluded that the vasomotor constitution of the particular soldier is the determining consideration and that asthenic types are most susceptible. Stucke [14] found that men who had followed indoor occupations were more susceptible to cold than those who followed outdoor occupations and that persons whom he described as vagotonics suffered most severely of all.

Gohrbandt,[15] who studied this phase of cold injury thoroughly, divided persons who suffer from cold into two groups, (1) those who show no overt residual signs after injury and (2) those who continue to show signs and symptoms, such as impaired circulation in the skin, low temperatures in the extremities, sensory disturbances, hyperhidrosis, and inadequate muscular response to exercise. Men in the latter group he regarded as constitutionally susceptible to cold and fit for military duty only in warmer climates. In his opinion, an army medical service should include a vascular center, one of the functions of which would be the differentiation of personnel who are susceptible to cold and those who are not. He did not consider that it would be practical for the unit medical officer to undertake this task.

Gohrbandt regarded the vagotonic or bradycardic individual as extremely susceptible to cold. In this group, he placed all those with pulse rates of less than 68 per minute and those with any proneness to allergic spasms, dermatographia, and early fatigue. He regarded sticky sweating of the hands and feet as a commonly associated symptom. He also quoted Koch's dictum to the effect that cardiac vagotonics are potentially circulatory sympatheticotonics and suggested that men who answer this description should not be assigned to service in cold climates. This is a sound principle. Its development and

[12] Lange, K., Weiner, D., and Boyd, L. J.: Frostbite: Physiology, Pathology and Therapy. New England J. Med. 237:383-389, 11 Sept. 1947.

[13] Block, W.: Die Bedeutung des Vegetativen Nervensystems beim Zustandekommen Örtlicher Erfrierungen. [The Significance of the Autonomic Nervous System in Frostbite.] Arch. klin. Chir. 204: 64-83, 20 Dec. 1942. Abstract *in* Bull. War Med. 4: 268, January 1944.

[14] Stucke, K.: Kälteschäden und Erfrierungen in Felde. [Cold Injuries on Active Service.] Beitr. Klin. Chir. 174: 1-10, 30 Nov. 1942. Abstract *in* Bull. War Med. 4: 507, May 1944.

[15] Gohrbandt, E.: Wiedereinsatz Frostgeschadigter. [The Return to Service of Soldiers who have Suffered from Frostbite.] Zbl. Chir. 70: 1584-1586, 30 Oct. 1943. Abstract *in* Bull. War Med. 5: 552, May 1945.

practical application, however, await a better understanding of the physiologic abnormalities involved in susceptibility to cold and the development of simple specific tests along the lines of those proposed by Lange and his associates.

Ian Aird, who abstracted Gohrbandt's article which has just been summarized, commented editorially on the more specific type of susceptibility to the local effects of cold (that is, hereditary cold fingers, chilblains, Raynaud's syndrome, and the conditions which give rise to them) and criticized him for not including them in his discussion. In Aird's own opinion, cold susceptibility can be detected on a moderately cold winter morning merely by inspecting the hands of the men who are drawn up on parade. This kind of testing is an obvious improvisation. It is no more capable of weeding out the persons who are less than grossly susceptible to cold than sick call inspection can identify a man with rheumatic heart disease who presents no gross physical signs.

The captured German medical officers and noncommissioned medical officers who were interviewed in January 1945 in the European theater (p. 204) consistently mentioned the constitutional makeup (that is, the state of the sympathetic and parasympathetic nervous systems) as a factor in cold injury. They also commonly expressed the opinion that age, previous cold injury, and the use of tobacco influenced individual susceptibility to cold injury.[16]

The theory has been advanced that persons who present cold agglutinins in the blood may be more susceptible to exposure to cold, and may present higher percentages of intravascular agglutination and ischemia as a result, than those in whom this finding is absent.[17] On the basis of this theory, Loewenthal studied 24 patients with trenchfoot and obtained data which he interpreted as indicating that cold agglutinins were found more often in their blood and tissue fluids than in the blood and tissue fluids of the normal soldiers used as controls. Boland, Claiborne, and Parker,[18] who also found a higher incidence of cold agglutinins in patients with trenchfoot than in normal controls, stated that these agglutinins were invariably present in the patients with gangrene who were included in their series. The significance of these observations remains to be elucidated.

In a survey of 158 patients with trenchfoot on the surgical service at the United States Army General Hospital, Camp Butner, N. C., then serving as a trenchfoot center, it was observed that over 95 percent fell into the group of cases described by Gage[19] as vascular variants. These men had previous histories of hyperhidrosis, cold feet, nervousness, which sometimes seemed

[16] Observations of the research team which studied cold injury in Korea during the winter of 1951–52 indicated a negative correlation between the use of tobacco and frostbite. There was a highly significant difference in the use of tobacco among frostbite victims and their bunkermate controls, with the men with frostbite consuming far less tobacco than the nonfrostbitten controls. Possible psychiatric factors may explain this finding.

The report of the team bore out to some extent Gohrbandt's theory that the bradycardic individual is particularly susceptible to frostbite. The mean pulse rate of cold injury casualties was 75.3 per minute compared to 86.8 per minute for controls.

[17] Report, Lt. Col. Fiorindo A. Simeone, MC, to the Surgeon, Fifth U. S. Army, subject: Trenchfoot in the Italian Campaign 1943–45.

[18] Boland, F. K., Claiborne, T. S., and Parker, F. P.: Trench Foot. Surgery 17: 564–571, April 1945.

[19] Letter, Col. I. M. Gage, MC, Headquarters, Fourth Service Command, to Brig. Gen. Fred W. Rankin, Chief Consultant in Surgery, Office of the Surgeon General, 23 Mar. 1945.

hereditary, and other evidence of sympathetic imbalance. They stated that they had developed cold injury under circumstances in which large numbers of their associates had not. A number of them presented marked dermatographia, with wide hyperemic flares along the pencil marks.

Preexisting Pedal Deformities, Infections, and Circulatory Abnormalities

In this same connection, Col. Charles B. Odom, MC, Consultant in Surgery, Office of the Surgeon, Headquarters, Third U. S. Army, noted that the number of deformities such as claw foot, hammertoes, and other pedal deformities was extremely high in patients with trenchfoot as compared to the rest of the hospital population.[20] He wondered how some of these men had ever been accepted in the infantry, and he had no doubt that when they sustained cold injury they were far worse off than men with normal feet. Other observers commented that men with circulatory deficiencies, flat feet, and other foot troubles were foot conscious, reported on sick call promptly, and therefore tended to have milder forms of cold injury. If, however, they could not obtain care, or if they were treated improperly, they presented a severer form of injury, after less exposure, than men without previous foot disabilities.

In both the Mediterranean and the European theaters, there was a large amount of fungous infection of the feet. It caused a good deal of concern, particularly in the European theater, because of the potential loss of manpower to which it might lead. Investigation showed that the incidence was related to a number of factors, including poor foot hygiene, the type of duty assignment, the use of shoes with rubber soles, the use of extremely heavy British-issue socks in warm weather, variations in the care of showers, failure to use preliminary foot baths, and the use of previously worn hospital slippers which had not been sterilized. The control of these factors invariably reduced the incidence of fungous infection. There was no apparent connection, however, between previous fungous infection of the feet and the development of cold injury.

An attempt to determine the possible relation of previous injury or disease to the occurrence of trenchfoot was undertaken in the Mediterranean theater but was not conclusive.[21] A review of the histories of 144 patients with trenchfoot who were admitted to a hospital in North Africa in the first winter of the Italian fighting showed no higher incidence of previous disease or injury than was found in a control series of 877 patients admitted to the same hospital for other causes. The distribution of possible etiologic factors, indeed, was strikingly similar in both series.

Fifty patients with trenchfoot who were studied intensively in Italy in November 1943, soon after the epidemic nature of the condition was realized, were investigated from the standpoint of dorsalis pedis pulsations. These

[20] See footnote 10, p. 384.
[21] See footnote 17, p. 386.

pulsations were not palpable in 11 men after a week of hospitalization, which is very close to the proportion (25 percent) found absent in 125 casualties with trenchfoot studied later in another general hospital in Italy. The over-all frequency with which these pulsations cannot be palpated in men of this age group, while it is not known, is almost certainly not as high as 25 percent. In neither of these studies was it possible to distinguish cause from effect, and conclusions concerning the etiologic significance of these observations are not justified.

A postwar study, by Silverman,[22] of the dorsalis pedis and posterior tibial pulsations in 1,014 infantrymen revealed that one or both were absent in 13 percent, although absence of both pulsations on the same side occurred only five times in the entire series, and both pulsations were absent in both feet in only one case. The posterior tibial pulsation was more frequently absent in Negro subjects, and the dorsalis pedis in white subjects. Both arteries were found to show wide anatomic variations, and Silverman emphasized that these variations should always be taken into account before pulsations were reported to be absent. The material in this survey, the conditions of which were carefully controlled, seems comparable to that studied in the Mediterranean theater.

In the Pacific, Col. I. Ridgeway Trimble, MC, consultant in surgery, felt strongly that men with circulatory anomalies of the lower limbs would be particularly susceptible to trenchfoot. He therefore made a serious, though unsuccessful, effort to have screening from this point of view made part of the preliminary physical examination (p. 222).

Physiologic processes.—While it is not within the scope of this volume to discuss the general physiologic processes involved in heat production in the body, or to describe the mechanisms of human-heat regulation, these functions cannot be entirely ignored. They are intimately related to the nutritional status of the host (p. 394), and lowering of efficiency or other alterations may account, in part, for the influence of recent infectious disease (p. 390) on cold susceptibility. When there is an excessive loss of body heat because of low environmental temperatures, the metabolic rate rises in an effort to maintain a balance between heat loss and heat production. The principal sources of the compensatory heat are the liver and the muscular tissues, especially those of the extremities. The mechanism involves increased tone of the skeletal muscles, involuntary muscle reactions, such as shivering, and the contraction of the smooth muscles of the skin which results in gooseflesh. All of these reactions consume energy and eventually produce fatigue. Some hemoconcentration also occurs, and there is probably an increase in the rate of circulation of the blood.

Numerous observations have been made on the basal metabolic rate in relation to environment, though none of the studies is conclusive. It is generally believed that thyroid function is increased in cold climates, and there is

[22] Silverman, J. J.: The Incidence of Palpable Dorsalis Pedis and Posterior Tibial Pulsations in Soldiers. An Analysis of Over 1,000 Infantry Soldiers. Am. Heart J. 32: 82-87, July 1946.

some evidence that oriental races and white men living under the same climatic conditions have different basal metabolic rates.[23] White persons living in tropical climates appear to have reduced metabolic rates. By comparison, rates for Eskimos are higher.

Experiments have been carried out under the auspices of the Medical Research and Development Board, Office of the Surgeon General of the Army, to determine changes in thyroid activity in hypothermia by the use of tracer radioactive iodine. Lange, Gold, Weiner, and Kramer [24] conducted experiments on rabbits to observe the possible protective effect of thyroid administration against cold injury. Animals given thyroid in amounts sufficient to raise their basal metabolic rates between 30 and 50 percent had a reduced rate of loss of body heat and a decided prolongation of survival time, which could be increased by as much as 54 percent when the optimal dosage of thyroid was administered. Conversely, there was an increase in the rate of loss of body heat and a reduction of survival time, in comparison with normal controls, when thyroid function was suppressed by the administration of thiouracil. The protection afforded by thyroid administration was not immediate. There was a timelag of 4 or 5 days after the drug was given before any protection against cold was discernible. These studies suggest that the level of the basal metabolic rate may serve as an index of susceptibility to cold, and also suggest that personnel with depressed or borderline rates may be unsuited for military service in cold climates.

Selye,[25] who studied the protective physiologic mechanisms which come into play as a result of long-continued stress of various kinds, concluded, in general, that mild stress reactions may be beneficial but that reactions which are excessive or of long duration may give rise to diseases of adaptation. Cold is an agent of stress.

The general adaptation syndrome may be subdivided into (1) the alarm reaction, which may be followed by shock phenomena, including hypothermia, hypotension, hemoconcentration, increased capillary permeability, and depression of the central nervous system; (2) the stage of resistance, which follows upon continued stress and the development of adaptation, characterized by enlargement of the adrenal cortex and increased secretion of cortical hormones; and (3) the stage of exhaustion, which occurs when the degree or duration of stress is such that adaptation fails and defenses are lost.

The defense mechanism, Selye has pointed out, is intimately related to the activities of the hypophysis and the adrenal glands, the hormones of which play an important role in metabolism. In McFarland's studies (p. 393), which include the stress factor of fatigue, information is summarized on the relationship between fatigue and the excretion of the 17-ketosteroids. In

[23] Best, C. H., and Taylor, N. B.: The Physiological Basis of General Practice. 2d ed. Baltimore: Williams and Wilkins Co., 1950.

[24] Lange, K., Gold, M. A., Weiner, D., and Kramer, M.: Factors Influencing Resistance to Cold Environments. Bull. U. S. Army M. Dept. 8: 849–859, November 1948.

[25] Selye, H.: The General Adaptation Syndrome and the Diseases of Adaptation. Practitioner 163: 393–405, November 1949.

extreme cases, this observer believes, there is a significant positive correlation. He also believes that further study of neuroendocrine changes would be valuable, since, if these reactions are a part of adaptation to all stresses, accurate and useful indexes of fatigue and other stresses might thus be determined. If McFarland's theory is correct, a promising avenue of approach to the cold problem would seem to be opened.

The Medical Department Field Research Laboratory, as part of its investigation of the physiologic effects of cold, endeavored to determine the factors which control the secretion of the various endocrine organs under conditions of stress, including cold. It was found that hyperglycemia produced in experimental animals by orally administered glucose caused an increase in adrenal cholesterol and that an insulin-produced hypoglycemia caused a decrease. The results thus indicate, respectively, an inhibition and a stimulation of the adrenal cortex. Loss of cholesterol from the adrenal gland, which was observed in experimental animals exposed to low temperatures, was interpreted as evidence of decreased resistance. When aqueous adrenal cortical extract was administered to animals exposed to cold, it prevented the lowering of the adrenal cholesterol to the levels observed in control animals.

The understanding of these various inherent constitutional factors is, at best, imperfect at this time, and further investigation along these lines is essential if military management of personnel under stress, including the stress of cold, is to reach an optimum level of effectiveness.

Recent infectious disease.—Russian authorities, especially Ariev (p. 240), laid great stress upon recent infectious disease, in addition to wounding and other trauma, as a factor predisposing to cold injury. Their principal concern, however, was with severe frostbite, not trenchfoot. Neither the World War I nor the World War II experience with cold injury affords a basis for this point of view or for any other authoritative opinion concerning the influence of infectious disease on susceptibility to cold trauma. On the other hand, it is a reasonable assumption that the physical stress of an infectious disease would increase susceptibility to cold by lowering the efficiency of the circulatory system, reducing the local skin resistance to trauma, increasing fatigue, and, in general, decreasing physical fitness.

Posture and dependency.—The position of the host has a decided influence on the incidence and severity of cold injury of the lower extremities. When Lange and his associates restricted the movements of rabbits during exposure to cold, they observed a decided decrease in survival time in the restricted animals as compared with that in animals exposed to the same conditions but left free to move about.

Attention has already been called to so-called shelterleg, a type of injury similar to trenchfoot, which occurred in persons sleeping in deck chairs or on benches or boxes, with the lower extremities dependent, in the cool, damp air-raid shelters in London (p. 9). Dependency was also shown to be an important factor in immersion foot in surviving shipwrecked sailors, who had been compelled to sit or stand for several days in lifeboats or on rafts, with

little opportunity for movement and with their feet wet or in water. The records of frontline units afford many examples of the high incidence of cold injury among men pinned down by enemy fire and forced to remain sitting or squatting in wet, cold foxholes for long periods of time. There were also numerous excellent individual and small unit illustrations of men similarly pinned down who had moved their feet and legs sufficiently to ward off cold injury. In one instance, cold injury developed among all the men in one frontline unit except those who left the position daily to go after the rations.

Fatigue.—The role of fatigue in the development of trenchfoot is difficult to isolate as an entity. Fatigue develops in proportion to the duration and intensity of stress. Similarly, the development of cold injury is related to the period of exposure. Time is a factor in both fatigue and cold injury, and periods of stress and exposure are likely to coincide. Fatigue is also inherent in exposure to cold, especially when loss of body heat and shivering are taken into consideration.

For these various reasons, difficulties arise in the evaluation of the host factor of fatigue. Crude measurements can be made in terms of old and new troops, and by the comparison of the incidence of trenchfoot in troops in the line or in combat for a few days with the incidence in troops in line or in combat for many days. Wartime data do not provide good examples of any specific studies made to determine the influence of fatigue in the production of cold injury, and the general data available by units are not specific enough to permit correlation studies to demonstrate its effects. As in the matter of individual training, it is necessary to make assumptions and draw broad conclusions from circumstantial evidence alone.

Fatigue is interpreted as meaning exhaustion of strength because of toil and weariness. It is mental and emotional as well as physical. It is important as a host factor in cold injury, if for no other reason than that soldiers, when they are fatigued, are less willing as well as less able to carry out such simple preventive measures as removing their shoes, putting on dry socks, massaging their feet, and exercising to restore the efficiency of the circulation in the lower extremities. Under circumstances of fatigue, discipline generally deteriorates, the deterioration including one of the key points in control of trenchfoot; namely, discipline of the individual soldier in carrying out measures for his own protection.

Soldiers in the trenchfoot opinion survey to be described (p. 400) were questioned about the number of days they had been without rest (table 16). Seventy percent of those with trenchfoot had been in combat 8 days or more before the onset of cold injury, and almost half (44 percent) of those who contracted it had fought for 15 days or more without rest. Details concerning the type of combat, periods of intense exposure, and other modifying factors are not available, but, if it can be assumed that they balanced out, it seems reasonable to infer from the data that fatigue, as expressed in days of actual combat, does influence the incidence of cold injury. The soldiers who did not contract cold injuries showed an almost identical distribution of combat days,

TABLE 16.—*Combat days without rest before onset of trenchfoot in 1,018 patients hospitalized in Zone of Interior*

Days without rest	Trenchfoot cases		Days without rest	Trenchfoot cases	
	Number	Percent		Number	Percent
0	20	2	7	72	7
1	0	0	8 to 14	265	26
2	10	1	15 to 30	295	29
3	20	2	31 and over	153	15
4	20	2	Unknown	61	6
5	61	6			
6	41	4	Total	1,018	100

but in this instance these men cannot serve as controls because fatigue may also predispose to injuries other than cold trauma.

Fatigue is also an element in the differential between units that had good rotation of individuals and total units, as opposed to those that had no rotation policy and that required units and individuals to stay in the line for reasons of tactical expediency. This point is discussed in more detail elsewhere (p. 446), but it may be said here that soldiers in combat are chronically fatigued and that their fatigue is resolved only when they are brought out of the line and provided with facilities for rest. The difference between the incidence of cold injury in units in combat and in units in reserve is striking, as would be expected; but the presence or absence of other modifying factors, such as exposure, wet clothing, lack of shelter, inadequate food, and perhaps other considerations precludes more than generalized inferences concerning the host factor of fatigue. It all comes down to the fact, already pointed out, that under combat conditions fatigue was not evaluated and could not be evaluated in relation to cold injuries or to battle casualties in general. For that matter, the influence of fatigue upon nonbattle injuries, especially accidents, is not more than hinted at in the available records.

Nonetheless, the influence of fatigue upon the incidence of cold injury can be roughly demonstrated by the following experience of three regiments of the 83d Infantry Division between 3 December and 27 December 1944.

Unit case history No. 1.—This division left the United States in the spring of 1944, entered active combat in Normandy soon after D-day, and by early fall had fought across France into Luxembourg. During November, the division had a light static defensive assignment. On 3 December, the 330th Infantry Regiment was thrown into hard fighting in an active offense in the Hürtgen Forest. Four days later, on 7 December, the 331st Infantry Regiment entered upon the same type of combat. The 329th Infantry Regiment was not committed until 11 December. All three regiments fought in thickly wooded, hilly, muddy terrain. The weather was continuously cold and rainy, and the troops lived in foxholes, with little rotation possible because of the tactical situation.

In other words, there was no fundamental difference in the mission of any of these regiments, and all three experienced the same tactical and environmental conditions. The only differential of importance was the period of combat. The order of magnitude of trenchfoot experience in the three regiments was in rough proportion to the period of time each spent in combat. The highest incidence was in the 330th Infantry Regiment, which had the longest period of combat, and the lowest in the 329th, which had the shortest. In this respect, the 331st Infantry Regiment was intermediate (chart 8, table 17).

A good deal of attention has been devoted to the effects of fatigue upon Air Force personnel and airline pilots and other operational personnel. McFarland's book on human factors in air-transport operations contains a review and critical analysis of the whole subject, as well as a summary of the general concepts of the nature of fatigue. Fatigue is discussed in relation to the operation of motor vehicles, and there is a special discussion of the temporary proneness to accidents observed among drivers of cross-country trucks after long hours at the wheel. Physical, mental, and emotional fatigue is defined, methods of measuring each of them are described, and acute fatigue and chronic fatigue are differentiated. Special stress is laid upon the fact that chronic fatigue is not relieved by short periods of rest and is therefore cumulative.

Much of McFarland's work, as is clear from this brief résumé, is directly applicable to many aspects of fatigue in combat ground forces. He did not, however, discuss the relation of fatigue to trauma, except trauma resulting from accidents, and further investigations and research in this field would be highly

CHART 8.—*Cold injury in 3 regiments of the 83d Infantry Division, European theater, for weeks ending 10 November 1944 through 5 January 1945*

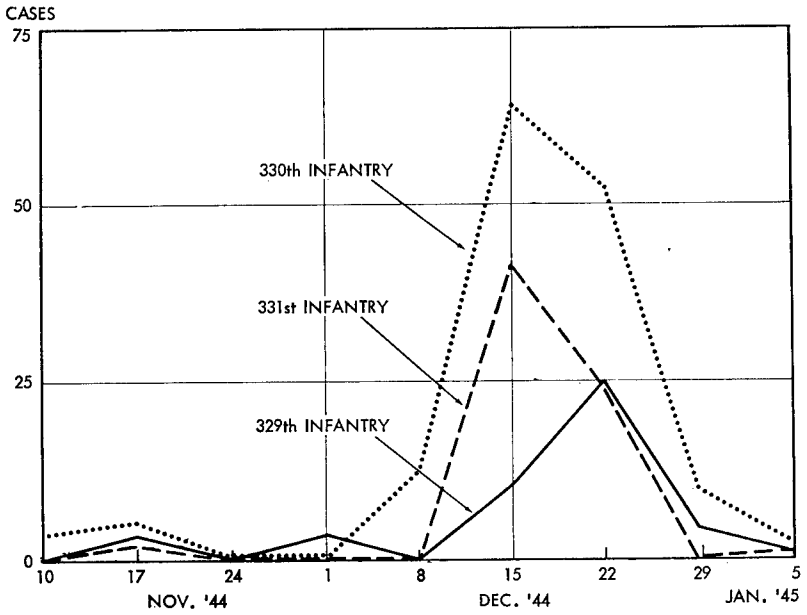


TABLE 17.—*Cold injury in 3 regiments of the 83d Infantry Division, European theater, for weeks ending 10 November 1944 through 5 January 1945*

Week ending—	329th Infantry	330th Infantry	331st Infantry	Total
1944				
November 10	0	3	0	3
17	3	5	2	10
24	0	0	0	0
December 1	3	0	0	3
8	0	12	0	12
15	10	63	42	115
22	25	52	24	101
29	4	9	0	13
1945				
January 5	1	2	1	4
Total	46	146	69	261

profitable. He emphasized the need for further research on neuroendocrine mechanisms as part of the fatigue process and as part of emotional fatigue. Physiologic changes resulting from fatigue, particularly as they affect nervous tissue, blood vessels, and the susceptibility of tissue in general to trauma also require a great deal more study.

Nutritional status.—Just as with fatigue, it is difficult to measure and assess the nutritional status of the individual soldier under combat conditions. Poor nutrition is undoubtedly a factor in the development of physical fatigue, and it may also influence the man's psychic responses in his reaction to the requirements for self-preservation. The nutritional status has a direct physiologic bearing upon the efficiency of the circulatory system and also upon the ability of local tissue to resist trauma and infection. Miller,[26] after studying groups of men living for periods of up to 10 days in extreme cold, with daily caloric intakes varying from no calories to 4,000 calories, noted a direct relationship between physical fitness and ability to rise to situations of stress. Men on low caloric intakes were inactive and responded with less serious effort to situations in which their survival was at stake. Failure to exercise in an effort to improve the circulation is part of the causation of cold injury, and failure to expend the necessary energy to change the shoes and socks and massage the feet is also a cause. In this study, both causes could be related to poor nutritional status combined with fatigue.

It is not always a simple matter to provide troops in active combat with adequate rations. Inadequacies are often associated with the stress of hard fighting, and sometimes with long periods of inactivity. During rapid motorized advances, or when forces are pinned down in static positions and are largely

[26] See footnote 4, p. 379.

cut off by the enemy, sufficient rations often cannot reach the frontline. Then men must subsist on emergency rations for periods well in excess of those for which these rations were intended. In these situations, it is conceivable that mild degrees of dehydration, as well as subclinical vitamin and protein deficiencies, will occur and may be sufficient to affect the general host susceptibility to cold injury.

No specific studies on these points were carried out during World War II, and a survey of unit histories does not reveal any circumstances in which nutrition appeared to be the only variable in the factors productive of cold trauma. A number of tactical situations were recorded, however, in which troops of battalion or regimental size were cut off by enemy action for periods varying from a few days to a few weeks, in circumstances in which poor nutrition undoubtedly was an important consideration in the causation of cold injury. At the same time, cold and wet, and a number of modifying factors such as exposure, lack of shelter, immobility, intense combat, fatigue, and emotional stress also came into play. It is therefore not possible to evaluate the factor of nutritional status accurately by the method of unit study.

It is nonetheless interesting in this connection, despite the limitation of many variables, to analyze the cold injury experience of the 8th Infantry Division, which was virtually isolated for a period of 2 weeks (chart 9, table 18).

Unit case history No. 2.—This division arrived in Ireland from the United States in December 1943. It crossed to the Continent early in July 1944, and by late October had fought across France to Luxembourg. By this time it

CHART 9.—*Cold injury in 3 regiments of the 8th Infantry Division, European theater, for weeks ending 17 November 1944 through 9 February 1945*

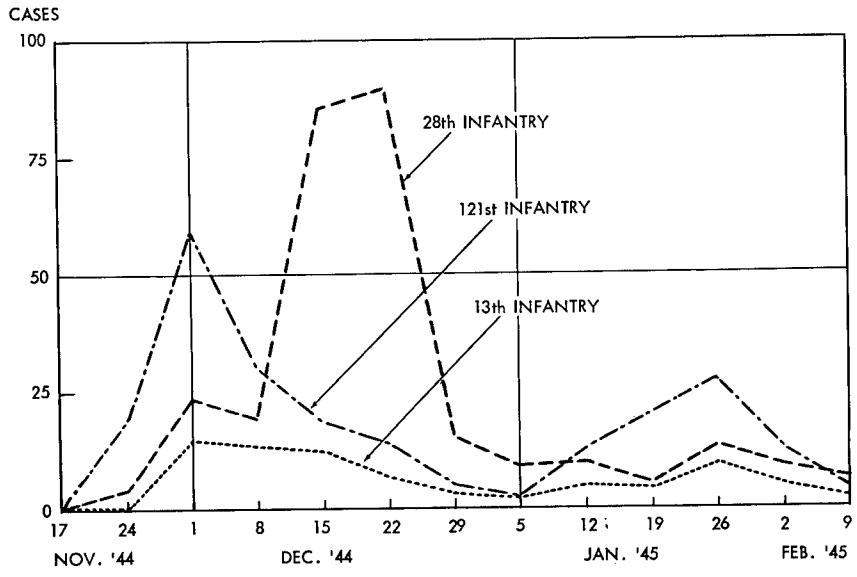


TABLE 18.—*Cold injury in 3 regiments of the 8th Infantry Division, European theater, for weeks ending 17 November 1944 through 9 February 1945*

Week ending—	13th Infantry	28th Infantry	121st Infantry	Total
1944				
November 17	0	0	0	0
24	0	4	20	24
December 1	14	24	59	97
8	13	19	31	63
15	12	86	18	116
22	7	89	14	110
29	3	15	5	23
1945				
January 5	2	9	2	13
12	5	10	12	27
19	4	5	19	28
26	9	13	28	50
February 2	5	8	12	25
9	2	6	4	12
Total	76	288	224	588

had become an experienced combat division. From 1 November to 20 November inclusive, it fought a defensive action in Luxembourg on a 30-mile front, over a terrain which was hilly and rugged but which was relatively dry except for the muddy lowlands. During this period, the weather was moderately cold and there was considerable rainfall, but the troops had fairly satisfactory shelter. Rotation was good, and each man had two hot meals daily. Trench-foot incidence did not exceed 25 cases per week.

On 21 November, the troops were moved to the Hürtgen Forest. Here, between 23 November and 6 December inclusive, they fought an active offensive action. The terrain was wooded and flat. The weather was moderate, but there was considerable rainfall, and the ground, which was poorly drained, became extremely muddy. An upsurge of cold injuries occurred late in November and in the first few days of December (chart 9, table 18), predominantly in the 121st Infantry Regiment. The incidence was not exorbitant and could be accounted for by heavy offensive action.

The type of combat action changed on 7 December, and from that time until 25 December the division made limited attacks in the same area to clean out towns. It also conducted sporadic, intermittent offensive actions. On 8 December, the 28th Infantry Regiment was almost completely cut off in the Hürtgen Forest and could not be relieved until 23 December. During this period, the men were isolated and were almost continuously pinned down by enemy fire. Supplies had to be delivered through a long, narrow corridor and could be brought forward only at night. The type of ration provided is not

stated in the regimental and divisional records, but circumstances such as these usually meant that K-rations had to be used. Hot food and facilities for heating food could not have been made available.

Before the period of isolation, this regiment had had less than 25 cases of cold injury a week. With isolation, there was an immediate and dramatic rise in incidence, there being 86 cases the first week of isolation and 89 cases the second. Almost as soon as the regiment had been relieved, the incidence fell to 15 cases per week, or fewer, and did not rise above this level for the next 7 weeks. Thereafter, except for 25 cases recorded for the week ending on 2 March 1945, cases per week did not exceed 8 during the time that cold injury was prevalent.

This was not a simple situation. Many variables were involved. The combat action was severe. Rotation was impossible. Shelter was limited to wet, muddy foxholes. All of these circumstances are conducive to cold injury. On the other hand, this was an experienced, battlewise unit. It had acquitted itself well in other engagements of equal intensity, in which it had had no undue incidence of cold injury. The principal difference in the situation described was isolation, which always greatly complicates the problem of providing adequate food for troops, while at the same time it increases exposure and decreases the effectiveness of triage and medical care. It can fairly be said, therefore, that inadequate nutrition was apparently a factor in bringing about an increased incidence of cold injury in this experienced unit during a period of isolation.

Psychosocial factors.—At the beginning of World War II, the status of knowledge of psychosocial factors and of the possibilities of influencing them through preventive psychiatry was not such as to permit an attack upon them with any confidence. These are crucial elements in the effectiveness of combat personnel. They encompass the total range of physical, mental, and emotional stress; battle casualties; nonbattle injuries; combat exhaustion; and neuropsychiatric disability in addition to cold injury. Their efficient analysis would require the combined efforts of qualified psychiatrists, psychologists, and sociologists, as well as of competent military leaders.

It is necessary, in spite of these lacks and requirements, to fill in the general background of the psychic effects of stress in order to appreciate how the addition of further stress, in the form of wet and cold, could intensify the situation. The data collected in World War II provide no means of measuring accurately the psychosocial host factor. It can be thought of only as a part of the over-all host factor of stress and as a component in the total causation of cold injury.

The cost of neuropsychiatric casualties, together with the concept that men wear out in combat, just as a truck wears out under continuous use, was not fully appreciated in the early phases of World War II by any medical officers, including psychiatrists. Later, both in Italy and on the Western Front, the value of psychiatric advice and consultation as a preventive measure was much more widely appreciated, and psychiatrists were assigned as far forward as

divisions. There were many times, however, when the tactical situation made the application of optimum psychiatric procedures impossible, and the effectiveness of these measures also showed unit variations. As a result, rates for psychiatric casualties remained high throughout the war, especially during periods when combat action was severe and protracted.

Of all combat branches, the infantry is exposed to the greatest danger of trauma. An analysis of attrition and replacement in the Fifth U. S. Army during its operations in North Africa [27] revealed that, by the time a regiment had been in combat 120 days, 50 percent of the original strength of its rifle battalions had been killed, wounded, or captured or was missing in action. The percentage would have been higher except for the removal of men from combat for illness or noncombat trauma. Neuropsychiatric rates of 1,200 and 1,500 per 1,000 per year were recorded in many rifle battalions, in comparison with rates of 30 or less in units of similar size in other branches of service.

Fifteen to twenty percent of the total nonfatal combat losses sustained during severe combat in World War II were usually found to be neuropsychiatric, the proportion depending upon the intensity and duration of continued combat. Limits of endurance for the average soldier were found to range between 200 and 240 regimental combat days. Soldiers who received psychiatric care at the end of 200 combat days or earlier could usually be returned to combat duty. Men treated later were, as a rule, permanently lost as combat personnel. The British in Italy expected to obtain service of approximately 400 combat days per rifleman, but their policy was to relieve frontline riflemen after a period of 12 days or less, for rest periods of 4 days. American troops in the same theater, in contrast, were often in combat up to 40 days without relief, and sometimes fought as long as 80 days. Another point to be noted is that the men who were kept in combat for the longest periods were the indispensable, competent, well-tried, frontline soldiers, such as company or platoon officers, noncommissioned officers, squad leaders, and key enlisted men. When these men did break from stress, they were likely to be irretrievably lost to the combat forces, and they were always difficult to replace.

Although motivation is a basic consideration, it is difficult to say precisely what role it plays in the production of trenchfoot. In the Mediterranean theater, for instance, when cold injury first appeared in the winter of 1943–44, the willingness of troops to endure conflict was on the decline. They had begun to feel that they were being kept in the line for too long periods, without provision for sufficient rest, and this feeling may well have influenced them in their lack of effort to protect themselves or, more correctly, influenced those of them who, at this time, had the means and knowledge to protect themselves.

An analysis of motivation in the second winter in Italy is still more difficult. Favoring deterioration were two factors, continued and very heavy combat, especially during the capture of Rome and the piercing of the Gothic Line, and the mere passage of time. There were, however, other factors operating to

[27] Letter, Brig. Gen. R. B. Lovett, Adjutant General, ETOUSA, to Commanding Generals of Major Commands, 4 Oct. 1944, subject: Prevention of Loss of Manpower from Psychiatric Disorders, enclosure thereto.

sustain morale. Although fighting was sometimes heavy, there was relative tactical inactivity during a large part of the winter. Many preventive and protective practices had been instituted, including the rotation of troops through rest areas, correction of many of the former discriminations against combat troops, especially when they were on leave in base areas, and the belated attempt to glorify the role of the combat soldier by such means as extra pay and the award of the Combat Infantryman's Badge. It is not possible to say, however, whether the decrease in trenchfoot during the second Italian winter was in any way influenced by a greater desire on the part of the men to protect themselves against cold injury than they had displayed during the first winter.

It is a curious fact that in the European theater, when trenchfoot rates were high, rates for neuropsychiatric disorders were reduced. The immediate explanation would seem to be that potential neuropsychiatric casualties found medical evaluation for mild cold injury an honorable as well as a convenient way to avoid combat, and that their number was large enough to affect the rates for these conditions. Such a course was undoubtedly taken by some soldiers. There were, however, other considerations. The soldier was often faced with an actual choice between severe injury or death on the one hand and acquiring trenchfoot by remaining immobile in his foxhole, on the other. He usually remained immobile. The fact that large numbers of men with bona fide trenchfoot were evacuated from combat units before they might be expected to become neuropsychiatric casualties would seem, automatically, to establish the relation noted between trenchfoot and neuropsychiatric disorders.

Intelligence and morale are both components of the group of psychosocial factors. Intelligence enters into the host complex, in that the intelligent soldier is more easily trained and more readily understands the necessity for the maintenance of fitness. Morale is an intangible state of mind and emotion that is difficult to elucidate. Moreover, the morale of the individual soldier, which is a host factor, cannot be disassociated from unit morale, which is a complex of leadership, motivation, confidence, and the state of discipline and training. Units in which the morale of the individual soldier was high always had less cold injury for the same reasons that they had lower rates for venereal disease, fewer courts-martial, and a minimum of accidents.

Psychiatrists and military leaders alike came to consider motivation in the individual soldier important in his ability to withstand stress of all kinds. It could be shown that an incentive beyond the urge for self-preservation and the desire to maintain self-respect was necessary for the soldier. The psychiatrists believed that rewards should be given for achievement. They also advocated tactical and strategic orientation of troops, individually and by groups, as broad as was consonant with security. The wisdom of this concept was amply demonstrated by the performance of such outstanding combat units as the 3d Infantry Division, whose combat missions were arduous and difficult over a period of more than 3 years. Considering the type of combat in which this division was engaged, it could have been expected that its rates for cold injury would sometimes be high; the over-all record, however, was excellent.

About all that can be said in summarizing the influence of psychosocial host factors is that many of them are intangibles not susceptible of precise measurement and that the war experience provided unfortunately little data concerning their true importance. No apparent sharp line separates the effects of physical stress, emotional stress, and mental stress. There is considerable reason to believe that there may be an organic approach to many of these psychiatric problems. It may be that the same neuroendocrine influences that now seem to condition fatigue are also components of the associated emotional reactions to stress. Be this as it may, the situation further indicates the need for additional study and research and for the evaluation of men as a whole rather than the mere collection of data dealing with individual facets of the behavior and physical responses of the individual. Much, in short, remains to be learned concerning the prevention of the cumulative effects of stress upon the individual host.

Training.—The effectiveness of a unit in combat depends upon training. The life of the individual soldier also depends upon it. In the military sense, training is a term of broad significance. It includes education, indoctrination, and motivation of the individual soldier, and the teaching of combat techniques to military units. The incidence of cold injuries varies greatly between experienced, well-trained units and inexperienced organizations not so well versed in the art and techniques of combat.

Training must therefore logically be considered both as an environmental and as a host factor. As a host factor, it concerns the hardening of the individual soldier. In this sense, it might also be interpreted broadly to include acclimatization and the necessary physiologic adjustments required to develop a good combat soldier in excellent physical condition.

At the same time, training involves a series of intangible human factors such as self-discipline, morale, intelligence, character, and habits of self-preservation. Training, in the present discussion and also later, when it is discussed as a social-environmental factor (p. 442), must be interpreted as including experience, because it is impossible to differentiate successfully between the influence of training as an educational process and the influence of experience as a teacher in the hard school of combat.

Opinion survey.—In the spring of 1945, the Preventive Medicine Service, Office of the Surgeon General, in conjunction with the Information and Education Division, Army Service Forces, undertook a survey of soldiers returned from overseas with trenchfoot.[28] The survey was designed to evaluate many factors, including host factors, to study men's attitudes and behavior, and to determine, as far as could be determined, why they had contracted cold injury.

The investigation covered 1,018 enlisted men who had become casualties from cold injury. The 234 controls, who were selected from a total of 600 men hospitalized at the same time for causes other than trenchfoot, were chosen because the conditions of their combat service were comparable to those sus-

[28] Report No. C-114, Information and Education Division, Army Service Forces, 2 June 1945, subject: Trenchfoot Survey.

tained by the men who had acquired trenchfoot. Both groups represented many units. Some had fought in Italy and others in the European theater during the winter season. Certain inferences can be drawn from the responses of both groups about the amount of instruction they had received concerning cold injury and about their knowledge of, and concern in, its prevention.

The report, made 21 June 1945, showed that only 55 percent of the men who contracted trenchfoot had heard about it before going into combat, whereas 79 percent of those who did not contract it had knowledge of it. Only 37 percent of the men with trenchfoot said that their officers or noncommissioned officers had told them how to prevent it; 71 percent of the men who did not contract it had had this type of training. Only 26 percent of the men with trenchfoot had given some thought to their chances of acquiring cold injury under winter combat conditions, while nearly twice as many (49 percent) of the men who did not contract it had considered the possibility. Queries concerning the opinion of the two groups about the amount of training they had received on certain items before they went into combat elicited variable replies (table 19).

No definitive conclusions can be drawn from these data. On the other hand, after the merits and fallacies of opinion surveys in general have been taken into consideration, the inference is permissible that the training the soldiers had received varied from individual to individual, and that those who had had the least training in cold injury prevention, and who had been the least interested in it, were chiefly the men who acquired the injury.

TABLE 19.—*Opinion on training in trenchfoot prevention of 1,018 patients with trenchfoot and 234 patients with other injuries hospitalized in Zone of Interior* [1]

Estimate of precombat training	Too much	About right	Too little	None	No answer	Total
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
Trenchfoot group	1	15	23	52	9	100
Control group	3	41	26	21	9	100

[1] The 234 patients who served as controls underwent the same conditions of exposure as the patients with trenchfoot.

A further example of the role of individual training in the causation of trenchfoot is illustrated by the experience of replacements (reinforcements) in combat units as compared with the experience of older, better trained, more battlewise soldiers. The official records of trenchfoot incidence do not differentiate between replacement or veteran status, but unit records and sanitary and other reports of unit sick contain numerous comments concerning the inadequate training status of replacements. The investigators from the Office of the Chief Surgeon, ETOUSA, who studied trenchfoot in several armies, division by division, consistently recorded similar observations. Some replacement troops acquired trenchfoot en route to frontline units from replacement centers. Trenchfoot occurred in one unit, the 89th Infantry Division, while it was still

in a replacement center. It was universally recognized that the incidence of cold injury among replacements was much higher in their first weeks of combat than it was for experienced soldiers.

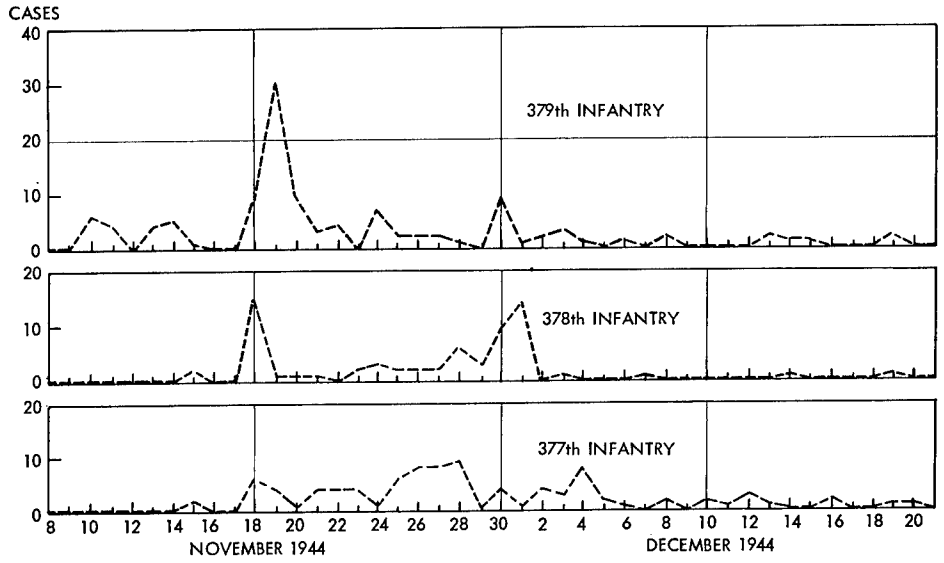
It is only fair to add that this situation cannot be attributed entirely to defects in training. Many times, soldiers who had been properly trained failed to appreciate the importance of the training they had had and consequently failed to apply what they had been taught, or were unable, because of the combat situation, to apply their knowledge.

The reverse of this situation is demonstrated by the experiences of old and tried units in which all the factors relating to trenchfoot or cold injury, including the individual training of the soldier, were good.

Unit case history No. 3.—The 95th Infantry Division [29] is an excellent example of what has just been said (chart 10, table 20). This division was on the offense during November and part of December. It made at least three river crossings, and it assisted in the reduction of the Metz fortresses. Yet at no time during this whole period was its incidence of trenchfoot high. The maximum number of cases on a single day never exceeded 35, and on only one other day did the number reach 30. It is interesting that during this period replacements for casualties of all types were slow in being brought forward, which means that the men at risk were for the most part well trained and experienced.

The excellent record of this division of course involves many other factors, but there can be little doubt that the good status of training of the individual soldier was one important reason for the low incidence of cold injury. In this

CHART 10.—*Cold injury in 3 regiments of the 95th Infantry Division, European theater, 8 November through 21 December 1944*



[29] Further details of the experience of this division are presented on p. 426 (unit case history No. 10).

TABLE 20.—*Cold injury in 3 regiments of the 95th Infantry Division, European theater, 8 November through 21 December 1944*

Date	377th Infantry	378th Infantry	379th Infantry	Total
1944				
November 8	0	0	0	0
9	0	0	0	0
10	0	0	6	6
11	0	0	4	4
12	0	0	0	0
13	0	0	4	4
14	0	0	5	5
15	2	2	1	5
16	0	0	0	0
17	0	0	0	0
18	6	15	9	30
19	4	1	30	35
20	1	1	10	12
21	3	1	3	7
22	3	0	4	7
23	3	2	0	5
24	1	3	7	11
25	6	2	2	10
26	8	2	2	12
27	8	2	2	12
28	9	6	1	16
29	1	3	0	4
30	4	9	9	22
December 1	1	14	1	16
2	4	0	2	6
3	3	1	3	7
4	8	0	1	9
5	2	0	0	2
6	1	0	1	2
7	0	1	0	1
8	2	0	2	4
9	0	0	0	0
10	2	0	0	2
11	1	0	0	1
12	3	0	0	3
13	1	0	2	3
14	0	1	1	2
15	0	0	1	1
16	2	0	0	2
17	0	0	0	0
18	0	0	0	0
19	1	1	2	4
20	1	0	0	1
21	0	0	0	0
Total	91	67	115	273

division, as in others, though the evidence in favor of training as a positive modifying factor in cold injury is largely circumstantial and corroborative, it is nevertheless indicative of the significance of this special factor, which deserves more careful evaluation in the future.

Environmental Factors

Environment is the medium through which agent and host are brought into contact and interact to produce cold injury. Elements providing the mechanism through which cold injury takes place are chiefly environmental. Physical environmental factors include temperature, altitude, precipitation, wind, thawing, terrain, and shelter. Socioeconomic environmental factors include leadership, medical care, type of combat action, rotation policies and practices, and certain elements of training and discipline.

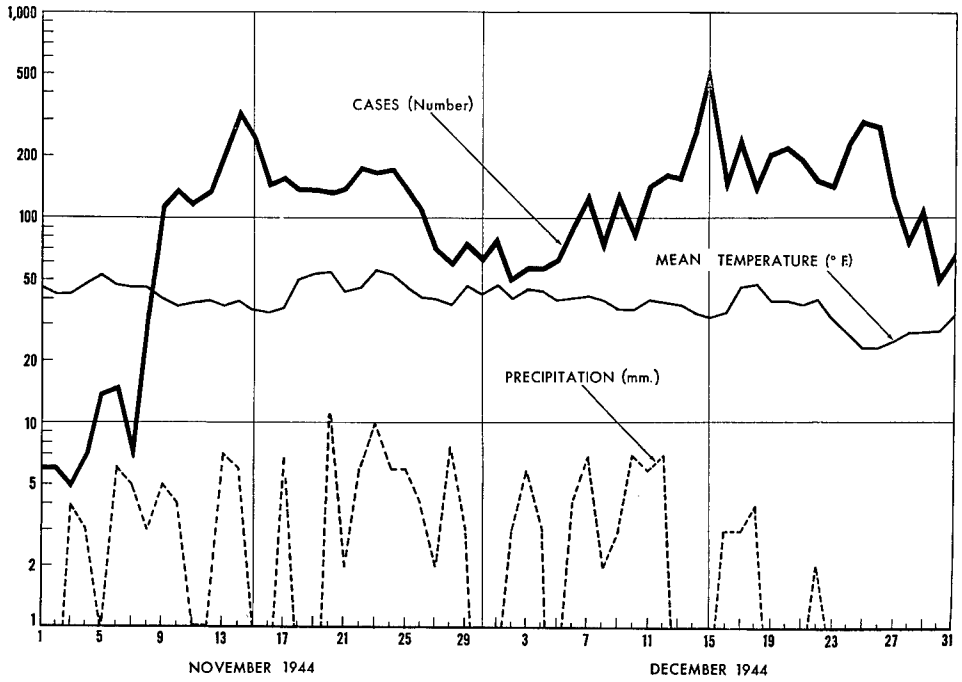
The biologic environment, which is so important in many mass diseases, has little or no relation to cold trauma. Cold, or cold and wet in combination, are the specific cause of cold injury in the same sense that a species of *Streptococcus* is the specific cause of puerperal fever or that *Bacillus typhi* is the specific cause of typhoid fever. The mechanisms through which the agent may act upon the host (man) are widely various. The typhoid baccillus may affect the host through the accidental drinking of contaminated water, the family use of milk containing typhoid bacilli, or the consumption at a church or other large supper of food made dangerous by the typhoid carrier who prepared it. The mechanisms which produce cold injury are much more varied and encompass a greater range of environmental variables. They may extend from a low, muddy terrain, coupled with severe combat, at one extreme, to lack of individual leadership during a simple static defense on the other.

Physical Environmental Factors

Weather.—Climate may be defined as the average weather of a given place or region. Weather is interpreted to mean the interaction of meteorologic components, including temperature, moisture, precipitation, wind, and similar factors, at a given time. Each of the more important of these factors must be analyzed separately if the total influence of weather as an environmental factor in the production of cold injury is to be fully understood.

Temperature.—Cold has been incriminated as the primary causative agent of cold injury, and basically this is a fact, but temperature, as it fluctuates by time periods and as it is associated with other modifying factors, chiefly determines the incidence and severity of this type of injury. This has been true in all recorded wars. It was true in the Mediterranean theater in World War II. It was equally true in the European theater (charts 11, 12, 13, and 14, and tables 21 and 22).

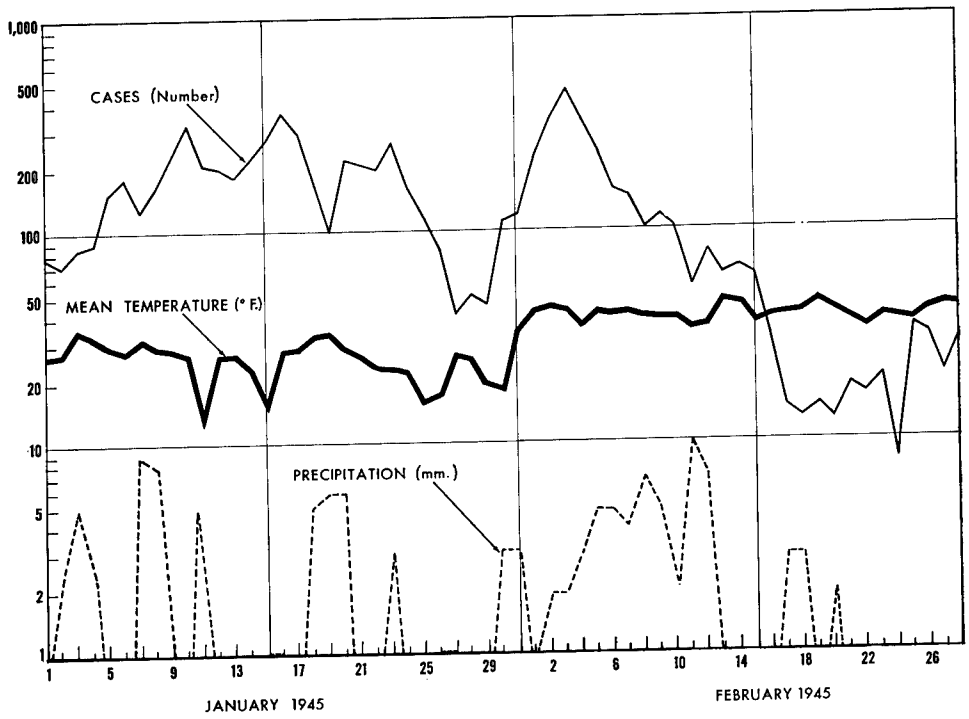
CHART 11.—*Cold injury cases, mean temperature, and precipitation, First U. S. Army, European theater, November and December 1944*



From 1 November through 20 December 1944, the mean daily temperature on the Western Front was about 40° F. (4.4° C.). Only infrequently during this period did minimal temperatures fall below freezing. Then, just before Christmas, a cold wave covered the whole area of the front, and daily mean temperatures were below or only slightly above freezing until the end of January.

It is not always possible to demonstrate that temperature per se has directly influenced the incidence of trenchfoot. Examination of the records of several divisions shows periods of high incidence of trenchfoot at times during the winter of 1944–45 when the mean daily temperature was relatively constant in the range from a little below to a little above 40° F. (4.4° C.). One explanation is that trenchfoot does not manifest itself immediately upon exposure. There is a definite incubation or lag period, of 3 days or more on the average, between the beginning of exposure and the appearance of the injury. As long as the temperature is below 50° F. (10° C.), trenchfoot is likely to occur, its development depending upon the presence or absence of other influencing factors, especially the synergistic factor of wet. To state it more simply, the appearance of trenchfoot depends chiefly upon factors that enhance loss of body heat rather than upon low temperature per se. In fact, as the brief

CHART 12.—*Cold injury cases, mean temperature, and precipitation, First U. S. Army, European theater, January and February 1945*

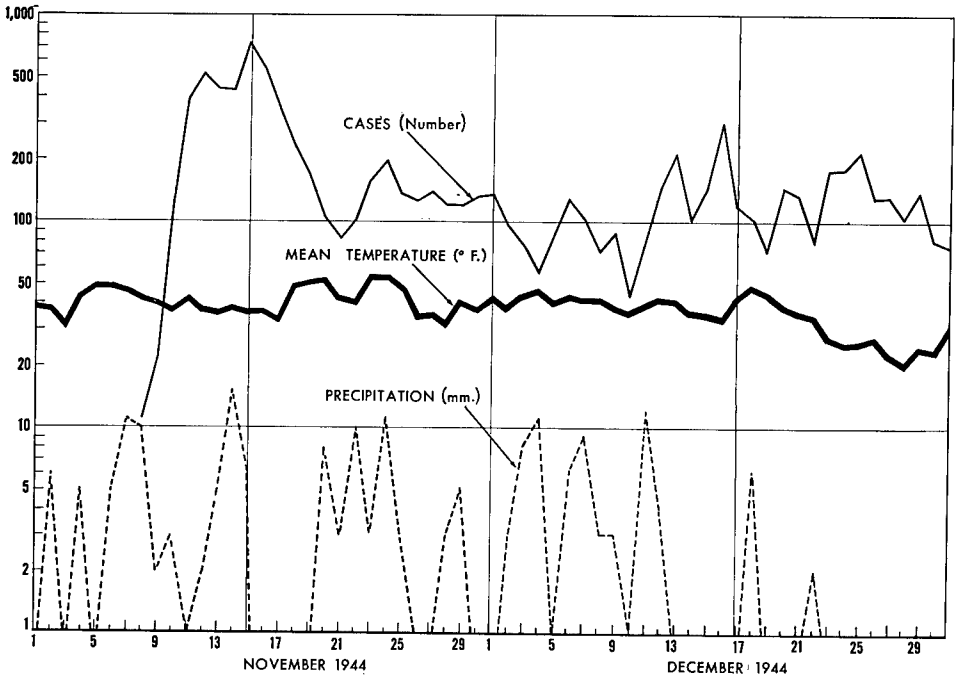


Pacific experience showed (p. 211), a form of cold injury can occur, if modifying factors are favorable, when temperatures are high. On the other hand, frostbite is closely related to temperature. It manifests itself almost immediately when the temperature falls below freezing. The incubation period, although dependent upon the duration of exposure, may be only a few minutes if the temperature is very low, and not more than a few hours if it is just below the freezing point.

The first major outbreak of trenchfoot on the Western Front in World War II reached its peak during the week ending on 17 November 1944 and continued into the first days of December. During this period, in which no frostbite was observed, temperatures varied from just below 40° F. (4.4° C.) to just above 50° F. (10° C.). Precipitation was unseasonably heavy at this time, and violent offensive fighting was in progress. Therefore, except for the fact that the average temperatures were within the accepted trenchfoot range, temperature as an environmental factor does not seem to have had a great deal to do with this epidemic of cold injury.

On the other hand, the epidemic which began the first days of January 1945 and reached its peak during the week ending on 19 January 1945 consisted of a relatively high proportion of frostbite cases. The incidence, which

CHART 13.—*Cold injury cases, mean temperature, and precipitation, Third U. S. Army European theater, November and December 1944*



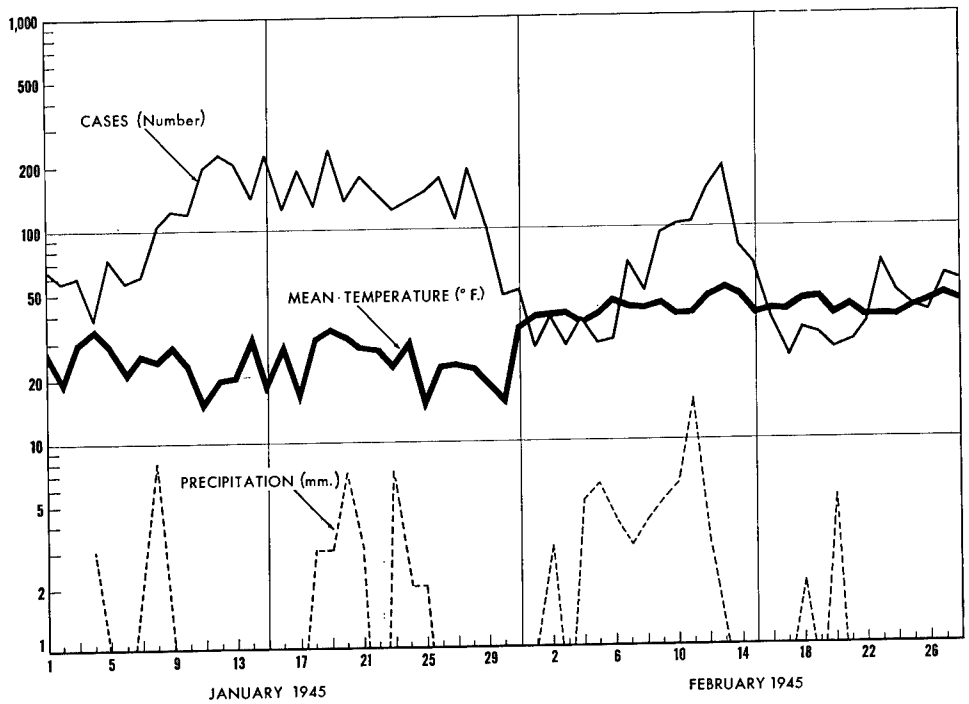
continued high all through January, apparently was directly contingent upon the temperature, which during this entire period was seldom above the freezing point.

Early in February 1945, frostbite practically disappeared. Then a thaw occurred, and the element of wet again became prominent. As a result, the cold injury curve, which had included a relatively large proportion of frostbite cases during the preceding weeks, leveled off from its downswing during the week ending on 9 February 1945, principally as the result of an increase in trenchfoot at this time (chart 15, table 23).

The combat experience of the 30th Infantry Division clearly illustrates the relation between cold and trenchfoot on the one hand and cold and frostbite on the other.

Unit case history No. 4.—Between 1 November and 15 November 1944, the 30th Infantry Division was in a holding action and on active defense near Aachen, in Germany. From 16 November through 12 December, it was engaged in an attack toward the Roer River. On 17 December it moved to Belgium, and from that date until 12 January 1945 it was in defense near Malmédy. The defense was active, with occasional local offensive action in favorable terrain, though little shelter was available. During all this time the cold injury record of the division was good (chart 16, table 24).

CHART 14.—*Cold injury cases, mean temperature, and precipitation, Third U. S. Army, European theater, January and February 1945*



On 13 January 1945, the division was committed to an offensive action in the Malmédy-Saint-Vith area, in deep snow. Exposure to cold was severe because of lack of shelter. For the week ending on 19 January (that is, during the first 6 days of the offensive), the total cold injuries for all three regiments took a sudden and dramatic upswing and reached a peak for the whole winter. By far the largest component of this outbreak was frostbite, as can be determined when the regimental curves for trenchfoot alone during the 2-week period are followed. During the week ending on 26 January, the outbreak became less intense, presumably because exposure was less, and, after 29 January, the curve leveled off as all units within the division were moved to an assembly area, where they were housed in villages.

The increase in the tenor of combat action undoubtedly played a considerable part in the upsurge of cold injuries during the 2-week period just described. Intense combat alone, however, was not responsible. This unit had been in active combat before this time and had suffered no undue increase in cold trauma. During the earlier period of combat, the temperatures had been milder. The principal differentiating factor in the later period was exposure to low temperatures under conditions in which shelter was not available and which did not offer sufficient opportunity to rotate individual soldiers or small units to rest or warming areas.

TABLE 21.—*Mean temperature, precipitation, and cold injury cases in the First U. S. Army, European theater, 1 November 1944 through 28 February 1945*

Day of month	November 1944			December 1944			January 1945			February 1945		
	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases
	° F.	Mm.	Number	° F.	Mm.	Number	° F.	Mm.	Number	° F.	Mm.	Number
1	45.5	1.0	6	47.5	0	79	27.5	0	79	44.0	0.5	238
2	41.5	0	6	41.0	3.0	51	28.5	2.5	72	46.0	2.0	347
3	41.5	4.0	5	45.0	6.0	57	36.0	5.0	87	45.0	2.0	484
4	47.5	3.0	7	44.0	3.0	57	34.0	2.5	92	38.0	3.0	343
5	51.5	1.0	14	40.0	.5	62	31.5	0	158	44.5	5.0	250
6	47.0	6.0	15	41.0	4.0	93	29.0	0	188	44.0	5.0	165
7	46.5	5.0	7	42.5	7.0	127	32.5	9.0	132	44.5	4.0	154
8	46.5	3.0	34	40.0	2.0	77	30.0	8.0	168	42.5	7.0	101
9	42.5	5.0	110	36.0	3.0	129	29.0	1.0	241	42.0	5.0	125
10	37.5	4.0	135	36.0	7.0	87	27.5	0	333	42.0	2.0	103
11	38.0	1.0	118	40.0	6.0	144	14.0	5.0	216	37.5	10.0	59
12	39.0	1.0	132	39.0	7.0	161	27.5	0	209	38.5	7.0	81
13	37.0	7.0	203	38.0	0	158	28.0	0	190	51.5	1.0	67
14	39.0	6.0	324	35.0	0	265	24.0	0	228	49.5	0	72
15	35.5	1.0	247	33.5	0	507	16.5	1.0	282	39.5	0	66
16	34.5	0	146	35.0	3.0	146	29.5	1.0	377	42.0	0	34
17	36.0	7.0	154	47.0	3.0	240	30.0	0	309	43.5	3.0	16
18	50.0	.5	138	48.0	4.0	146	34.5	5.0	175	44.0	3.0	11
19	53.0	.5	137	40.0	0	212	35.5	6.0	103	49.5	0	16
20	54.5	11.0	133	40.0	0	225	30.0	6.0	228	45.0	2.0	14
21	44.5	2.0	138	38.5	0	199	27.5	0	214	41.5	0	20
22	46.0	6.0	171	41.0	2.0	154	24.5	0	208	37.0	0	18
23	55.0	10.0	164	33.5	0	146	24.0	3.0	272	42.0	0	22
24	53.0	6.0	171	25.5	0	232	23.0	0	163	41.0	0	9
25	46.0	6.0	139	24.0	0	300	16.5	0	121	40.0	0	38
26	41.0	4.5	108	24.0	0	285	18.0	1.0	85	44.5	2.0	35
27	40.0	2.0	71	26.0	0	133	27.5	1.0	43	47.5	0	23
28	38.0	8.0	61	28.5	0	80	27.0	.5	53	46.0	0	34
29	46.5	3.0	76	29.5	0	113	20.0	0	48	----	----	----
30	43.0	0	64	29.0	1.0	51	19.0	3.0	118	----	----	----
31	----	----	----	34.0	0	66	36.0	3.0	126	----	----	----
Total	----	----	3,234	----	----	4,782	----	----	5,318	----	----	2,945

It has been pointed out already that cold injury has been known to occur at temperatures as high as 60° to 70° F. (15.6° to 21.1° C.) when there is long and constant exposure to wetness (p. 211). At the other extreme are frostbite, which occurs with relatively short periods of exposure at freezing temperatures and just below, and sudden freezing of the tissues, which occurs with exposure to even lower temperatures. These facts suggest that cold injury must be acquired with progressively less exposure at progressively lower temperatures. To demonstrate this principle, carefully controlled experiments would be necessary within the range of temperatures in which military operations have been carried out in winter. Experiments of this kind have not yet been conducted.

That low temperature is an extremely important factor in cold injury is borne out by the fact that in all divisions, young and old, experienced and

TABLE 22.—*Mean temperature, precipitation, and cold injury cases in the Third U. S. Army, European theater, 1 November 1944 through 28 February 1945*

Day of month	November 1944			December 1944			January 1945			February 1945		
	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases
	° *F.*	*Mm.*	*Number*	° *F.*	*Mm.*	*Number*	° *F.*	*Mm.*	*Number*	° *F.*	*Mm.*	*Number*
1	38.0	0	-------	42.0	0	135	26.5	0	65	37.5	1.0	27
2	37.0	6.0	-------	37.0	3.0	95	19.0	0	57	38.5	3.0	37
3	31.0	0	-------	42.5	8.0	76	29.0	0	58	38.5	.5	27
4	44.0	5.0	-------	45.0	11.0	56	33.5	3.0	37	35.5	5.0	36
5	48.0	0	-------	40.0	1.0	83	28.5	1.0	73	38.0	6.0	28
6	48.0	5.0	-------	42.5	6.0	127	21.0	0	57	44.5	4.0	29
7	46.0	11.0	-------	41.5	9.0	101	25.5	2.0	60	41.5	3.0	67
8	42.5	10.0	11	41.0	3.0	71	24.0	8.0	102	41.0	4.0	49
9	40.5	2.0	21	37.0	3.0	87	28.0	1.0	143	43.0	5.0	91
10	37.0	3.0	129	35.5	1.5	43	23.0	0	128	38.0	6.0	99
11	41.5	1.0	387	38.5	12.0	79	15.0	0	192	38.5	15.0	102
12	36.5	2.0	501	41.5	4.0	146	19.5	0	242	46.0	3.0	147
13	35.5	5.0	432	40.0	0	201	20.0	0	205	50.5	1.0	189
14	37.5	15.0	424	35.5	0	103	30.0	0	150	47.5	0	77
15	36.0	6.0	719	34.0	0	142	18.0	0	217	38.0	0	64
16	36.5	0	543	33.0	.5	292	27.5	0	121	39.5	0	37
17	33.5	0	350	41.5	0	117	16.5	0	187	39.5	0	24
18	48.0	0	228	47.5	6.0	100	30.0	3.0	128	44.0	2.0	32
19	50.0	0	163	44.0	0	71	36.0	3.0	234	45.0	0	30
20	52.0	8.0	102	38.5	0	143	30.5	7.0	133	37.5	5.0	26
21	42.0	3.0	82	36.0	0	133	27.0	3.0	172	41.5	0	28
22	40.0	10.0	103	34.5	2.0	77	26.5	0	145	36.5	0	34
23	53.0	3.0	157	26.5	0	176	22.5	7.5	120	36.5	1.0	65
24	53.0	11.0	192	25.0	0	177	28.5	2.0	133	36.5	0	47
25	46.5	3.0	135	25.0	0	212	15.0	2.0	144	40.0	1.0	40
26	34.0	1.0	125	26.5	0	127	24.0	0	169	42.0	1.0	38
27	35.0	0	138	22.5	0	129	24.5	0	119	45.5	0	56
28	31.0	3.0	120	20.0	0	102	23.5	0	185	43.0	0	53
29	40.0	5.0	119	24.0	0	137	18.5	0	102	-------	-------	-------
30	37.0	0	131	23.0	0	79	15.0	0	47	-------	-------	-------
31	-------	-------	-------	29.0	0	75	33.0	0	50	-------	-------	-------
Total	-------	-------	5,312	-------	-------	3,692	-------	-------	3,975	-------	-------	1,579

inexperienced, and with good control policies and procedures as well as less satisfactory ones, the cold injury incidence rose on the Western Front during the periods of extreme cold between the last week of December 1944 and the first day of February 1945. Modifying factors generally balance out and leave low temperature as the dominant explanation for what happened.

Precipitation.—Wetness, which has its source in precipitation, is a part of the agent complex in cold injury. When it is associated with cold, wetness greatly increases the incidence of cold injury. Precipitation is an environmental factor; that is, it is a component of many of the mechanisms which result in cold injury. The environmental role of terrain is extremely important from the standpoint of precipitation. It may be of such a nature as to cause a rapid runoff of precipitation, which is then less conducive to cold injury. If drainage is poor, on the other hand, the water table is high, mud or flooding results, and precipitation is then more conducive to cold injury.

TABLE 23.—*Cold injury admissions and rates for the First, Third, Seventh, Ninth, and Fifteenth U. S. Armies, European theater, for weeks ending 3 November 1944 through 27 April 1945*

[Rate expressed as number per annum per 1,000 average strength]

Week ending—	First U. S. Army		Third U. S. Army		Seventh U. S. Army		Ninth U. S. Army		Fifteenth U. S. Army		Total	
	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate
1944												
November 3	17	3.1	-------	-------	184	51.9	1	0.4	-------	-------	202	12.3
10	322	55.7	161	32.7	286	75.5	45	14.7	-------	-------	814	46.4
17	1,324	184.1	3,356	591.7	585	152.0	98	25.0	-------	-------	5,363	260.0
24	1,052	172.7	1,027	214.8	365	94.9	478	135.7	-------	-------	2,922	160.2
December 1	598	98.5	903	186.3	465	116.8	461	124.6	-------	-------	2,427	130.5
8	524	85.3	609	127.5	262	67.8	313	83.8	-------	-------	1,708	92.2
15	1,451	223.2	801	168.8	521	127.7	141	39.2	-------	-------	2,914	154.0
22	1,322	192.3	933	190.8	434	100.6	40	12.7	-------	-------	2,729	142.0
29	1,289	214.1	1,060	174.6	554	116.1	238	69.3	-------	-------	3,141	154.7
1945												
January 5	605	96.1	444	66.8	556	112.8	77	23.7	-------	-------	1,682	79.6
12	1,487	238.0	924	141.9	815	166.7	64	19.1	94	233.0	3,384	158.2
19	1,664	270.6	1,242	184.6	667	130.9	79	23.5	0	-------	3,652	170.9
26	1,291	213.0	1,016	149.3	974	165.0	32	9.5	0	-------	3,313	149.3
February 2	973	168.8	567	86.1	1,188	192.1	73	19.6	1	3.7	2,802	124.4
9	1,622	299.5	327	53.7	795	126.1	107	22.4	0	-------	2,851	123.9
16	482	88.0	715	119.6	262	42.1	28	5.6	46	136.0	1,533	66.5
23	117	21.5	239	40.9	178	31.3	16	2.9	0	-------	550	24.1
March 2	216	35.6	320	52.4	83	15.3	81	13.7	1	1.4	701	29.0
9	309	50.8	410	66.7	95	17.7	42	7.0	2	1.8	858	34.6
16	168	27.5	293	49.2	102	16.1	8	1.3	0	-------	571	22.0
23	27	4.4	68	10.6	239	36.4	1	.2	0	-------	335	12.4
30	14	2.3	6	1.0	73	11.0	0	-------	2	1.0	95	3.5
April 6	26	4.3	3	.5	23	3.9	0	-------	0	-------	52	1.9
13	35	5.9	3	.5	23	3.9	0	-------	0	-------	61	2.3
20	6	.9	3	.4	24	4.0	0	-------	0	-------	33	1.1
27	12	1.9	9	1.3	14	2.3	0	-------	0	-------	35	1.2
Total	16,953	106.8	15,439	99.8	9,767	72.2	2,423	20.2	146	14.2	44,728	76.1

Baron Larrey was the first to observe the association between precipitation and temperatures above the freezing point in the production of cold injury (p. 31), but the full significance of this factor was not appreciated until the British experience in World War I. In 1915, Smith, Ritchie, and Dawson (p. 241) first demonstrated the role of wet, and thus of precipitation, by animal experiments in which one group of rabbits had dry footing and the other was kept in cages with muddy bottoms. The incidence of cold injury in the second group was significantly higher than in the animals which had been subjected only to cold.

Precipitation sets the stage for cold injury because it forms mud, floods valleys, raises streams, and causes the ground water table to rise to such a point that foxholes and trenches become damp, muddy, or partly filled with

CHART 15.—*Total cold injury incidence rates for the First, Third, Seventh, Ninth, and Fifteenth U. S. Armies, European theater, for weeks ending 3 November 1944 through 27 April 1945*

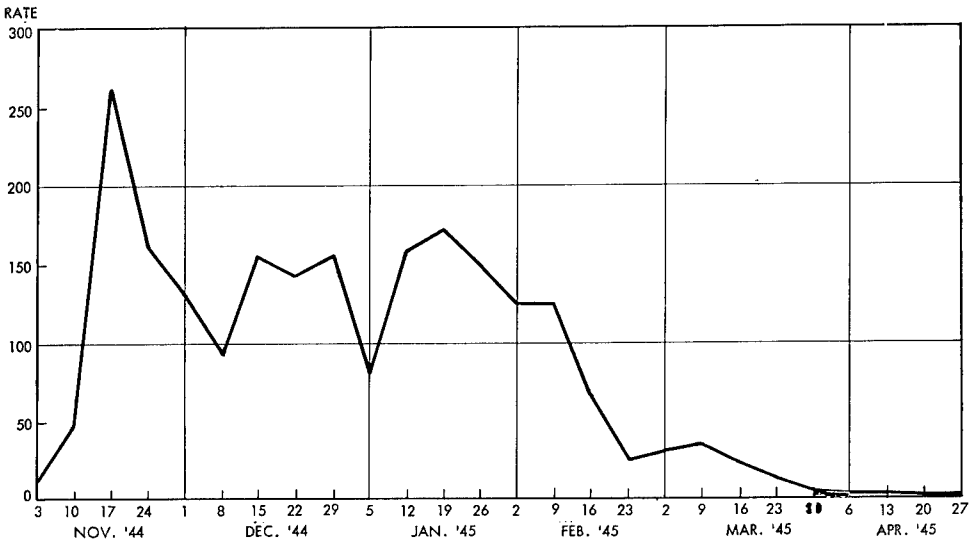


CHART 16.—*Cold injury in 3 regiments of the 30th Infantry Division, European theater, for weeks ending 3 November 1944 through 16 February 1945*

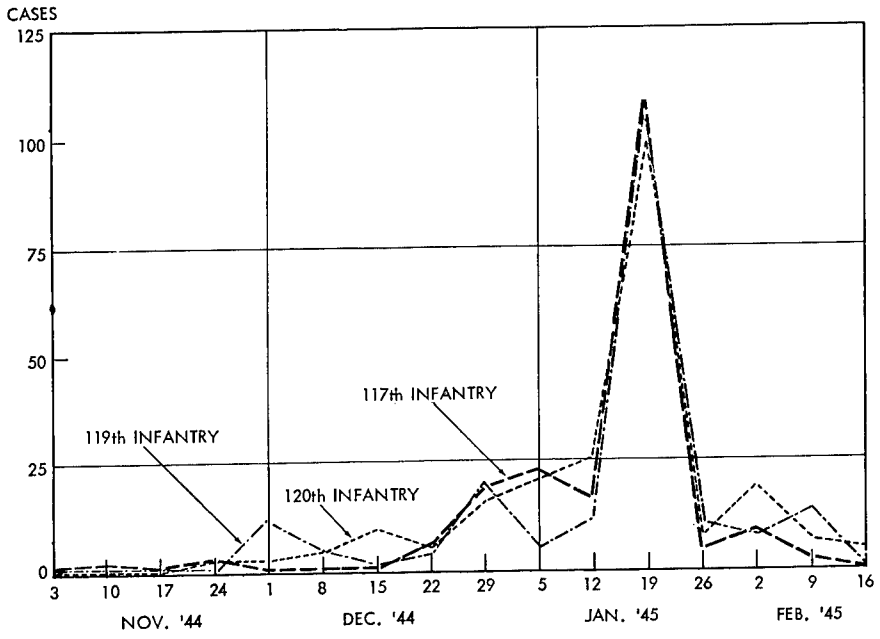


TABLE 24.—*Cold injury in 3 regiments of the 30th Infantry Division, European theater for weeks ending 3 November 1944 through 16 February 1945*

Week ending—	117th Infantry	119th Infantry	120th Infantry	Total
1944				
November 3	0	0	0	0
10	1	0	0	1
17	0	0	0	0
24	3	0	3	6
December 1	1	12	3	16
8	1	5	5	11
15	1	2	10	13
22	6	4	6	16
29	19	20	16	55
1945				
January 5	23	5	21	49
12	17	12	26	55
19	109	105	99	313
26	5	11	8	24
February 2	9	8	19	36
9	3	14	7	24
16	0	1	5	6
Total	198	199	228	625

water. Precipitation in the form of snow or sleet may encourage the development of frostbite, and melting snow acts to produce trenchfoot in the same manner as water from any other source.

In 1944, the unusually heavy precipitation during the autumn and early winter was chiefly responsible for the first epidemic of cold injury (trenchfoot) on the Western Front. This epidemic reached its height in mid-November. Heavier rainfall in that army area was the chief reason why this epidemic assumed greater proportions in the Third U. S. Army than in the First. In the Third U. S. Army, trenchfoot took the form of a sudden, far-reaching point epidemic. In the First U. S. Army, the buildup was slower and the peak was lower. Terrain was also an important consideration in the Third U. S. Army incidence; its predominant features were streams, valleys, and low-lying land.

Thawing.—Thawing of snow, sleet, ice, and frozen ground brings about wet and mud. Wet and mud, in combination with the temperatures at which thawing occurs, provide conditions ideal for the development of trenchfoot. Thawing is thus an environmental factor favoring trenchfoot in combination with both temperature and wet. If it occurs during the day, when temperatures are maximal, and is combined with freezing during the night, when they

are minimal, it may give rise to both trenchfoot and frostbite in troops subjected to these environmental conditions.

Data for the Western Front support these observations. A general thaw began on 31 January 1945 and extended along the whole length of the front. The last of the big theaterwide epidemics of cold injury had begun on 5 January (chart 15) and was to continue until 23 February. The epidemic reached its peak during the week ending on 19 January and then began a rather precipitous downswing. With the onset of the thaw which began on 31 January, the curve abruptly leveled off for the week ending on 9 February and did not resume its precipitous downward trend until the following week. During the week ending on 2 February, the predominant cold injury was frostbite. During the week ending on 9 February, trenchfoot was theaterwide, because of the wet and mud produced by the thaw which began on 31 January.

The experience of the 9th Infantry Division during this period was typical.

Unit case history No. 5.—This division after previous operations in Africa and Sicily had been in combat action continuously on the Continent from 4 days after the initial Allied landings in Normandy. It was thus a battle-tried division, of great experience, with a good record for both combat and cold injury. At no time before the last few days of January 1945 (chart 17, table 25) had cold injury been a very important cause of loss of personnel, although the division had seen heavy combat under conditions favoring trenchfoot and had had only short alternating periods of defense or reserve.

CHART 17.—*Trenchfoot and frostbite in 3 regiments of the 9th Infantry Division, European theater, for weeks ending 3 November 1944 through 16 March 1945*

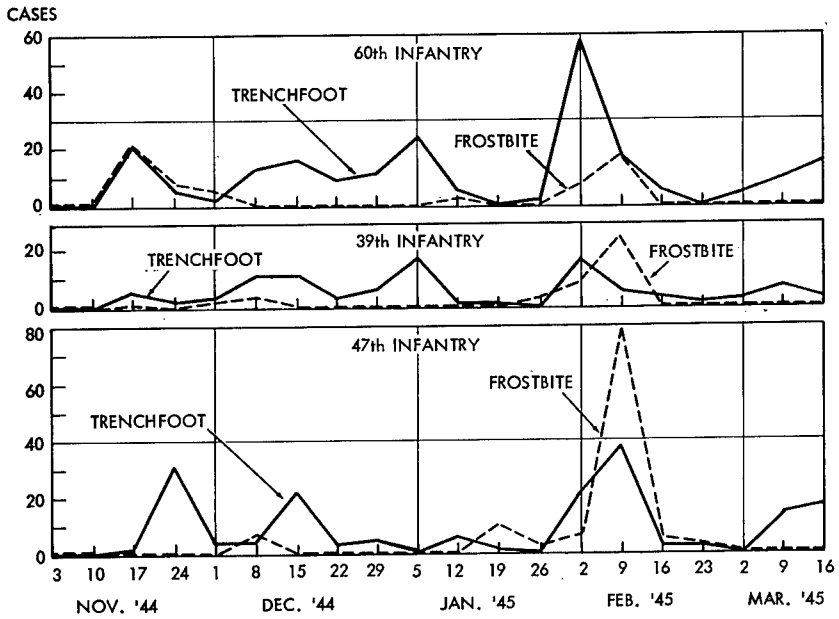


TABLE 25.—*Cold injury in 3 regiments of the 9th Infantry Division, European theater, for weeks ending 3 November 1944 through 16 March 1945*

Week ending—	39th Infantry	47th Infantry	60th Infantry	Total
1944				
November 3	0	0	0	0
10	0	0	0	0
17	7	2	44	53
24	2	35	14	51
December 1	5	3	6	14
8	16	8	14	38
15	12	23	17	52
22	4	4	9	17
29	7	6	11	24
1945				
January 5	19	1	25	45
12	1	8	5	14
19	2	11	0	13
26	2	3	1	6
February 2	27	27	64	118
9	31	122	38	191
16	5	6	4	15
23	2	2	0	4
March 2	4	1	4	9
9	8	17	9	34
16	4	16	14	34
Total	158	295	279	732

In the period immediately preceding the 31 January thaw, operations were in the Monschau area. This is high, rolling, and forested country. The weather was moderately cold to cold. The ground was frozen and was covered by 12 to 18 inches of snow. The action was static defense. On 29 January, the division jumped off in an attack in deep snow. The weather was still cold, but there was alternating freezing by night and thawing by day. On the first day of the attack, the snow was dry, and frostbite was the predominant cold injury. By 6 February, the thaw had become general. By 10 February, the snow had, for the most part, melted, so that streams were swollen, and fields, forests, and roads were deep in mud. Chart 17 shows the trenchfoot and frostbite experience of the three regiments of the 9th Infantry Division and demonstrates the effect of alternate freezing and thawing in the production of both forms of cold injury, as well as the high incidence of trenchfoot during a period when precipitation was absent or light.

The ratio of trenchfoot to frostbite in the 60th Infantry Regiment was diametrically opposite to that in the 47th (chart 17). The 60th Infantry was operating in the worst terrain of the Monschau woods during the week ending

2 February; alternate thawing and freezing had exposed this regiment to considerable wet in comparison with the other two regiments in the division, a fact which partly explains the higher trenchfoot incidence in the 60th. In addition, this regiment made three successive marches in low terrain in which exposure was great and during which there was limited time for the individual care of the feet. The 47th Infantry, on the other hand, made a long march in the snow in higher terrain, immediately following which it was thrown into repeated attacks before the objective could be reached. Men were fatigued and had little opportunity to care for their feet. Again, alternate thawing and freezing is the explanation, with trenchfoot by day and frostbite by night in tired soldiers who, because of the tactical situation, were unduly exposed to cold at night and were unable to obtain rest. Immediately after this experience, the division went on to the Roer River, which was crossed about 1 March. The Erft Canal was crossed shortly afterward. As a result, wet feet produced another rise in the trenchfoot incidence.

Thus, thawing, by introducing the element of wetness, is an important environmental factor in the production of cold injury. At the same time, conditions are ideal for frostbite if soldiers who are subjected to thawing during the day must operate by night or are exposed by night to minimal, below-freezing temperatures, without adequate shelter.

Wind.—Though it is an established fact that exposure to wind hastens loss of body heat, efforts to measure the degree to which the loss is brought about by winds of various velocities have been chiefly carried out in extreme temperatures in the Arctics. Siple (cited by Court [30]), in 1939, was the first to use the excellent descriptive term "wind chill" to imply the combined cooling effect of moving air and low temperature. On the basis of observations made in the Antarctic in 1940, he developed a formula to describe wind chill and its fluctuations according to temperature and wind velocity. From this formula, the meteorologists in the Quartermaster Corps developed a table of wind-chill values, as well as graphic charts which depicted the relative comfort range for various combinations of wind speed and temperature.

Wind-chill maps were also developed for North America and certain other areas, but they were in expectation of military operations in the Arctics and were not of specific practical value for winter tactics in temperate climates because they took no account of the element of wetness in combination with moderate temperatures. They are mentioned in this chapter only because they demonstrate that it is practical to measure wind chilling.

Measurements of wind chill were not made either in the Mediterranean or European theater in World War II. Even if they had been made, they would have been of no practical value unless they had been based upon carefully controlled observations involving correlation between wind, temperature, and wetness.

Although wind was undoubtedly a factor in the production of both trenchfoot and frostbite on the Western Front in the winter of 1944–45, it is not

[30] Court, A.: Wind Chill. Bull. Am. Meteorol. Soc. 29:487–493, December 1948.

feasible to study its effect by the comparative experiences of units of any size. Apparently, it was progressively more important as temperatures became progressively lower. This is another aspect of cold injury in which lack of data and of observations during actual combat indicates the need for further study and research for the benefit of both medical officers and commanders.

Without these data, it is obviously impossible to discuss the effect of wind as an environmental factor except in general terms. Loss of body heat through wind chill, which is a heat exchange through convection, is only one of the ways in which the body loses heat. The degree of convective heat loss is always governed by the amount and type of clothing worn. Under no circumstances, according to Court, can convective heat loss account for more than 80 percent of the total body-heat dissipation.

To reduce the facts to the simplest possible terms, the body generates heat, while clothing holds warm air in and keeps cold air out. Air in itself is an excellent insulator, and clothing is most effective in holding warm air in (1) when it fits loosely enough to allow for a layer of air next to the skin, (2) when the inner layers of the cloth of which it is composed are woven loosely enough to allow air pockets between the fibers, and (3) when the garments are worn in layers, so that there are air pockets and air layers between the layers of clothing. Still air is an insulator, and in it warmth is approximately equivalent to insulation. All movement, even winds of 5 miles per hour or less, reduces the effectiveness of the insulating properties of still warm air. The more porous the insulating clothing, the easier it is for the wind to penetrate and destroy the insulating properties of trapped and layered air. Wind accelerates the dissipation of body heat when the insulating properties of clothing are modified by sweating, evaporation, and the conduction of heat through it when it is wet.

Wind chill, as Court pointed out, is only one of a number of problems which must be studied in physiologic laboratories before the loss of body heat by all means can be accurately computed. Among them are (1) the relation of breathing rates to the activity level, (2) the temperature and moist content of exhaled air, (3) the insensible perspiration rate at low temperatures, and (4) the surface temperature and radiative efficiency of the completely clad body. Court further pointed out that even when these problems are clarified, certain other considerations are likely to make measurements of wind chill and similar factors subordinate to subjective feelings of comfort or discomfort in the individual. These considerations include host differences in individuals, such as race, sex, age, body build, acclimatization, physical fitness, nutritional adequacy, sufficiency of clothing, and, in particular, mental attitudes.

Terrain.—Terrain is an environmental factor which not only has a direct bearing on the incidence of trenchfoot but which also determines whether injuries caused by cold shall be predominantly trenchfoot, predominantly frostbite, or a combination of both. The weight of terrain as a modifying factor in cold injury has already been discussed in some detail in the section

on multiple correlation studies of 21 divisions (p. 373). It is also discussed briefly in connection with altitude, precipitation, and thawing.

Generally speaking, exposure in open, hilly, or mountainous terrain, usually covered by snow that does not melt in cold weather, is likely to produce frostbite. Trenchfoot is the more probable cold injury when temperatures are high enough to cause thawing, and when slush, mud, and water are underfoot. More often than not, combat activities are carried out in valleys, along streams, and in flat terrain subject to flooding and characterized by highwater tables. In flat terrain, the water table is often high, and it is also impossible to dig foxholes deep enough to avoid eventual flooding. In valleys and in low, flat terrain, troops in attack must cross muddy or flooded fields and swamps. During these crossings, they get wet, regardless of the clothing or type of footgear with which they are supplied.

River crossings are among the most difficult military operations. They involve service support personnel, especially Engineer and Signal Corps personnel, as well as combat personnel, who usually bear the brunt of cold injury. Under these circumstances, it is virtually impossible to avoid wet feet and wet clothing over the lower extremities. If the temperature is within the trenchfoot range and if exposure is sufficiently long, the cold injury incidence will almost inevitably be high, and soldiers other than infantrymen will share the infantryman's liability to cold injury.

Terrain may modify the incidence of cold injury in other ways. It may be of such a character as to offer shelter from the enemy and provide opportunities for adequate care of the feet. Conversely, it may provide concealment for the enemy and give him command of open country, with deadly crossfire and unlimited observation. Then, defending troops would be forced to remain in cramped positions in foxholes, with little opportunity for movement or for the employment of preventive measures against cold injury.

The experiences of a number of units on the Western Front during World War II show the importance of terrain as a modifying factor in cold injury.

Unit case history No. 6.—The 104th Infantry Division arrived in France early in September 1944. Its first combat experience was gained with the First Canadian Army, in active offense on the Maas River. The fighting was in agricultural country, which was low and flat and was traversed by many ditches and small canals. Foxholes promptly filled with water from a water table only 6 or 8 inches below the surface. After a week in these surroundings, the division was moved to a sector between Aachen and Eschweiler, where the terrain was rolling, fairly high, forested, and well drained. Combat action was sporadic offense, and there was some opportunity for shelter. The first peak of cold injury (chart 18, table 26) could be almost entirely explained as the result of operations of a new division, in terrain highly favorable to trenchfoot. The second peak, early in December, was the result of a different factor, namely, combat action, which took place in terrain not in itself conducive to trenchfoot.

CHART 18.—*Cold injury in 3 regiments of the 104th Infantry Division, European theater, for weeks ending 3 November 1944 through 5 January 1945*

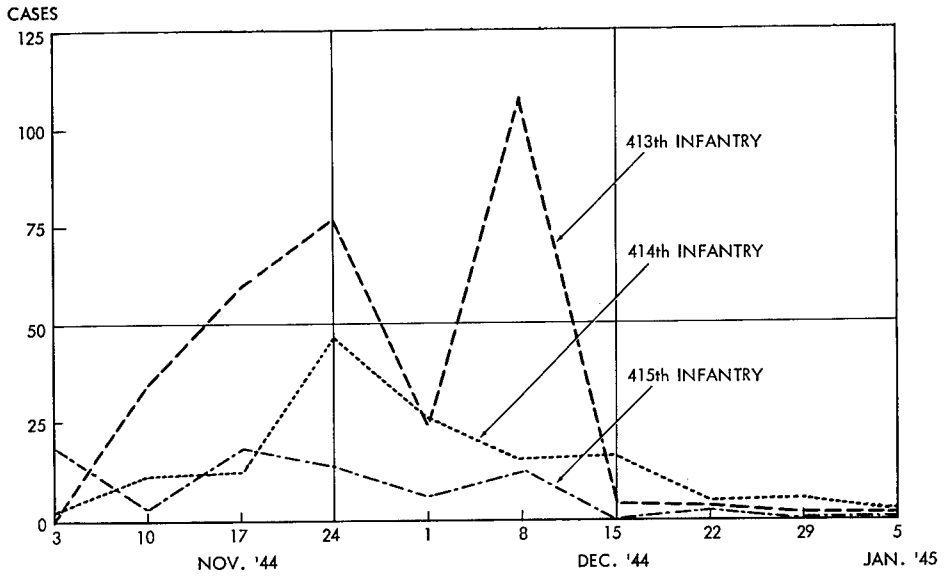


TABLE 26.—*Cold injury in 3 regiments of the 104th Infantry Division, European theater, for weeks ending 3 November 1944 through 5 January 1945*

Week ending—	413th Infantry	414th Infantry	415th Infantry	Total
1944				
November 3	0	2	19	21
10	35	11	3	49
17	59	12	18	89
24	77	46	14	137
December 1	24	26	6	56
8	108	15	12	135
15	4	16	0	20
22	3	4	2	9
29	1	5	0	6
1945				
January 5	1	1	0	2
Total	312	138	74	524

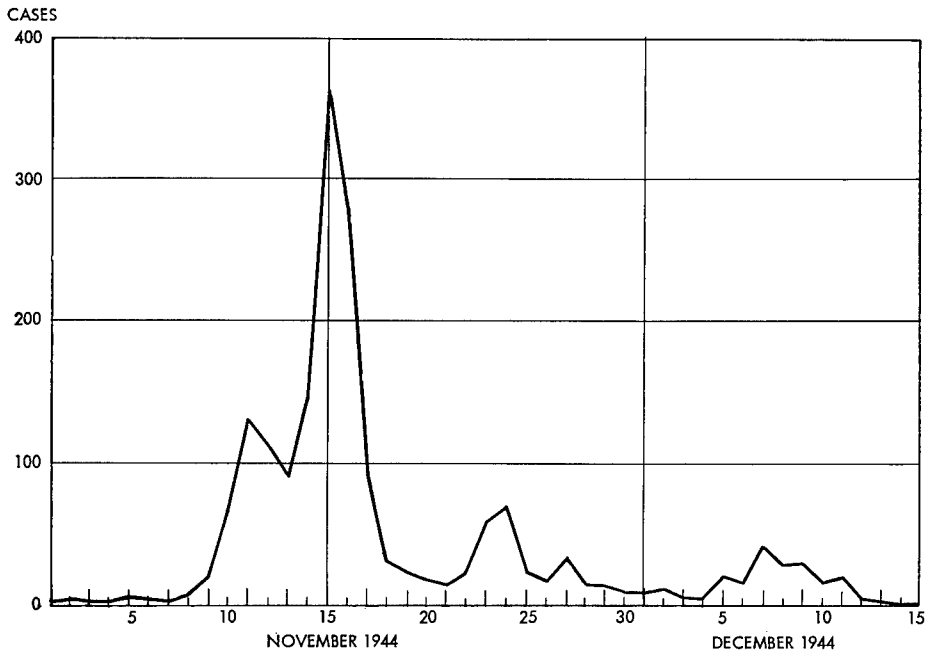
The strikingly higher incidence of cold injury in one regiment, the 413th Infantry Regiment, is also easily explained. It operated in worse terrain than either the 414th or 415th Infantry Regiments, and at the same time encountered strong opposition, while the other two regiments were less strongly opposed.

Unit case history No. 7.—The 26th Infantry Division, assigned to the Third U. S. Army, began combat operations in the November offensive in the area east of Nancy, where the terrain was low and marshy and rain fell daily. In a forced crossing of the Seille River, two companies of the 101st Infantry Regiment had to wade across in water more than waist deep. Within a day or two, cases of trenchfoot were being reported from all three companies. In the beginning, these companies had the highest trenchfoot rates of any units within the division.

When the 338th Infantry Regiment from the same division was put into action, in a right flanking position, in open, flat, wet, muddy terrain, it was pinned down, within a short time, by enemy fire from Dieuze. It was 5 days before its relief was accomplished, and there was a large outbreak of trenchfoot as the result of the experience. The number of cases was greatly reduced as the division progressed to the upper Saar Valley, where combat action was chiefly in the towns; but a second, though much smaller, peak occurred in late November, when the troops had to fight through the open, muddy area of the Maginot Line (chart 19). Incidence of cold injury in the division is shown in the following tabulation:

	Cases		*Cases*
November 1944:		November 1944—Continued	
1	2	24	71
2	3	25	24
3	2	26	18
4	2	27	34
5	5	28	15
6	4	29	14
7	3	30	9
8	8	December 1944:	
9	19	1	9
10	67	2	12
11	130	3	5
12	115	4	3
13	90	5	22
14	144	6	16
15	361	7	43
16	279	8	29
17	91	9	30
18	32	10	16
19	25	11	21
20	17	12	5
21	14	13	2
22	22	14	0
23	59	15	0

CHART 19.—*Cold injury, 26th Infantry Division, European theater, 1 November through 15 December 1944*



Unit case history No. 8.—The 29th Infantry Division, which landed in France on D-day, had become a well-trained, well-led, experienced, and battle-wise division by the time it had fought across France and into Belgium. In the 2-week period 18 November through 1 December 1944, it was in an active offense toward the Roer River, in open, flat country, with poor drainage. The weather was only moderately cold, but there was much rain, and mud was deep. The 116th Infantry Regiment, which operated over open ground, often in water over the tops of the men's overshoes, had 72 cases of trenchfoot during this period (chart 20, table 27). The terrain over which the 175th and 115th Infantry Regiments fought was higher and drier and offered more protection. The numbers of cases in these regiments were 26 and 6, respectively.

Unit case history No. 9.—The 78th Infantry Division did not arrive on the Continent until 22 November 1944. It was therefore without combat experience when, during the week ending on 15 December, it moved into the frontlines near Rötgen, Germany, and was immediately thrown into active offensive action. The terrain was hilly and partly forested, with many streams in the valley and much deep mud. Much of the time, the men were in exposed foxholes. When the 309th Infantry Regiment advanced, it was obliged to make several waist-deep stream crossings. When the 310th Infantry Regiment advanced, similar crossings were not necessary. The 311th Infantry Regiment was kept in reserve for most of the period. The 309th Infantry Regiment had 304 cases

CHART 20.—*Cold injury in 3 regiments of the 29th Infantry Division, European theater, for weeks ending 17 November through 29 December 1944*

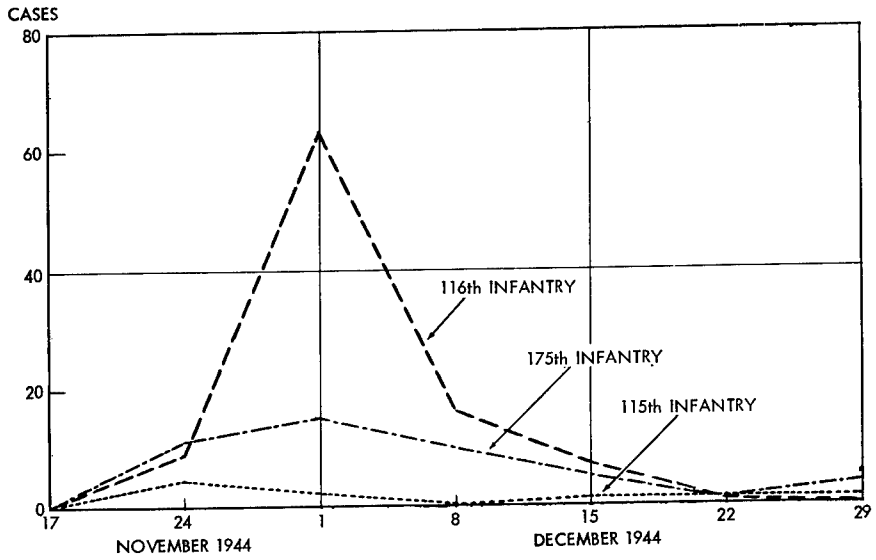


TABLE 27.—*Cold injury in 3 regiments of the 29th Infantry Division, European theater, for weeks ending 17 November through 29 December 1944*

Week ending—	115th Infantry	116th Infantry	175th Infantry	Total
1944				
November 17	0	0	0	0
24	4	9	11	24
December 1	2	63	15	80
8	0	16	10	26
15	1	7	5	13
22	1	1	1	3
29	1	0	4	5
Total	9	96	46	151

of trenchfoot (chart 21, table 28), the 310th had 197, and the 311th had 18 during the period 9 December through 22 December.

The experience of the 9th Infantry Division (unit case history No. 5, p.414) with respect to the influence of thawing has already been related. Its unit history also furnishes an excellent example of the modifying influence of terrain. Between 7 December and 17 December, a company of this division advanced to occupy trenches from which the Germans had been driven. The trenches were located in an open field and were filled with about 18 inches of water. Because of the intensity of enemy fire, the unit was pinned down in them for about 4 days. Twenty-nine of the one hundred and twenty men in the company con-

CHART 21.—*Cold injury in 3 regiments of the 78th Infantry Division, European theater, for weeks ending 1 December 1944 through 26 January 1945*

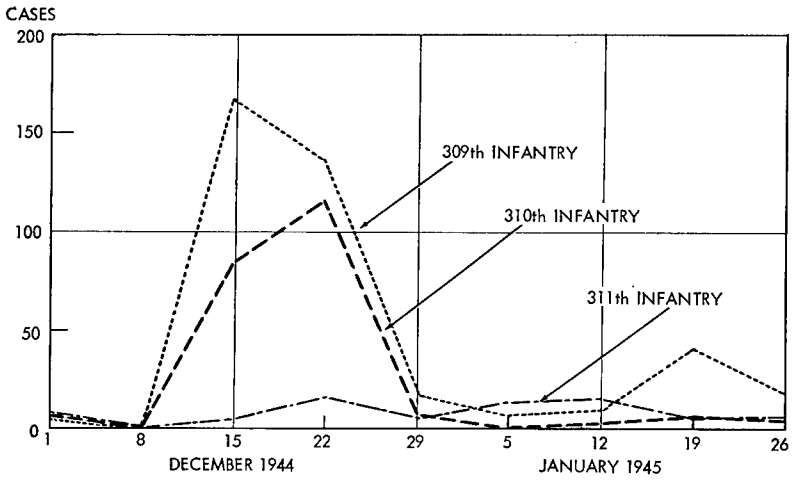


TABLE 28.—*Cold injury in 3 regiments of the 78th Infantry Division, European theater, for weeks ending 1 December 1944 through 26 January 1945.*

Week ending—	309th Infantry	310th Infantry	311th Infantry	Total
1944				
December 1	6	6	7	19
8	0	0	0	0
15	169	83	3	255
22	135	114	15	264
29	17	6	5	28
1945				
January 5	6	0	13	19
12	8	1	15	24
19	40	5	4	49
26	17	2	3	22
Total	398	217	65	680

tracted trenchfoot. A unit of similar size which eventually was able to get forward to relieve this unit brought with it straw and boards, to be used like the board tracks laid down in the trenches in World War I. As a result, the men kept themselves relatively dry and did not sustain a single case of trenchfoot.

Altitude.—Altitude enters into the possible occurrence of cold injury for several reasons. It predisposes to the intensity of cold. Because of the cold, it further determines, to some extent, whether precipitation shall be in the form of snow or rain. In general, the type of terrain at higher altitudes is such

as to discourage the formation of mud, marshy areas, large flooded areas, and broad streams. On the other hand, military operations in rough terrain are likely to be carried out in valleys, where the nature of the ground intensifies wetness. Exposure is usually greater when difficult operations are carried out in mountainous terrain. It is unlikely, however, that at altitudes at which ground forces usually fight, physiologic host changes caused by heights would be important enough to influence cold injury to any material degree.

Temperatures likely to induce cold injury are reached earlier in the season in mountainous terrain, and daily fluctuations from low minimums at night to high maximums at midday appear to be greater in the mountains than on level ground. Combinations of frostbite and trenchfoot are prone to appear at the beginning and end of the cold injury season. Altitude thus introduces a number of environmental considerations, though in all of them the basic factor is the intensification of cold at progressively greater heights.

American ground forces experienced combat in mountainous terrain both in Italy and in Western Europe during World War II, but data concerning the effect of altitude on the incidence of cold injury are not readily available.

Socioeconomic Environment

The social environment has a significant influence on the incidence of cold injury. As has been pointed out several times already, this form of trauma is an occupational disease of the infantryman, especially of the frontline rifleman. Infantrymen experience more trenchfoot than support or service troops in the same way, and for many of the same reasons, that outdoor laborers contract pneumonia more often than office workers.

The susceptibility of infantrymen is well proved by examination of the incidence of cold injury in armored divisions. In four armored divisions which saw heavy service on the Western Front in the winter of 1944–45, 72 percent of 1,837 cases of trenchfoot were concentrated in the infantry battalions (table 29). Similarly, 87 percent of the 1,018 patients with trenchfoot interviewed in Zone of Interior hospitals (p. 400) were infantrymen (table 30).

TABLE 29.—*Cold injury cases in armored, artillery, and infantry personnel of armored divisions, European theater, 28 October 1944 through 16 March 1945*

Armored division	Number of cases by component			Total	Occurrence in infantry
	Armored (tank)	Artillery	Infantry		
					Percent
2d	240	------	511	751	68
3d	138	------	241	379	64
5th	41	5	255	301	85
7th	81	4	321	406	79
Total	500	9	1,328	1,837	72

TABLE 30.—*Trenchfoot by arm or service in 1,018 patients hospitalized in Zone of Interior*

Arm or service	Cases	Percent
Infantry	886	87
Field artillery	40	4
Engineers	31	3
Tanks and tank destroyers	31	3
Medical Department	10	1
Others	20	2
Total	1, 018	100

Combat action.—The most important single modifying factor in the causation of cold injury is the type of combat action. It is true that its influence cannot be entirely isolated from the concomitant influence of terrain, shelter, training, and experience. It is also true that combat action is, in turn, modified by leadership, the status of supplies of clothing and food, and the foot discipline of the individual soldier. Nonetheless, the intensity and type of combat determine the stress under which fighting men operate, with the result that fatigue, nutritional status, and psychosocial factors are also materially influenced by these considerations. These interrelated and interwoven considerations can best be summed up in the statement that combat action largely determines the degree of exposure and partly determines the susceptibility of the host and the opportunity which the individual soldier and his unit will have to carry out protective measures against cold injury.

The incidence of cold injury varies according to the mission of the troops. Units in reserve or in rest areas have little. Units in the line on holding missions, or operating in static defense of various degrees, are subjected to greater exposure, and there is likely to be a moderate increase in the incidence of cold injury. Difficult defensive operations, which require irregular attacks to strengthen lines and maintain positions, are associated with almost the same high peaks of incidence that occur during trying offensive operations. Under some circumstances, in fact, this type of operation may be responsible for even larger numbers of cases.

A study initiated by the Preventive Medicine Division, Office of the Chief Surgeon, ETOUSA, bore out these facts. When divisions were in reserve in rest areas, or were on the move, without combat duties, trenchfoot averaged 2.4 cases per day. When they were in static defense or engaged in holding operations, the daily average rose to 3.5 cases per day. When they were on active defense, repelling enemy attacks, the average rose to 14 cases per day.

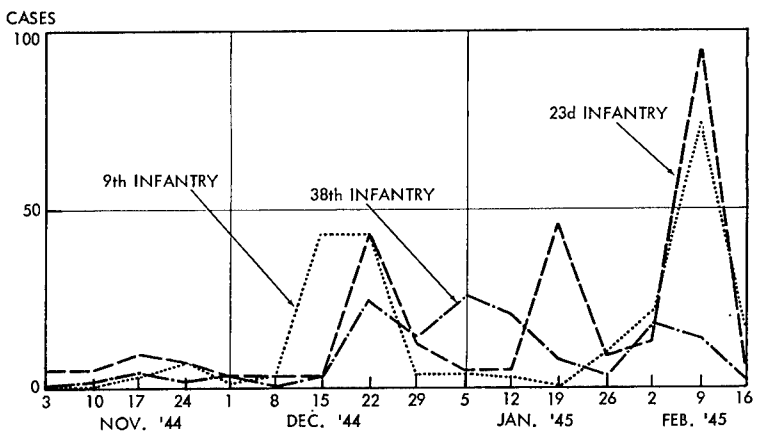
Several of the unit case histories already related, particularly those recorded to demonstrate the influence of terrain, show equally well the part played by the type of combat action in the causation of cold injury. The specific situations summarized in the following histories also illustrate this point.

Unit case history No. 10.—The story of the 95th Infantry Division has already been told in part (p. 402), to illustrate the effect of training and experience. By November 1944, it had experienced a great deal of combat and was a tried, reliable, and effective organization, with good discipline. Its total record of cold injury for the whole winter was among the best for any combat division, but a review of the records shows that even this staunch and battlewise unit had peaks of cold injury incidence when the going was hard (table 20, chart 10).

This division operated in the Moselle Valley in the envelopment of the Metz fortresses. Crossings of the Moselle River were required, and the whole operation was difficult, especially during the 12-day period before the fall of Metz on 18 November. The peak of the cold injury incidence was reached on 19 November (chart 10), a date which, allowing a suitable timelag for the development of the injury, precisely fits the combat pattern. After Metz fell, the division moved eastward to Saarlautern in a rapid advance, but fighting was easier, and there was a reduction in the number of cases of trenchfoot. As the city was approached, however, fighting again became harder, and the Nied River had to be crossed. This was accomplished on 1 December. The difficult combat situation was again accompanied by a rise in the incidence of trenchfoot.

Unit case history No. 11.—The 2d Infantry Division landed in France on D-day plus 1, and by the middle of October had fought across France and Belgium to Saint-Vith. It remained in this area, in a static defense operation with active patrolling, until the first days of December. During November and the first week of December, the incidence of trenchfoot was negligible (chart 22, table 31). There was an immediate divisionwide increase in the number of cases, however, when the division went into an active attack against pillboxes near Elsenborn during the week ending on 15 December. The German

CHART 22.—*Cold injury in 3 regiments of the 2d Infantry Division, European theater, for weeks ending 3 November 1944 through 16 February 1945*



counterattack on 16 December resulted in active defensive fighting for the following week, accompanied by a still greater increase in the trenchfoot incidence. During the week ending on 29 December, which was the second week after the German counteroffensive, combat action was again defensive, with active patrolling. The number of cases of trenchfoot fell precipitously, and there was no increase during the next several days, when combat took the form of static defense.

The 23d Infantry of the 2d Infantry Division was attached to the 1st Infantry Division on the 15th of January 1945, and was in an active offense until the 22d, a period for which there was a marked increase in the incidence of cold injury for this unit. The remainder of the division was on defense and line holding. The 23d Infantry also had returned during the week ending 26 January. On the 29th of January 1945, the division jumped off in an offense toward the Roer River. During the first few days, the snow was deep and the weather cold, but with the onset of the February thaw the terrain became wet and very muddy. Troops were in foxholes in heavily wooded hills in which there were many villages. Almost immediately after the onset of this operation, there was a drastic rise in the incidence of cold injury which reached a peak of 179 cases for the week ending 9 February 1945. The division assumed

TABLE 31.—*Cold injury in 3 regiments of the 2d Infantry Division, European theater, for weeks ending 3 November 1944 through 16 February 1945*

Week ending—	9th Infantry	23d Infantry	38th Infantry	Total
1944				
November 3	0	4	0	4
10	0	4	1	5
17	2	8	3	13
24	6	6	1	13
December 1	1	2	2	5
8	2	2	0	4
15	42	2	2	46
22	42	42	23	107
29	3	11	13	27
1945				
January 5	3	4	24	31
12	2	4	19	25
19	0	45	7	52
26	9	8	2	19
February 2	20	12	16	48
9	73	94	12	179
16	14	5	1	20
Total	219	253	126	598

a static defense on the west bank of the Roer on 9 February, in which circumstances it remained until 28 February. During the first 2 or 3 days of this action the principal component of cold injury in the division was frostbite. The thaw began about 1 February, and immediately trenchfoot and frostbite were almost equally apparent in the division (table 31). The last case of frostbite occurred on 8 February, but on 9 and 10 February there were 13 and 14 cases of trenchfoot, respectively (table 32).

TABLE 32.—*Daily incidence of trenchfoot and frostbite, 2d Infantry Division, European theater, 29 January through 11 February 1945*

Date	Trenchfoot	Frostbite	Total cold injury
1945			
January 29	0	3	3
30	3	4	7
31	1	2	3
February 1	11	10	21
2	5	5	10
3	22	32	54
4	35	30	65
5	14	15	29
6	2	10	12
7	0	4	4
8	0	5	5
9	13	0	13
10	14	0	14
11	1	0	1
Total	121	120	241

Unit case history No. 12.—The experience of the 5th Infantry Division in the fighting before Metz represents a different element of combat action. This division had been stationed in Ireland for 18 months, and foot discipline and the prevention of cold injury had been an important part of its training. The division landed in France shortly after D-day and, by early November 1944, had fought forward to the Metz area. In the November offensive, it jumped off toward Metz near Pont-à-Mousson, in the flat, rain-drenched Moselle Valley. Enemy resistance was heavy, and almost immediately cold injury began to occur in all three regiments (chart 23, table 33) though, for some inexplicable reason, it was at first disproportionately high in the 10th Infantry Regiment.

Otherwise, the total experience by regiments throughout the difficult fighting preceding the reduction of Metz on 18 November demonstrates the effect on cold injury of movement versus a holding offense in severe combat. The division attack was on a broad, swinging front. The 11th Infantry Regiment maintained a holding and slow moving attack position on the left

CHART 23.—*Cold injury in 3 regiments of the 5th Infantry Division, European theater, 11–24 November 1944*

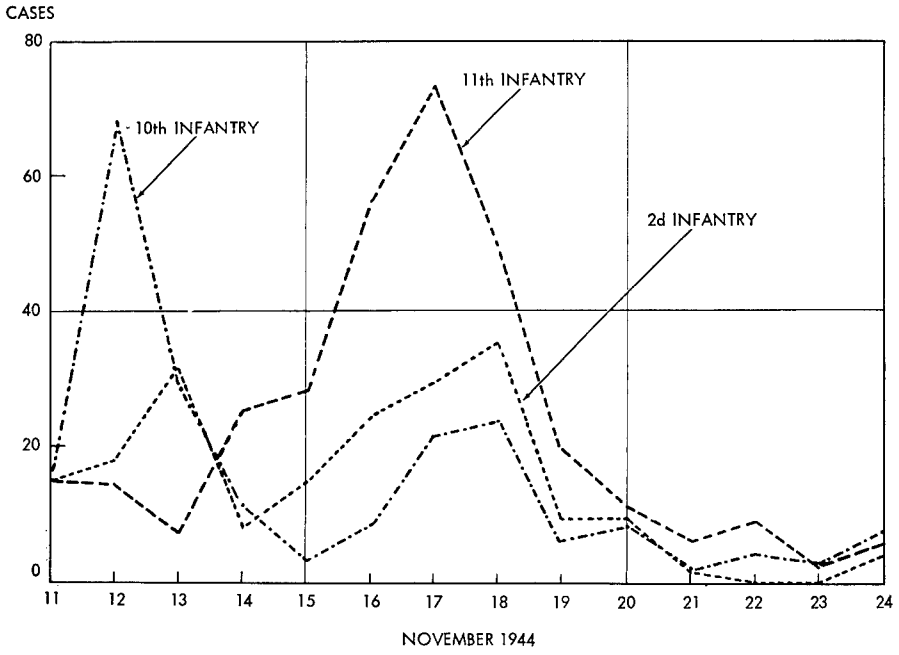


TABLE 33.—*Cold injury in 3 regiments of the 5th Infantry Division, European theater, 11–24 November 1944*

Date	2d Infantry	10th Infantry	11th Infantry	Total
1944				
November 11	15	16	15	46
12	18	68	14	100
13	31	29	7	67
14	8	11	25	44
15	15	3	28	46
16	24	8	56	88
17	29	21	73	123
18	35	23	49	107
19	9	6	20	35
20	9	8	10	27
21	2	2	5	9
22	0	4	8	12
23	0	3	2	5
24	3	7	6	16
Total	198	209	318	725

flank, before Metz. The 2d and 10th Infantry Regiments moved rapidly in an enveloping maneuver in the center and on the right flank. Except for movement, all elements of the combat situation were essentially the same. Yet between 11 November and 21 November inclusive, the 11th Infantry Regiment had 302 casualties from cold injury, against 195 cases each in the 10th and 2d Infantry Regiments.

Clothing supply.—Keeping warm and dry is fundamental in the prevention of overexposure to the elements. The kind and the adequacy of the clothing and footgear worn by combat soldiers therefore directly influence their susceptibility to cold trauma. The mere statement of that fact does not, however, cover the situation. There are a number of considerations implicit in it as follows:

1. Clothing must be developed scientifically, to take advantage of air insulation and the layering principle. This means the provision of lightweight, wind-resistant, water-repellent outer garments, to be worn over layers of loosely woven inner garments. In World War II, the Quartermaster General approached this problem on the basis of so-called clothing assemblies. Research on clothing in relation to man's physiologic needs in extremes of climate and the development of fabrics with known protective qualities led to the establishment of types and designs for various articles of clothing which, when worn together, gave maximum protection against cold. The total uniform for this purpose was designated a clothing assembly. A great deal of effort and research went into the development of these assemblies to meet specific conditions, and, on the whole, both principles and designs were good.

2. Clothing must be designed from the standpoint of practical possibilities. It is probably not possible to design combat clothing that will adequately protect fighting personnel under extreme conditions of intense combat activity in cold and wet weather. In these circumstances, long exposure under great stress can scarcely be avoided. The most practical plan, therefore, in designing clothing for military operations in the winter, is to take into account only average conditions of exposure to weather in the coldest months of the year and to attempt to protect the combat soldier within a range of 10° F. above and below these averages.

3. Clothing and footgear must be designed so that there will be no interference with circulation in any part of the body.

4. Clothing must be worn so as to take advantage of the principle of insulation; that is, air must be present between the skin and first layer, as well as between all succeeding layers.

5. Clothing must be in proper supply. Adequate supplies must be brought to the division area. They must also be distributed to the smallest units farthest forward in such a way that individual soldiers will be able to change into warm, dry clothing as the need arises. The supply of all necessary items to tens of thousands of men scattered in combat units along several hundred miles of a long fighting front is a major problem in logistics.

6. Even granting that clothing is properly designed and that supplies and distribution of clothing assemblies are sufficient, it is still necessary, for the greatest protection to be obtained from clothing, that both the commander and the individual soldier understand the principles involved and the methods of utilizing the garments provided. The importance of this consideration was not always realized in World War II, but failure to assemble the uniform for wear as intended can greatly decrease its ability to protect the wearer against cold. Since trenchfoot is caused not only by exposure of the feet but also by loss of body heat, insufficient protection of the torso by failure to include the sweater or the jacket or some other garment in the assembly can be responsible for the development of cold injury.

The chief responsibility for the development and production of all types of clothing rests with the Quartermaster General of the Army. Before the entrance of the United States into World War II, the Office of the Surgeon General had had little to do with the development of winter clothing, and the Attu operation was over before there was active medical participation in this phase of operations.

In June 1942, the National Research Council set up a subcommittee on clothing, whose personnel included, among others, representatives from the Office of the Surgeon General of the Army and of the Navy, the Office of the Air Surgeon, the Medical Research Laboratory at Fort Knox, the Rochester Desert Laboratory, the Harvard Fatigue Laboratory, and the Textile Foundation; liaison personnel from the Royal Air Force also were included. The original function of this committee was to develop a lightweight, functional flying uniform for aviators, but this function was soon expanded to cover clothing problems of naval and ground forces. The observations made have been brought together by Newburgh,[31] who served as chairman of the subcommittee. The text includes data on acclimatization, methods for determining heat exchange, physiologic adjustments to heat and cold, and studies of the protective properties of clothing. This résumé of what is known of host reactions and responses to heat and cold simply emphasizes the need for continued research if man's ability to cope with cold trauma in war is to be fully understood.

The work of this subcommittee was complemented by the work carried out at the Armored Medical Research Laboratory, which had been established at Fort Knox in September 1942, with the specific mission of conducting research on physiologic problems of practical significance to this branch of the service. Special attention was directed to the study of the soldier in relation to his duties. Later studies included tests of the adequacy and range of winter combat clothing.

The problems of the choice, supply, and utilization of clothing in the Aleutians and in the Mediterranean and European theaters have been presented in detail under the appropriate headings (pp. 90 and 111). Of interest in this connection is the report by Maj. Paul Siple, the representative of the Quarter-

[31] Newburgh, Louis H.: Physiology of Heat Regulation and the Science of Clothing. Philadelphia: W. B. Saunders Co., 1949.

master General, who arrived in the European theater in February 1945, with the mission of observing the adequacy of the supply and distribution of winter clothing. In essence, he reported as follows:

While the complete clothing assembly designed for frontline troops was in itself adequate, it was provided in insufficient quantities. In many instances, too, it was provided so late in the winter that it was not available during the coldest weather, when it was most needed. The campaign was therefore fought by most combat personnel in uniforms deficient in proper protection because of inadequate insulation, poor balance of insulation, lack of windproofness, lack of water repellency, and faulty closure.

The clothing initially provided for winter combat in the European theater, the report continued, did not provide ample enough insulation because it was poorly balanced, it lacked sufficient thickness, it was worn inefficiently, and it did not provide a satisfactory means of preventing movement of air from destroying insulation through the garments or at the points of closure. As an example, the legs were covered by only two layers of clothing, wool drawers, and wool serge trousers. When the soldier was standing, even when he was not exposed to wind, this covering provided only about half an inch of insulation and only about two-thirds of the protection needed under average conditions. When the absence of windproofness in the wool trousers was taken into consideration, the warmth-retaining value of protection for the legs was lowered by about 50 percent. When the man was seated, with underwear and trousers tight over the seat, thighs, and knees, the protection was even less. It was easy to understand why soldiers frequently complained of cold hands and cold feet. Loss of body heat, as a result of the defects in clothing just described, and additional losses through openings of the garments at the neck, the wrists, and the ankles reduced the body temperature to the point at which the most exposed parts of the body, that is, the hands and feet, gave the first evidence of the imminence of possible cold injury.

There were other reasons why the clothing situation was often unsatisfactory. One was that, because of lack of training in the use of clothing in cold weather, items of the uniform assembly were often misassembled. In other instances, the items could not be assembled properly because of piecemeal issue.

Special types of winter clothing were in short supply in the Army in Europe throughout most of the winter season; but standard items, such as underwear, wool shirts and trousers, overcoats, field jackets, and gloves, were always in adequate supply in the theater. Even standard items, however, were not always available to the troops. Because of the urgent tactical necessity for mobility of the individual soldier in combat, commanders sometimes allowed their men to discard clothing which was not needed during strenuous activity. Afterward, resupply or redistribution was not always possible.

Footgear.—The United States combat boot, as pointed out earlier (p. 150), was not well designed. It tended to shrink after it had become wet, and the uppers were so scantily cut that, however tightly they were laced, they could not be brought together. In addition, and also as previously noted, the United

States soldier had been accustomed to tight-fitting clothes and snug-fitting shoes in civilian life, and he carried those habits with him into the Army. For these and other reasons, there were numerous errors in the fitting of army shoes. In many instances, no allowance was made for the fact that feet tend to enlarge under marching and other strenuous activities. Nor was sufficient, if any, allowance made for the fact that heavy woolen socks, or two pairs of socks, would be worn during the winter instead of the thin cotton socks worn during the summer. The soldiers, it must be granted, sometimes created their own difficulties. When they had been properly fitted originally, they would trade shoes among themselves until they found the snug-fitting kind to which they had been accustomed in civilian life.

Similarly, when galoshes were provided, they were not always worn. Sometimes the men were directed to leave them behind. Sometimes they simply discarded them of their own initiative because they were cumbersome to wear into combat.

Socks in the lighter weights were in generous supply at all times in the various theaters of operations. Heavy wool ski socks were scarce throughout the winter combat period in the first winter in Italy, as well during the period of heavy fighting and cold, wet weather on the Western Front.

It is easy to speculate on the effects of these and other deficiencies in clothing and footgear, and on bad practices in their use, but it is less easy to prove exactly how they influenced the incidence of cold injury. The effect of clothing and footgear per se cannot be isolated from other factors and measured alone. The combat situation and the idiosyncrasies of supply must always be taken into account. So must human factors. Footgear, for instance, cannot be designed that will force the soldier to wear it into combat, or to change his socks at stated intervals, or to remove his shoes at night, when he knows full well that he may have to leave the scant protection of his foxhole at a moment's notice.

Even when allowance is made for these considerations, the incidence of cold injury in both the Mediterranean theater and the European theater seems clearly related to the completeness of provision of clothing and footgear. A study by the Preventive Medicine Division, Office of the Chief Surgeon, ETOUSA, showed unmistakably that the total cold injury rate during the period of combat was 4.3 per 1,000 for divisions fully equipped in November 1944, 10.5 per 1,000 for those not fully equipped until December, and 11.7 per 1,000 for those not fully equipped until January 1945. The study also revealed that, when only trenchfoot was related to the degree of completeness of equipment, the rates were, respectively, 2.5 for November, 6.0 for December, and 8.5 for January. These proportions might have been expected, since footgear is not the only item of clothing related to the production and prevention of cold injury.

The whole experience in Italy and western Europe in World War II serves to emphasize the need for simpler and more efficient types of clothing and footgear to reduce exposure during winter operations. The Theater Quarter-

master was emphatic on this point. In March 1945, at the Paris conference (p. 184), he pointed out that the uniform must be made simple and basic, if only because transportation is limited in wartime and allowances for the movement of supplies would therefore always be limited; food, gasoline, and ammunition have priority in tonnage moving forward. Similarly, the production of clothing in the Zone of Interior would be expedited if all items were kept simple and uniform; there were limits to what could be produced when an army was growing rapidly and straining production of a wide variety of items. The quality of the raw materials and the workmanship in British uniforms, the Theater Quartermaster concluded, might not meet United States standards, but British clothing was simple, and it had been kept uniform, with the result that supplies were adequate all during the fighting in Europe.

The experience in Italy and in western Europe also showed that supply procedures and practices must be simplified and that command and all other personnel must be thoroughly trained in the most efficient use of the clothing and footgear provided.

As the war progressed, special items of clothing were reduced to a minimum. Observers from the Quartermaster Corps not only studied the use of the various items under as many conditions as possible but also went to great lengths to sample soldier opinion about them. The results of these surveys sometimes appeared to have more influence on changes of policy and clothing directives than they merited, a fact which emphasizes the need for better training of the soldier in the efficient use of clothing and what could be expected from it.

Shelter.—Shelter is an important consideration in the incidence of cold injury because it is a means to shorten periods of exposure to the elements, as well as periods of exposure to enemy observation and fire. Seeking shelter to avoid exposure to cold and wet in combat is as natural and as sensible as coming into one's own home to avoid the rigors of a winter day. It is not an easy matter, however, to provide shelter for troops in combat. Though terrain enters into the problem, whether or not shelter is practical depends chiefly upon the tactical situation.

Under many combat situations, it is impossible to provide shelter of any kind except that offered by natural features of the terrain and the hasty digging of individual foxholes. What can be provided ranges from none at all, which means complete exposure in open ground, through quickly improvised, unimproved foxholes, foxholes in which there is time for improvement and greater protection, tents, dugouts, pillboxes, other improvised shelter and damaged buildings, to, finally, unscarred buildings suitable for the comfortable housing of troops. Soldiers able to take shelter in buildings, basements, or dugouts, or even tents and improved foxholes, are obviously much better able to look after themselves and to take the measures necessary to prevent cold injury than are those who must pass their nights in hurriedly dug foxholes.

As the war progressed on the Western Front in the winter of 1944–45, the men developed many expedients to improve their lot, even in the crudest of shelters. Often they obtained and utilized some form of heat, even in far

forward positions, such as charcoal braziers or hexyl methylamine tablets, which provide fairly intense heat. At other times, when observation by the enemy did not forbid it, exposed soldiers poured gasoline on the ground or into containers filled with loose earth or sand or constructed some other similar device and then set fire to the fuel to provide the warmth they needed for protection from the cold. Many hundreds of gallons of priceless motor fuel were thus consumed. This wastage pointedly indicates the need for developing practical means and methods for providing shelter and heat under adverse conditions, as well as the need for the provision of more satisfactory types of clothing and footgear. Incidentally, the use of heat in this manner may sometimes have added to the seriousness of the cold injuries sustained instead of decreasing their incidence (p. 317).

Some of the unit histories already related illustrate the influence of the element of shelter as well as of terrain and combat. Other illustrations follow:

Unit case history No. 13.—The 90th Infantry Division was engaged in operations in the Saar Basin during the first half of December 1944. Two regiments crossed the Saar River at Dillingen on 6 December. As the fighting developed, the 357th Infantry Regiment was pinned down in foxholes in the open, while the 358th and 359th Infantry Regiments, although operating against equally resolute resistance, fought in the town of Dillingen where some shelter was available as well as some protection from exposure. By 12 December (chart 24, table 34), the 357th Infantry Regiment had experienced a sharp

CHART 24.—*Cold injury in 3 regiments of the 90th Infantry Division, European theater, 14 November through 21 December 1944*

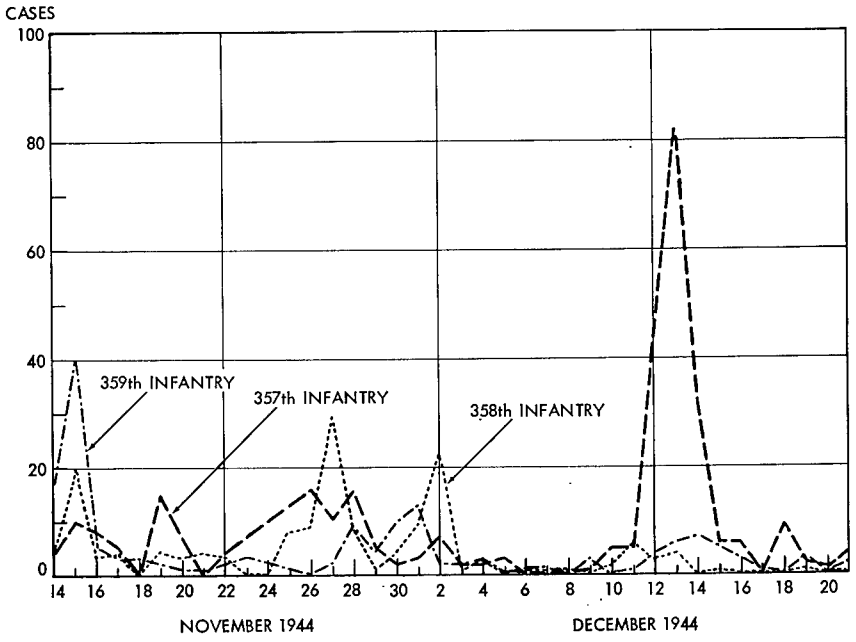


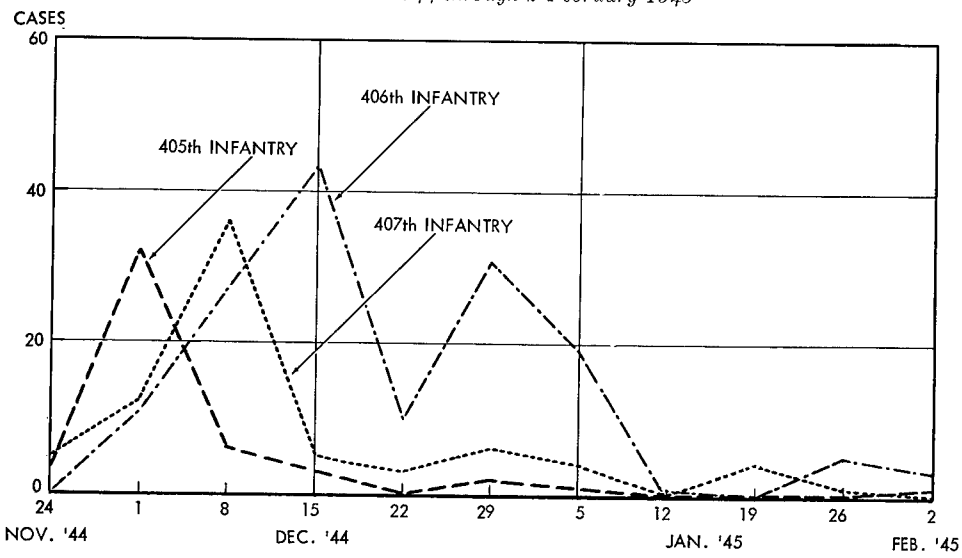
TABLE 34.—*Cold injury in 3 regiments of the 90th Infantry Division, European theater, 13 November through 21 December 1944*

Date	357th Infantry	358th Infantry	359th Infantry	Total
1944				
November 13	0	0	0	0
14	4	5	17	26
15	10	20	40	70
16	8	3	6	17
17	5	4	3	12
18	0	0	3	3
19	15	4	2	21
20	7	3	1	11
21	0	4	1	5
22	4	3	2	9
23	7	0	3	10
24	10	0	2	12
25	13	8	1	22
26	16	9	0	25
27	10	29	2	41
28	16	8	9	33
29	5	1	4	10
30	2	4	10	16
December 1	3	9	13	25
2	7	22	2	31
3	2	1	2	5
4	2	3	3	8
5	3	0	0	3
6	0	0	1	1
7	0	0	1	1
8	0	1	0	1
9	1	0	3	4
10	5	2	0	7
11	5	6	1	12
12	45	3	4	52
13	82	4	6	92
14	33	0	7	40
15	6	1	5	12
16	6	0	3	9
17	0	0	1	1
18	9	0	0	9
19	2	1	3	6
20	1	0	0	1
21	4	0	2	6
Total	348	158	163	669

rise in trenchfoot cases; between that date and 14 December, inclusive, it reported 160 cases, while little increase in incidence was noted in the 358th and 359th Infantry Regiments. The principal difference in conditions was that the latter regiments had some shelter.

Unit case history No. 14.—A still better illustration of the importance of shelter is furnished by the experience of the 102d Infantry Division. This division did not arrive in France until late in September 1944 and therefore was new to combat. On 1 November, the 406th Infantry Regiment was detached and the other troops were placed in an inactive defense position where they remained until 27 November. On 28 November, the 406th Infantry Regiment was returned to divisional control. From that date until 3 December, an offensive action toward the Roer River was conducted in the Übach area. For the weeks ending on 1 December and on 8 December, there was a sharp increase in cold injury (chart 25, table 35).

CHART 25.—*Cold injury in 3 regiments of the 102d Infantry Division, European theater, 24 November 1944 through 2 February 1945*



Between 4 December 1944 and 2 February 1945, the division remained in the same sector, in a quiet defensive position. The men of the 405th and 407th Infantry Regiments were for the most part in buildings and basements and therefore had relatively adequate shelter. The 406th Infantry Regiment, on the other hand, because of the sector it had to defend, had to seek shelter in foxholes. The strikingly higher incidence of trenchfoot in this regiment after the initial offense and during the static defensive weeks, can be accounted for by one principal differential, the absence of adequate shelter.

TABLE 35.—*Cold injury in 3 regiments of the 102d Infantry Division, European theater, for weeks ending 24 November 1944 through 2 February 1945*

Week ending—	405th Infantry	406th Infantry	407th Infantry	Total
1944				
November 24	3	0	5	8
December 1	32	11	12	55
8	6	27	36	69
15	3	43	5	51
22	0	10	3	13
29	2	31	6	39
1945				
January 5	1	19	4	24
12	0	1	0	1
19	0	0	4	4
26	0	5	1	6
February 2	1	3	0	4
Total	48	150	76	274

Command leadership and attitude.—Leadership is an intangible quality which is difficult to define or measure precisely. It is not the intention to attempt to do either here, but some general statements may nonetheless be made concerning it.

Leadership is a socioenvironmental factor. The standard of leadership materially influences the unit liability to cold injury. Lack of leadership predisposes to a high incidence. When leadership is good, the discipline and esprit de corps are such that the tedious and sometimes tactically disadvantageous measures which are required to prevent cold injury are willingly carried out for the good of the command. Good leadership can modify or control many of the host and environmental factors responsible for cold injury. Good planning, astute decisions, and firm example can determine the outcome of combat action. Good leadership is always concerned with the welfare of the individual soldier. The necessary steps are therefore taken to insure appropriate supplies of food and clothing, adequate medical facilities, and rest and rotation schedules that will reduce fatigue and increase fighting efficiency.

A good commander understands and accepts his responsibility for the prevention and control of mass diseases and injuries that may affect his unit. In so doing, he makes full use of the special knowledge and skills of his technical advisors. He cannot, because of tactical and other circumstances, always accept the advice given him, at least in all details, but he is very certain of the consequences when he rejects the advice. He does not wait until a large number of casualties from cold injury has lowered the effectiveness of his

unit. Instead, he institutes education, training, and indoctrination programs well in advance of the possible occurrence of cold injury. It is by no means the least important manifestation of good leadership that a good commander establishes such liaison and understanding with the men under him that they appreciate the role of the unit in the general conflict. They know what they are fighting for, and they understand the reasons for the policies and procedures they are called upon to carry out. United States soldiers will always respond willingly when they understand the rationale of such measures and the benefits to be derived from them for themselves and their units. It is almost impossible to force them to carry out measures whose rationale they do not understand.

This is not theoretical reasoning. It was repeatedly observed in both the Mediterranean and the European theaters that well-led units always had the best average records for cold injury. Numerous divisional records prove this point. The story of the 29th Infantry Division has already been related (unit case history No. 8, p. 421). This battle-tried unit, in spite of hard fighting, had only 164 cases of cold injury during the entire winter of 1944–45 on the Western Front. Similarly, the record of the 95th Infantry Division (unit case history No. 3, p. 402), which had even harder combat missions than the 29th Infantry Division during this winter, illustrates the effects of excellent leadership. During the hard fighting between 1 November 1944 and 15 January 1945, it had only 325 cases of cold injury of all types.

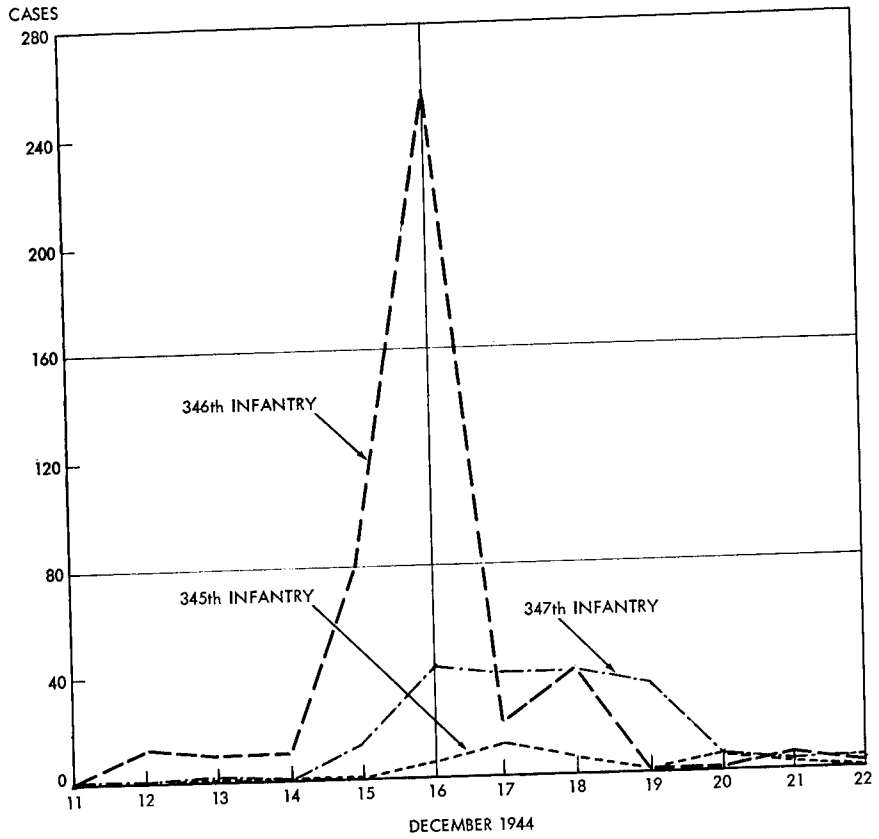
The following record of the 87th Infantry Division represents both good and bad leadership:

Unit case history No. 15.—This unit was assigned to the Third U. S. Army early in December 1944. It had had no previous combat experience. On 11 December, it was committed in a drive toward Saareguemines, directly east of Metz. The weather was moderately cold, and there was daily rainfall. The terrain consisted largely of ridges and valleys and was not forested, so that the ground was very muddy.

The story is now best continued by regiments:

The 346th Infantry Regiment was the first to gain contact with the enemy. Its casualties were heavy at first and the attack bogged down on a gently sloping hillside because of the intensity of enemy fire. On its second day of combat, casualties were again high, and 12 cases of trenchfoot made their appearance. At the same time, combat exhaustion cases accounted for 15 percent of total casualties. Battle casualties dropped to 7 on the fourth day. On the following day, which was the 15th of December, the number of trenchfoot cases far exceeded battle casualties and for the most part came from the 1st Battalion. On the 6th day of combat, this battalion alone had 206 trenchfoot casualties. By the end of a week of fighting, the 346th Infantry Regiment had experienced over 400 cases of trenchfoot in men fully equipped with overshoes and winter clothing (chart 26, table 36; chart 27, table 37).

CHART 26.—*Cold injury in 3 regiments of the 87th Infantry Division, European theater 11–22 December 1944*



The record of the other regiments was quite different. The 345th Infantry Regiment was not committed until 30 December and was in intensive combat only for a matter of days. It experienced only a few cases of frostbite. The 347th Infantry Regiment was committed to the support of the 346th the fourth day of the battle (14 December). It began to suffer casualties from trenchfoot almost immediately, but at no time in the period under consideration did the daily number of cases exceed 42, and the total for the whole period was only 178.

The records of the 346th Infantry Regiment show that the regimental commander and the commanding officer of the 1st Battalion were chiefly at fault in the poor record of this regiment, and especially of this battalion, with respect to cold injury. Lack of progress in the attack, with demoralizing enemy fire, resulted in a considerable break in morale. A complete breakdown in foot discipline was the direct result. Poor attention to the welfare of the riflemen in the regiment also played a part in the high incidence of trenchfoot.

TABLE 36.—*Cold injury in 3 regiments of the 87th Infantry Division, European theater, 11–22 December 1944*

Date	345th Infantry	346th Infantry	347th Infantry	Total
1944				
December 11	0	1	0	1
12	0	12	0	12
13	0	11	1	12
14	0	11	0	11
15	0	81	13	94
16	4	255	42	301
17	12	20	38	70
18	6	40	39	85
19	1	1	32	34
20	5	1	6	12
21	2	6	3	11
22	0	2	4	6
Total	30	441	178	649

CHART 27.—*Cold injury in 3 battalions of the 346th Infantry, 87th Infantry Division, European theater, 11–22 December 1944*

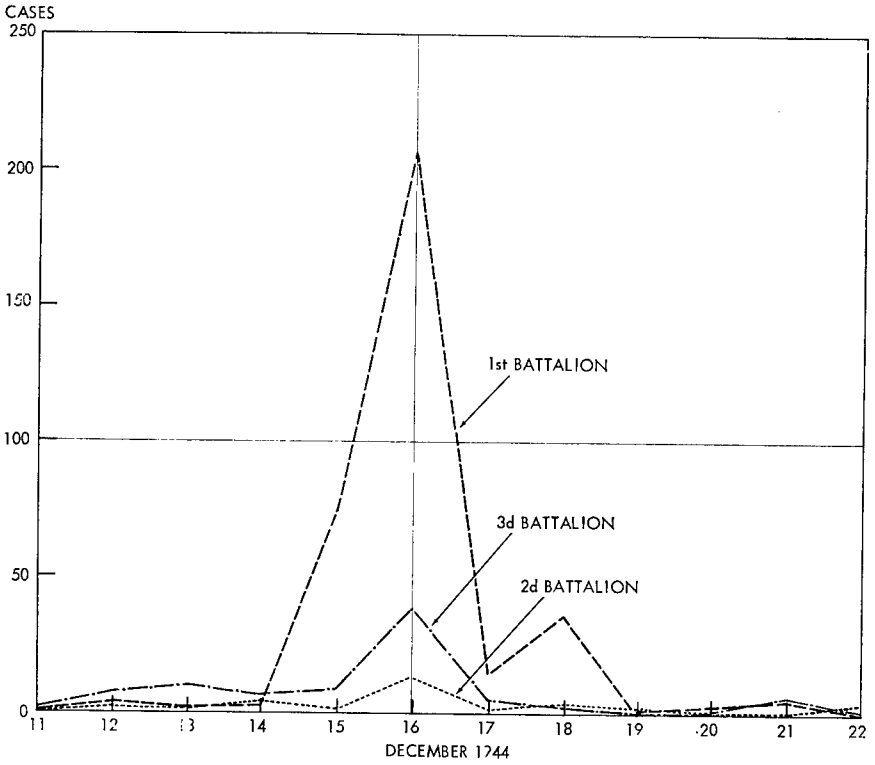


TABLE 37.—*Cold injury in 3 battalions of the 346th Infantry, 28th Infantry Division, European theater, 11–22 December 1944*

Date	1st Battalion	2d Battalion	3d Battalion	Total
1944				
December 11	0	0	1	1
12	3	2	7	12
13	1	1	9	11
14	2	3	6	11
15	72	1	8	81
16	206	12	37	255
17	14	1	5	20
18	35	3	2	40
19	0	1	0	1
20	1	0	0	1
21	2	0	4	6
22	0	2	0	2
Total	336	26	79	441

Because training was not good enough to support the troops in time of trial, the regiment suffered a serious point epidemic of cold injury. It is true that this was a new, untried, and inexperienced unit. It was called upon to spearhead an attack in difficult terrain and in opposition to heavy German forces, which used tanks in defense, but it is equally true that leadership was the principal factor responsible for the high incidence of trenchfoot.

The story of these regiments emphasizes a vital principle in the prevention of cold injury; namely, that this type of injury, with its prevention, is a problem of the small units. One regiment of this division (chart 26) was careless. One battalion in this regiment (chart 27) was at fault. It is interesting to speculate whether or not the errors could be traced down to poor leadership in certain companies. It is probable that the same principles held in them.

Training and experience.—From the standpoint of cold injury, training and experience are inseparable from individual and unit discipline. Effective training is based on good discipline, and the development of good discipline is a part of the soldier's training. When men are well trained and properly disciplined, they profit from experience and become better able to look after themselves and save themselves from trauma, whether it be from enemy weapons or from cold.

The good record of some experienced and battlewise divisions with respect to the incidence of cold injury has already been mentioned. Among them are the 104th Infantry Division (chart 18) and the 90th (chart 24). The 99th Infantry Division furnishes a reverse example of the effect of inexperience and lack of battle training.

Unit case history No. 16.—The 99th Infantry Division arrived in England in October 1944, landed in France during the first week of November. It was committed to combat on 9 November, in a static defense, with active patrols. The country was hilly and partly forested. The weather was moderately cold. It rained, and some snow fell. The ground was either muddy or slushy. The division remained in the line under these conditions through 12 December. Cases of cold injury, principally trenchfoot, began to appear almost as soon as it was committed, and there was a peak of 194 cases for the week ending 24 November (chart 28, table 38). Weather conditions were favorable for its occurrence, it is true, but combat missions were light, and the high incidence could be attributed only to inexperience and to lack of training in the measures required to prevent cold injury. A contributory factor may have been the incomplete provision of galoshes during this period.

A second, even larger, outbreak of cold injury occurred between 13 December 1944 and 5 January 1945. On 13 and 14 December, the 395th Infantry Regiment and a battalion of the 393d Infantry Regiment were in active combat. The action shifted to heavy defense against the German midwinter counterattack of 16–18 December. Between 19 December and 28 December, a retrograde movement was made, and combat action took the form of active defense. Between 29 December and 28 January, action was also defensive, with active patrolling. The second outbreak of cold injury was, like the first, largely attributable to the inexperience of the troops, though intensification of the combat action also played a part.

CHART 28.—*Cold injury, 99th Infantry Division, European theater, for weeks ending 10 November 1944 through 16 March 1945*

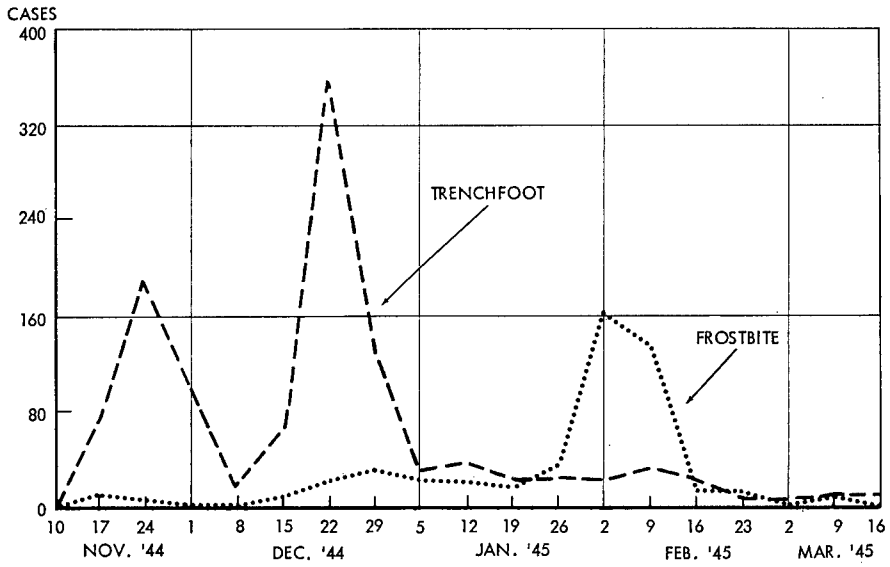


TABLE 38.—*Cold injury in 3 regiments of the 99th Infantry Division, European theater, for weeks ending 10 November 1954 through 16 March 1945*

Week ending—	393d Infantry	394th Infantry	395th Infantry	Total
1944				
November 10	0	0	0	0
17	72	0	4	76
24	102	62	30	194
December 1	19	65	17	101
8	1	13	0	14
15	5	29	41	75
22	146	150	88	384
29	46	83	26	155
1945				
January 5	16	28	2	46
12	13	37	3	53
19	7	25	2	34
26	16	38	2	56
February 2	109	58	12	179
9	58	79	45	182
16	7	14	9	30
23	2	4	1	7
March 2	0	1	0	1
9	0	4	5	9
16	0	3	1	4
Total	619	693	288	1, 600

A third peak of cold injury in this division occurred between 26 January and 16 March 1945. From 2 February onward, operations were in melting snow, rain and mud, at temperatures between 30° and 40° F. (−1.1° and 4.4° C.), but the high incidence was also to be explained by heavy combat, sometimes in extreme cold.

Foot discipline.—Foot discipline in itself cannot, of course, be separated from discipline in general. It is part of both unit and individual training. The incidence of cold injury was always low when it was good. Foot discipline, moreover, was best in those divisions in which the practice of inspection of the feet was established early, and in which the inspection was not only by commissioned officers but also by noncommissioned officers down to, and including, the squad level. Even under severe combat conditions, it was repeatedly observed that when discipline was good sufficient time and safe enough surroundings could usually be found for the use of protective measures. Even if daily care was not possible, in most situations care of the feet could be resumed before the end of the mean incubation period for trenchfoot, that is, approximately 3 days, though as temperatures approached the freezing point the margin of safety became less.

A study by Colonel Gordon's office showed that, during the winter of 1944–45, six divisions which had not been in combat before 1 November 1944 averaged 15.5 cases of cold injury per day of combat, while 13 units with long combat experience averaged only 7.6 cases per day. Although several factors undoubtedly helped to explain this difference, the observers attributed it chiefly to better foot discipline in the experienced divisions. The inexperienced divisions had not received adequate training in the individual care of the feet, or, if they had been trained, they had not come to recognize the importance of the training and therefore did not apply what they had learned. As a result, when they were first committed to action under conditions favorable to trenchfoot, many became casualties to cold and mud.

Intense combat activity influenced the incidence of cold injury, at least indirectly, because it brought about a relaxation of foot discipline. It was the observation of a number of division surgeons that when the incidence of cold injury was rising a prompt decline would ensue, regardless of combat activity, whenever commanding officers took a firm stand in insisting upon individual care of the feet.

A specific example of the effect of foot discipline is furnished by the three regiments of the 45th Infantry Division as follows:

Unit case history No. 17.—All three regiments of the 45th Infantry Division fought under similar conditions, with roughly similar missions, between 28 October and 29 December 1944. During this period (chart 29, table 39) the 180th Infantry Regiment had 48 cases of cold injury, the 179th, 108 cases, and the 157th, 209 cases. When the division was surveyed, the only explanation found for these differences was that training was rather poor in the 157th Infantry Regiment, was satisfactory but no more in the 179th, and was excellent in the 180th.

CHART 29.—*Cold injury in 3 regiments of the 45th Infantry Division, European theater, for weeks ending 3 November through 29 December 1944*

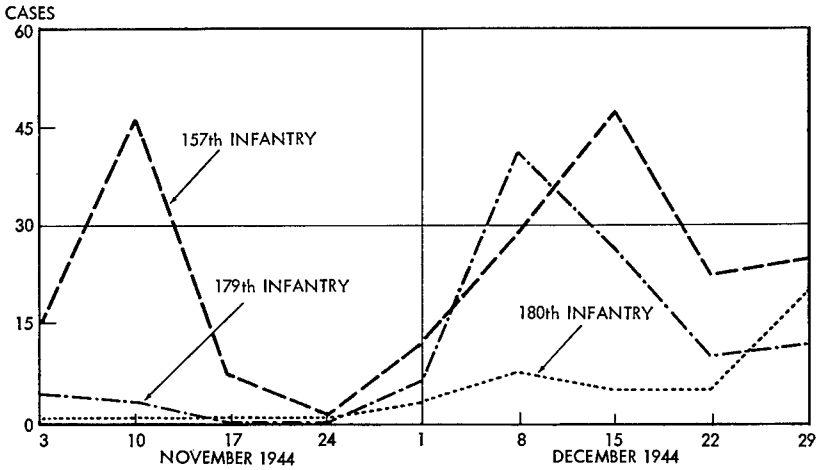


TABLE 39.—*Cold injury in 3 regiments of the 45th Infantry Division, European theater, for weeks ending 3 November through 29 December 1944*

Week ending—	157th Infantry	179th Infantry	180th Infantry	Total
1944				
November 3	14	5	1	20
10	47	4	1	52
17	8	0	1	9
24	2	0	1	3
December 1	13	7	4	24
8	29	42	8	79
15	48	27	6	81
22	23	11	6	40
29	25	12	20	57
Total	209	108	48	365

The story of the 9th Infantry Division has already been used (unit case history No. 5, chart 17) to illustrate the effects of both thawing (p. 414) and terrain (p. 422). It also illustrates the effect of foot discipline. Both frostbite and trenchfoot were kept at low levels. There was one small outbreak of trenchfoot in the middle of November, before the troops were completely supplied with galoshes, and a second, minor elevation in December, coinciding with a period of active defense. When this division was surveyed, it was concluded that its excellent record could be attributed to a number of factors, including (1) its battle experience, (2) the early date at which it was supplied with galoshes, (3) the extensive use of drying tents, (4) the unusual ingenuity shown in obtaining and issuing charcoal braziers for the use of frontline troops, and (5) the intensive program of instruction, in which the burden of prevention of cold injury was placed on the individual soldier.

Similar observations could be multiplied. All of them can be interpreted as indicating the importance of foot discipline, which includes familiarity with the measures which the individual soldier can use to prevent cold injury and the diligent application of these measures.

Rotation.—Rotation, or the regular relief of troops from frontline positions in which exposure to the elements is great, materially influences the incidence of cold injury. The most adverse conditions of weather and terrain can be tolerated by combat soldiers for short periods if they can be rotated within units or by units, both large and small, and thus be provided with opportunities to carry out appropriate control measures.

The practice is beneficial at any level, from individual frontline riflemen and squads through progressively larger units by echelon, up to and including whole divisions. A good rotation policy begins with the individual soldier in the frontline. In forward areas, it need consist of no more than the opportunity to withdraw from his foxhole to a crude shelter a few hundred yards to the rear, where, in relative safety, he may change his clothing, exercise a little, and carry out appropriate measures, including massage, for the care of his feet. In the battalion area, better arrangements can be made for foot care, and facilities improve progressively in regimental and division areas. Somewhere along the line, bathing and laundry facilities are available, the men can obtain a few hours of rest, and, under ideal circumstances, they are provided with hot food and the morale-lifting advantages of the Red Cross truck and of getting mail and writing letters home.

Intervals of rotation should vary according to the size of the units. In frontline units, the rotation of individuals and small units depends upon weather and the intensity of combat action. In World War II, it was the consensus of division surgeons that a period of 3 days or more was usually required for trenchfoot to develop at temperatures above freezing, while, below that level, frostbite could develop in a few hours. In progressively larger units, rotation should be progressively less frequent but for longer intervals. In addition to the importance of rotation in the prevention of cold injury, its employment for this cause bolsters morale in general, lessens fatigue, and decreases losses from neuropsychiatric causes.

A definitive rotation policy was never established by United States armies in Europe. Instead, divisions determined and executed their own rotation practices, while, within divisions, the policies were usually left to the discretion of regimental or battalion commanders. Under these circumstances, policies and practices naturally varied widely. They were good in some units and poor in others. In all, they were of necessity greatly influenced by the exigencies of combat.

During the German counteroffensive in December 1944, the defense operation in the first few days was so urgent that good rotation practices could not be executed. The intensity of the fighting during the later United States counterattack had the same inhibiting effect. The combat situation was therefore partly responsible for the second Army-wide cold injury epidemic on the Western Front (chart 15). In situations such as these, the determination of the extent of rotation must be a command decision, but the establishment of the general principles of rotation by army, or even by army group, and the insistence that these principles be applied consistently within the limits permitted by the combat situation, would have influenced the cold injury incidence downward in World War II. It would also have reduced losses from combat exhaustion and psychoneurosis.

The effectiveness of rotation in reducing the incidence of trenchfoot is well illustrated in the following experience of the three regiments of the 35th Infantry Division:

Unit case history No. 18.—This division landed on the Continent in July 1944 and fought across France in the Third U. S. Army. At the beginning of the November offensive, it was in the line east of Nancy, in muddy, rolling, open country near the Seille River. As the offensive opened, a division order was issued directing that galoshes be left behind.

The 320th Infantry Regiment made an all-night march to get into position, then crossed the river. Three days later, it began to report trenchfoot casualties (chart 30, table 40). At this time, the 134th and 137th Infantry Regiments went into action. Rain fell continuously, and the foxholes were usually half filled with water. During the first 9 days of the operation, the 134th and 320th Infantry Regiments had, respectively, 161 and 163 cases of cold injury. For the same period, the 137th Infantry Regiment had only 36 cases. Conditions for all three regiments were substantially the same, with one exception: The 137th Infantry Regiment fought through a few small, built-up areas and had what amounted to daily rotation of small groups, to allow for drying the clothing and caring for the feet. It was the opinion of those who studied the cold injury situation in the three regiments that it was principally good rotation practice in one regiment, as opposed to the lack of rotation in the other two, that accounted for this striking difference in the trenchfoot experience.

CHART 30.—*Cold injury in 3 regiments of the 35th Infantry Division, European theater, 8–30 November 1944*

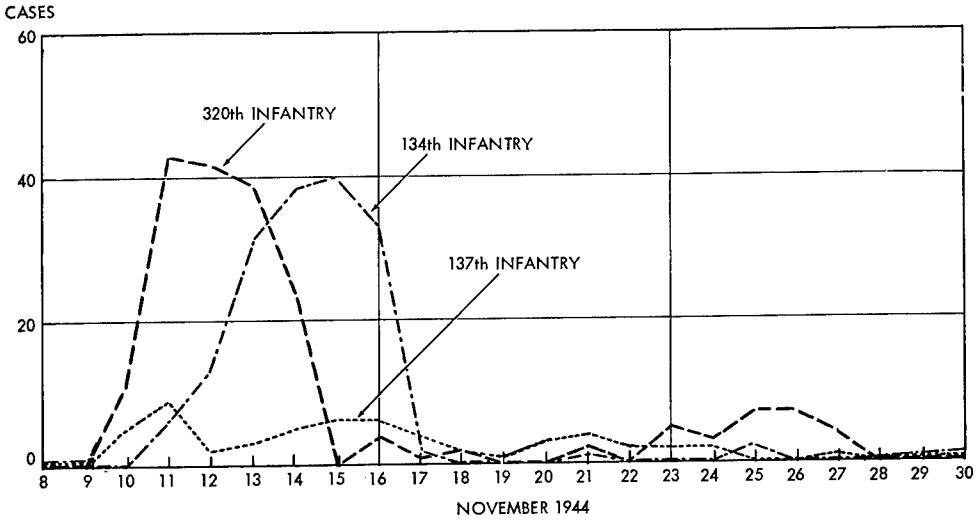


TABLE 40.—*Cold injury in 3 regiments of the 35th Infantry Division, European theater, 8–30 November 1944*

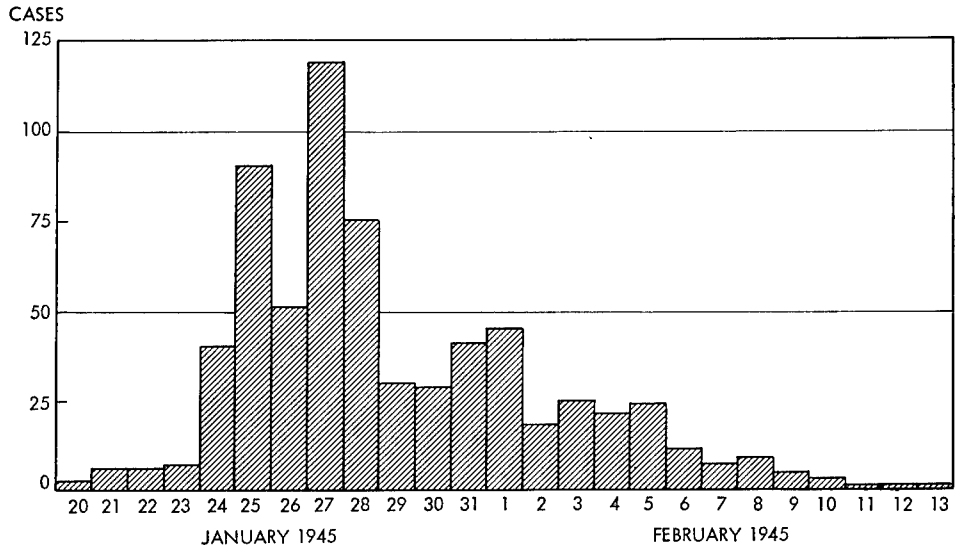
Date	320th Infantry	134th Infantry	137th Infantry	Total
1944				
November 8	0	0	0	0
9	0	0	0	0
10	11	0	5	16
11	43	6	9	58
12	42	13	2	57
13	39	31	3	73
14	24	38	5	67
15	0	40	6	46
16	4	33	6	43
17	1	2	4	7
18	2	0	2	4
19	0	0	1	1
20	0	0	3	3
21	2	1	4	7
22	0	0	2	2
23	5	0	2	7
24	3	0	2	5
25	7	2	0	9
26	7	0	0	7
27	4	0	1	5
28	0	0	0	0
29	0	0	0	0
30	0	1	0	1
Total	194	167	57	418

Interrelationships of Causative Factors

The following records of the 3d and the 36th Infantry Divisions summarize effectively much of what has been discussed in the earlier pages of this chapter.

Unit case history No. 19.—The 3d Infantry Division, a battle-experienced, hard-hitting unit, which was the mainstay of the Seventh U. S. Army, reduced the Colmar Pocket, and then fought out into the Colmar Plain toward the Rhine during January and February 1945. The interrelationships of many of the modifying factors of cold trauma which have been discussed are apparent in the graphic record (chart 31). When the incubation period of cold injury is considered, the influence of weather, type of combat action, wetness from river crossings, terrain, and adequacy of clothing and equipment is well demonstrated.

CHART 31.—*Cold injury incidence, 3d Infantry Division, European theater, 20 January through 13 February 1945*



Date	Combat action	Weather	Terrain	Clothing supply	Equipment
1945					
Jan. 20–22	Training; patrol; moving into position.	Cold; snow; sleet.	Flat; rolling; cultivated and one forested; one regiment in mountains.	----------	
Jan. 20–21	----------	----------	----------	90 percent of troops had shoepacs.	85 percent complete; 85 percent adequate.
Jan. 23	River crossing	----------	----------	----------	
Jan. 24–26	Attack; heavy opposition; counterattack; holding.	Unchanged; snow.	Flat	----------	
Jan. 27	Attack	Slightly warmer	Flat; cultivated	----------	
Jan. 28–29	Holding; consolidating gains.	Unchanged	Unchanged	----------	
Jan. 30	River crossing	----------	----------	----------	
Jan. 31–Feb. 2	Attack; consolidating gains; holding.	Warmer; rain; thawing 1 February.	Unchanged	----------	
Jan. 28–Feb. 2	----------	----------	----------	Gradual loss of some articles of clothing.	Gradual loss of equipment.
Feb. 3–7	Attack; holding	Warmer; rain	Flat; cultivated	----------	80 percent complete.
Feb. 8	Holding	----------	----------	----------	
Feb. 9–12	Reserve	----------	----------	----------	

Unit case history No. 20.—The 36th Infantry Division had a considerable experience with cold injury in Italy during the winter of 1943–44. In the fall of 1944, it participated in the landings in southern France. During the succeeding winter, it found itself in almost constant contact with the enemy. In its progress, it fought on a wide front, through difficult, mountainous terrain. All movement of any consequence had to be on foot. After 15 September, the weather was cold, and, during November, rain fell almost continuously. Several streams had to be crossed, and the constant rains kept the troops wet even when they were on high ground.

The cold injury experience to date and the problems encountered during 1944 were summarized by the surgeon of the 36th Infantry Division in his December 1944 sanitary report, as follows:

Trench foot has caused a serious loss of manpower within the Division during combat operations in the winter months in Italy and France due to the cold wet climates encountered. The highest incidences were reported during the months of January with 401 cases, February with 270 cases, November with 279 new and 97 recurrent cases, and December, with 155 new and 45 recurrent cases. During the month of November, 77 cases of trench foot were received over a four day period from one Regiment of the Division that was attacking during a driving rain. These troops had been issued an extra pair of heavy wool socks and an extra light wool pair. Although most of them had shoepacs they had four times as much trench foot as the rest of the division. The other two Regiments of the Division were in a holding position and had a total of 19 cases of trench foot. Another observation of two adjoining companies under the same conditions of exposure was made when one company had 10 cases of trench foot over a six day period while the other company had 3 cases. It was found that the men of the company having 10 cases had had no exchange of light wool socks while those of the other company had dry socks exchanged 5 times. This was corrected. The marked decrease during the month of December is attributed to comparatively dry weather encountered during the month and to the educational program conducted during the months of October and November on foot hygiene and the prevention of trench foot. Shoepacs were issued to the troops during the month of November with instructions for their proper wear and the importance of changing to dry clean socks and dry inner soles daily. Approximately 1,700 men of this division do not have shoepacs or overshoes because of the lack of proper sizes in Quartermaster stocks. Every effort is being made to issue combat boots of sufficient size to permit wearing of heavy wool socks and a light wool pair. A system has been worked out by which the infantry S-4s [supply] replace the dirty socks with clean dry socks daily by sending the clean socks forward with the daily ration issue. The high casualty rate among Commissioned and Non-Commissioned Officers, resulting in frequent turnover of the command while in combat causes the necessary supervision of foot hygiene in small units and footgear discipline to be less efficient than is desired, even though constant attention is given to this matter in Battalion, Regimental and Division Headquarters. Instructions on prevention of trench foot given at the direction of Seventh Army to personnel of Replacement Depots and Convalescent Hospitals is believed to be an important aid in the educational program against this disease. Random comments in the report of the trench foot survey of the 36th Division emphasize still other causes for the high trench foot incidence:

"Unfortunately, the tactical situation has largely precluded the possibility of rotation of men. No regiment has been in reserve and riflemen have been in the line for long periods of time.

"There has been no policy to set up houses or tents to be used specifically as drying rooms for front line soldiers. It is felt that if houses or dug-outs are available, soldiers, will go to them to warm themselves and build fires to dry their clothing of their own accord.

"Shoe pacs were issued during the second week of November. About 2,000 men do not have them because of wrong sizes. * * *

"This division tried to get socks to front line soldiers each day with rations. It is believed that sock exchange is fairly satisfactory.

"The division went through the Italian winter campaign and officers and men in that campaign are well trained in the prevention of trench foot. Replacements are not well trained in care of the feet.

"* * * trench foot is a disease of riflemen. With the exception of a small percentage of supporting troops, such as company aid men and combat engineers, the disease should not occur in any except infantry riflemen. Even the heavy weapons companies have very little trench foot.

"Battle conditions play a very important part in the development of trench foot. The surgeon believes that 24 to 36 hours exposure in wet, cold weather, without supply, will be sufficient to produce trench foot.

"The Surgeon believes that control of trench foot is purely a command function. If the command is well trained in the prevention of trench foot and realizes its importance, the rate of trench foot will be very low in that organization. He also points out that when unit officers are frequently changed, the trench foot incidence is always higher than in units which retain their officers for longer periods."

It was not until late in January 1945 that a thoroughgoing, well-rounded cold injury prevention program was, or could be, instituted in the 36th Infantry Division. By this time, all replacements were receiving detailed instruction on the proper care of the feet, both when they first were assigned to the division and upon assignment to regiments. Supplies of shoepacs, light wool socks, and ski socks were now adequate. In its holding operations, the division had found it feasible to establish a good rotation system by the use of houses, dugouts, or tents immediately behind the frontline, where each man could spend an hour out of every 6 or 8 hours warming himself, changing his socks, and massaging his feet.

Even under these improved conditions, a report by a unit surgeon of this division for January 1945 noted that "the lack of close supervision of some small unit commanders has caused the incidence of trenchfoot to rise in these units during the past weeks."

At this time, each unit surgeon was required to furnish a report of these and other deficiencies to the commanding general of the division, who took the necessary corrective action. The result was a notable decrease in the incidence of trenchfoot.

SUMMARY

It is evident, from what has been said in this chapter, that the causation of cold injury is an intricately woven fabric of agent, host, and environmental factors, and that no single one of the factor strands can be altered without influencing, or being influenced by, the other factor strands. The final design is an interaction and interrelationship of them all. One factor may predominate in influencing the incidence at one particular time. Then the situation may change, and another, or others, may gain in influence.

The various modifying factors described in the examples given were predominant for the periods selected, but no single factor could be completely divorced from all the others. In the absence of more precise data, however, and of more detailed observations, the examples do serve (1) to emphasize the roles of the various factors involved, and (2) to point up the need for further study, research, and evaluation of the influence and interrelationship of the several agent, host, and environmental factors responsible for cold trauma. The surveys which provided the data for these selected studies brought into play the principles of simple, sound field investigation.

The data and examples thus secured provide a reasonable and convincing basis for concluding that cold trauma, as a component of mass trauma, behaves in accordance with the biologic principles and laws that govern disease or injury as a community problem. The specific causative agent in cold injury is cold, but a number of modifying factors enter into its total causation. These can best be analyzed if they are divided into agent, host, and environmental factors. Studies of war records by theaters and units, and the reports of epidemiologic surveys by division in the European theater, demonstrated that epidemiologic behavior of cold trauma differs in only minor degrees from that of communicable disease.

Evaluation of this experience has shown that the agent factors are cold and wet and that wet may be conceived of as having a synergistic relationship to cold. Host factors include status of individual training, fatigue, nutritional status, previous cold injury experience, inherent constitutional factors, psychosocial factors, and posture and dependency. Both the physical environment and the social environment are factors in the causation of cold injury. Physical environmental factors include weather (that is, temperature, precipitation, and wind), thawing, terrain, and altitude. Socioeconomic environmental factors include type of combat action, clothing supply and equipment, shelter, command leadership and attitude, training and experience, foot discipline, and rotation. Some of these are individual considerations and some apply to the unit. All of them entered into the total causation of cold injury in the European Theater of Operations in World War II, but it was only by assessing their individual weights by unit, by means of epidemiologic methods, that definitive preventive and control procedures could be applied.

CHAPTER XIV

The Cold Injury Record of the 84th Infantry Division[1]

Many divisions in the European Theater of Operations had worse cold injury records than the 84th Infantry Division. Some had better records. Some were in heavier combat for longer periods of time. The history of the 84th Division, however, has been selected as a unit case study in cold injury for the following three reasons:

1. The experience of this division clearly demonstrates the influence of several modifying factors in cold injury without, at the same time, making it necessary to pursue an extremely complicated combat narrative.

2. Its combat engagements were sharply divided into a difficult initial combat period, when trenchfoot was predominant; an intensive combat situation in which terrain and weather combined ideally to give rise to frostbite; and a return to exactly the same weather conditions as those previously experienced, which favored the development of trenchfoot but in which trenchfoot did not occur at all and the incidence of frostbite was negligible, chiefly because the combat situation, while active, could be regarded as mild to moderate for a division that had become battlewise and self-sufficient.

3. This division had received good training, in which the prevention and control of trenchfoot were included.

The 84th Infantry Division, which was made up of the 333d, 334th, and 335th Infantry Regiments, artillery and supporting troops, was re-formed in August 1942 from a World War I outfit. It was fully trained in the United States, where it was activated on 15 October 1944. It assembled in England, and the first elements arrived on the Continent on 1 November. The division went at once to the front. It was attached to the XIII Corps but was initially placed under the operational control of the British 30 Corps, Second Army, for commitment with British troops.

During November and December, the XIII Corps had the following missions: (1) To maintain liaison with the British on the left; (2) to maintain liaison with the U. S. XIX Corps on the right; (3) to protect the left flank of the Ninth U. S. Army; (4) to capture Geilenkirchen and the high ground northeast of it; (5) to seize the line of the Roer River from Flossdorf to Linnich,

[1] The tactical material in this chapter is based on two books by Theodore Draper: (1) The 84th Infantry Division in the Battle of the Ardennes. Liége: Société d'Impression et d'Edition Société Cooperative, April 1945; and (2) The 84th Infantry Division in the Battle of Germany, November 1944–May 1945. New York: The Viking Press, 1946. The clinical material is derived from the medical histories of the 84th Infantry Division for 1944 and 1945.

inclusive; (6) to seize the Beeck-Würm-Lindern area; and (7) to prepare for crossing the Roer River.

The assignment of the 84th Infantry Division in these missions was (1) to reduce Geilenkirchen, (2) to carry out the Beeck-Würm-Lindern operation, and (3) to make plans for crossing the Roer River in December. For a unit which was entering combat totally inexperienced, these were indeed formidable tasks.

8–28 NOVEMBER 1944

Since the missions and the cold injury experiences of one regiment of this division differed considerably from those of the other two regiments, it is convenient to discuss them separately.

335th Infantry Regiment

Tactical situation.—The 335th Infantry Regiment was detached from the parent 84th Infantry Division on 9 November and was attached to the 30th Infantry Division, under the XIX Corps. Until 16 November, the entire XIX Corps was engaged in defense and regrouping activities. Combat activity was light. The 335th Infantry was placed in the line in the Geilenkirchen area in a holding action characterized by occasional active defense. On 17 November, the corps moved in an attack that met moderate to heavy resistance, but the 335th, as an inexperienced unit, was not heavily engaged in these operations.

The weather during this period was cold, but the temperatures remained above freezing. Heavy rains had fallen, however, and the mud was deep in the generally flat terrain. Large expanses of open field were broken by small towns from 1 to 3 miles apart, and coal mines in the area also provided some shelter.

Cold injury.—During this period, the 335th Infantry Regiment sustained only a few cases of trenchfoot, not quite as many, in fact, as the 334th Infantry, which had not yet been committed.

333d and 334th Infantry Regiments

Tactical situation.—The first action for the 334th Infantry Regiment came on 18 November, when it launched an attack designed to capture high ground to the northeast of Geilenkirchen. The following day, the 333d Infantry went into its initial combat, with the British 43d Division. Geilenkirchen fell at the end of that day, and the attack was continued, against heavy resistance, to the north and northeast. The high ground northeast of Beeck was captured on 23 November, and Beeck itself fell on 30 November. On 24 November, both regiments reverted to XIII Corps control and resumed defensive action to hold the ground which had been gained.

During the period 18 November through 25 November, as will be pointed out shortly, rain fell much of the time, and the troops were forced to remain for long stretches in water-filled foxholes, in which water was sometimes within a foot of the top.

Cold injury.—In the 8 days of combat just described, 349 casualties with trenchfoot were evacuated from the division, 340 of whom came from the 333d and 334th Infantry Regiments. Assuming that the strength of a regiment is 4,000 men, this is a rate, for the 8 days, of 37.2 evacuated trenchfoot casualties per 1,000 strength.

Division Conference on Trenchfoot

By 24 November, the division staff had become greatly concerned over the increasing incidence of trenchfoot, and certain preventive measures had already been instituted. At a conference called on this date to discuss the situation, attended by the division G–4 (logistics), quartermaster and surgeon and the regimental surgeons of the two regiments most seriously affected, a report was prepared, approved by the division commander, and forwarded to the commanding general of the XIII Corps. The seriousness of the situation was pointed out in this report, and the factors underlying the outbreak of cold injury were outlined.

The incidence of trenchfoot in the 84th Infantry Division, this memorandum noted, had risen precipitously from 2 cases on 10 November to 133 cases on 23 November.[2] Of the 133 casualties recorded for 23 November, 108 were from the 334th Infantry Regiment, the great majority being from the 2d and 3d Battalions. Both of these battalions had been pinned down in foxholes for periods of 12 hours each by heavy artillery and mortar fire. During the week in which the 333d and 334th Infantry Regiments were heavily engaged in combat, rain fell much of the time and water collected, sometimes up to a depth of 2 feet, in the foxholes in which the soldiers were compelled, for tactical reasons, to spend all day and part of the night. Enemy artillery fire repeatedly forced the men in these units to dig in, with the result that they had no opportunity to care for their feet before they were again committed to combat.

Soldiers from the 334th Infantry who were interviewed in the medical collecting station all stated that they had received instruction in the prevention of trenchfoot before they went into the line. They had not, however, been able to carry out the measures recommended. Some of them had not had their shoes off for 6 days. While some of them had changed their socks daily, all of them pointed out that, under the existing climatic conditions, it was impossible to change into dry socks. Most of the men had not removed their shoes as instructed because they were afraid that if they did they would be unable to get them back on. Not all of the troops had had overshoes, but many who

[2] It will be noted that these figures are slightly higher than those presented in table 41. The explanation is that these figures cover all casualties, including those not evacuated from the division, while figures in table 41 cover only the casualties evacuated.

possessed them had discarded them, partly because they were useless in already rain-filled foxholes.

These facts were corroborated in an afteraction report for the month of November by the surgeon of the XIII Corps, who summed up the reasons for the high incidence of trenchfoot in the 84th Division, as follows:

An inexperienced division was engaged in combat for 8 days under the most adverse conditions of weather and terrain. Combat was intense, and some elements were pinned down by enemy fire for as long as 12 hours at a time. Overshoes were not available in large sizes for several days after the battle began, and all troops had not been equipped with their full allowance of socks. The principal causes for these trenchfoot casualties, in addition to extremely unfavorable weather and terrain and lack of equipment for winter operations, were listed as (1) failure to relieve troops at frequent intervals, (2) failure to provide areas for changing and drying wet clothes and footgear, and (3) failure of some troops to carry out the foot hygiene which they had been taught.

Preventive Measures

Even before the conference on trenchfoot was held, the commanding general of the 84th Infantry Division had reacted to the dangerous situation and had been fully supported in his plans by the commander of the XIII Corps. After 22 November, it became division policy to rotate a battalion at a time out of the line, for 2 or 3 days of rest in billets in which hot showers were available. On 23 November, each regiment established a center with facilities for rest and rehabilitation from combat exhaustion. These centers also served as rotation points for combat soldiers to dry themselves out and to obtain changes of socks and of other clothing. By 24 November, enough heavy socks and overshoes were available to equip the entire division. On the same day, a daily sock exchange was instituted. Dry socks were to be brought forward with the rations, and the sodden socks worn by combat soldiers were to be exchanged for them. In practice, this arrangement worked out somewhat less satisfactorily than it sounds, partly because of frequent failures to turn in worn socks and partly because proper sizes were often not available in the socks brought up for replacement.

On 29 November, the commanding general of the 84th Division issued a memorandum to all unit commanders in which he specifically put the responsibility for the control of trenchfoot upon commanders of all echelons. It was made clear that a high incidence of trenchfoot in any unit would be regarded as an indication of command failure in that unit. All officers were instructed to institute daily foot inspections immediately. Command responsibility was interpreted to mean that the inspections would be held not only by commissioned officers but also by noncommissioned officers of platoons and squads; it was desired that these men should realize that the prevention of trenchfoot was quite as much their responsibility as it was the responsibility of commissioned officers.

The memorandum of 29 November also included extracts from pertinent War Department, theater, and army-group directives dealing with the prevention of trenchfoot. It was directed that all commanders familiarize themselves with the details of these extracts thoroughly and at once.

Analysis of Experience

It is improbable that an outbreak of trenchfoot could have been entirely avoided in the circumstances in which these inexperienced troops were thrown, almost abruptly, into intense combat, in flat, waterlogged, muddy terrain, when the mean temperature ranged between 42.5° and 56.5° F. (5.83° and 13.6° C.) and it rained 60 percent of the time. The result was that over an 8-day period a severe point epidemic of cold injury occurred (chart 32, table 41.)

The immediate command response to this experience evidenced good leadership. This is further shown by a statement of the division surgeon in his sanitary report for December 1944. The marked decrease in the incidence of trenchfoot, frostbite, and immersion foot which occurred during this period, the surgeon noted, could be attributed chiefly to (1) frequent inspections by unit commanders and medical officers and (2) the splendid cooperation of the men themselves in following the directives with preventive measures.

29 NOVEMBER–20 DECEMBER 1944

Tactical situation.—On 29 November, the 84th Infantry Division participated in the offensive in which the town of Lindern was captured. Thereafter, the division continued a slow-moving offensive toward the low-lying approaches to the Roer River, and, by 15 December, it had assumed a holding defense facing the river. Terrain and weather conditions were similar to those just described.

Cold injury.—On 29 November, the day the attack began, 6 cases of trenchfoot were reported by the division, and 24 cases were reported the following day. After this date, while trenchfoot continued to occur, the rate was greatly reduced. There were a number of reasons for this improvement, as follows:

1. The combat situation was less intense.
2. Individual and unit preventive measures had been put into operation.
3. Supplies of overshoes and socks were now adequate.
4. Rotation was being practiced throughout the division.

The practices just listed had been effective in spite of the continuation of adverse environmental conditions including continued rain, unfavorable terrain, and the waterlogged and very muddy ground.

Only a few cases of trenchfoot were reported between this date and 20 December 1944, when the course of events abruptly ended the holding action.

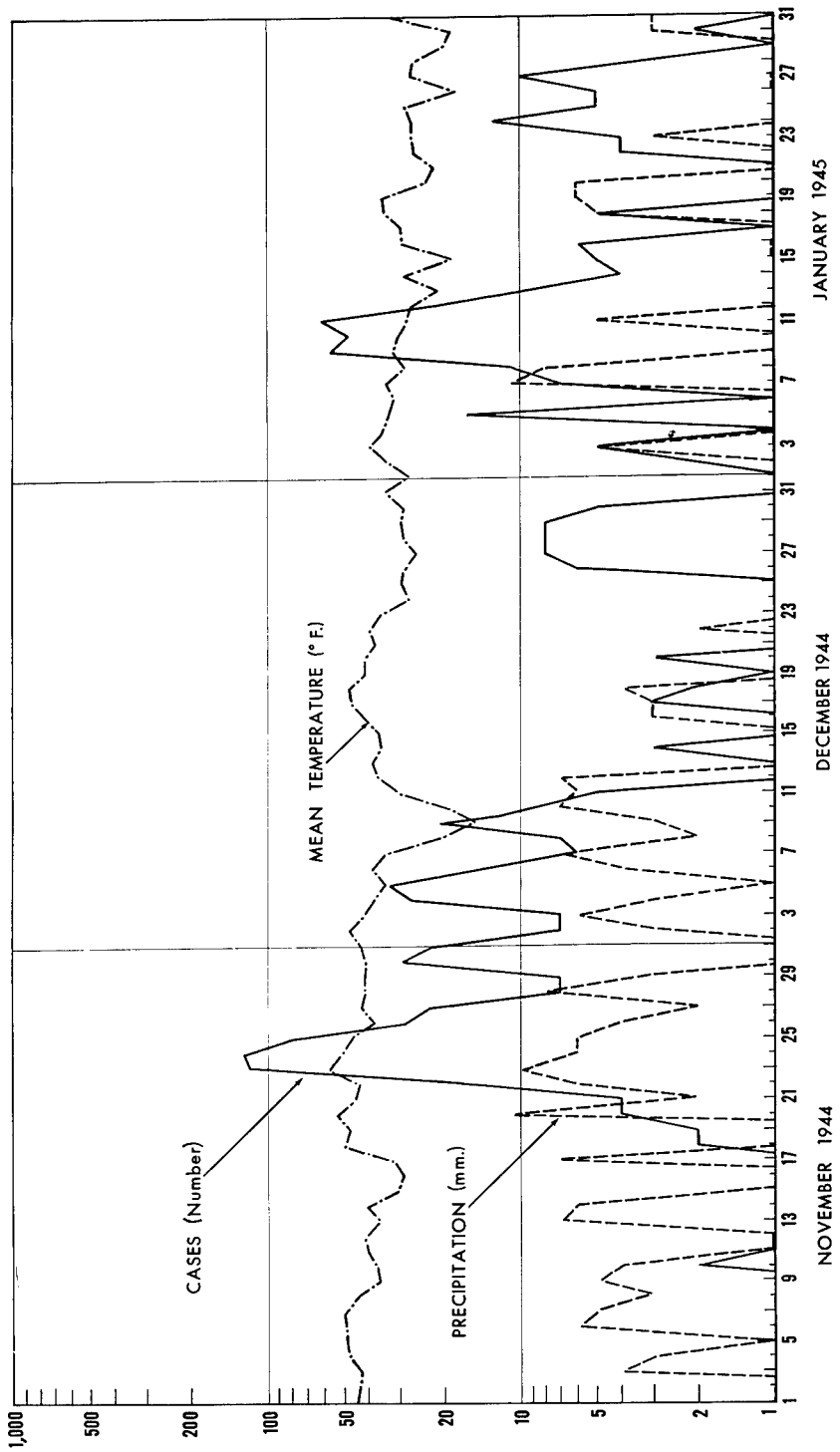


CHART 32.—*Mean temperature, precipitation, and cold injury cases evacuated from the 84th Infantry Division, European theater, 1 November 1944 through 31 January 1945*

TABLE 41.—*Mean temperature, precipitation, and cold injury cases evacuated from the 84th Infantry Division, European theater, November 1944 through January 1945*

[Weather data were prepared by the Air Weather Service Military Climatology Division]

Day of month	November 1944			December 1944			January 1945		
	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases	Mean temperature	Precipitation	Cases
	°F.	Mm.	Number	°F.	Mm.	Number	°F.	Mm.	Number
1	44. 0	1. 0	------	43. 0	0	22	27. 5	0	------
2	43. 5	0	------	47. 5	3. 0	7	34. 0	1. 0	2
3	42. 5	4. 0	------	40. 5	6. 0	7	39. 5	5. 0	5
4	47. 5	3. 0	------	38. 0	3. 0	27	34. 5	1. 5	1
5	49. 0	1. 0	------	34. 0	1. 0	33	33. 0	0	16
6	49. 0	6. 0	------	38. 5	4. 0	14	31. 5	0	1
7	50. 0	5. 0	------	34. 0	7. 0	6	34. 0	11. 0	7
8	44. 5	3. 0	------	20. 5	2. 0	7	28. 5	8. 0	11
9	36. 0	5. 0	------	15. 0	3. 0	21	31. 5	1. 0	57
10	37. 5	4. 0	2	19. 5	7. 0	12	30. 5	0	48
11	40. 0	1. 0	1	30. 5	6. 0	5	28. 0	5. 0	62
12	40. 5	1. 0	1	36. 5	7. 0	------	27. 0	0	22
13	36. 5	7. 0	------	38. 5	0	1	21. 0	0	9
14	40. 5	6. 0	1	35. 5	0	3	29. 0	0	4
15	30. 5	1. 0	------	36. 5	0	------	18. 5	1. 0	5
16	29. 0	0	------	41. 5	3. 0	------	29. 5	1. 0	6
17	31. 5	7. 0	------	47. 0	3. 0	3	30. 0	0	1
18	48. 5	. 5	2	48. 0	4. 0	2	34. 5	5. 0	5
19	47. 5	. 5	2	40. 5	0	1	35. 5	6. 0	------
20	53. 0	11. 0	4	40. 5	0	3	23. 5	6. 0	------
21	45. 5	2. 0	4	37. 0	0	------	22. 0	0	------
22	42. 5	6. 0	17	39. 0	2. 0	------	26. 5	0	4
23	56. 5	10. 0	118	35. 5	0	------	27. 0	3. 0	4
24	50. 0	6. 0	125	27. 5	0	1	27. 0	0	13
25	46. 0	6. 0	77	29. 5	0	------	28. 5	0	5
26	38. 5	4. 0	29	28. 5	0	6	18. 0	1. 0	5
27	43. 0	2. 0	23	26. 0	0	8	27. 0	1. 0	10
28	41. 5	8. 0	7	29. 0	0	8	26. 5	. 5	3
29	41. 5	3. 0	7	29. 5	0	8	20. 0	0	1
30	40. 5	0	30	29. 0	1. 0	5	19. 0	3. 0	2
31	------	------	------	34. 0	0	------	32. 0	3. 0	1
Total	------	------	450	------	------	210	------	------	310

21 DECEMBER 1944–2 JANUARY 1945

Tactical situation.—On 20 and 21 December, the entire 84th Infantry Division was withdrawn from its position facing the Roer River and moved southeastward to Marche, Belgium, where it was to enter into an extremely active defensive operation against the German midwinter counteroffensive and was also to participate in the American offensive that followed. The suddenness

of the German attack required the immediate marshaling of all defensive resources, as well as the assignment to individual units of missions that under less urgent circumstances would have been considered ill-advised military policy. The perilous situation in the vicinity of Marche, as well as the confidence of the Germans in the success of their offensive, is illustrated by the following excerpt from the surrender note which they dropped on Bastogne on 22 December: "The fortune of war is changing. This time the USA forces in and near Bastogne have been encircled by strong German armoured units. More German armoured units have crossed the River Our near Ourtheville, have taken Marche and reached St. Hubert by passing through Homores-Sibret-Tillet."

The Germans proved to be somewhat overconfident. Late in the day on 21 December, the 334th Infantry Regiment of the 84th Division arrived in Marche, which was never taken. By nightfall of the following day, the entire division was settled in and around the town, under the control of the VII Corps, First U. S. Army. For the first 3 days, the division operated in a military void, without friendly forces on either flank. In effect, it constituted an island of defensive resistance against the *2d SS Panzer Division* and the *116th Panzer Division*. By 22 December, the 12-mile-long line between Hampteau and Hogne required the spacing of foxholes 150 yards apart.

The lack of intelligence and the confusion of the situation led the 84th Division commander to undertake probing reconnaissance operations to the west and southwest of Marche. The 3d Battalion of the 335th Infantry was given the former mission, and the 1st Battalion of the 333d Infantry the latter. Each battalion, in advances in excess of 10 miles each from Marche, ran into heavy enemy resistance. At this time, the 3d Battalion was all that was in front of the *2d Panzer Division*. The good leadership and aggressive concept that inspired these probing tactics can be considered responsible for deflecting the German drive to the south of Marche, at a time when armor had not yet been brought up to the support of the 84th Division, but the German advance, nonetheless reached to within 4 miles of Dinant on the Meuse River and acutely threatened the encirclement of Marche.

By 24 December, the 84th Division had dug in on the front at both ends of the Marche-Hotton road. Its flanks, meantime, had been filled in, on the right by the 2d Armored Division and on the left by the 3d Armored Division. Great tank battles raged around Celles, and the *116th Panzer Division* tried, without success, to crack the center of the divisional line. The German attack on the town of Verdenne and a counterattack by the 84th Division to wipe out an enemy pocket collided head on. The Germans took the town temporarily, but it was soon retaken by the 84th Division, after a seesaw battle.

A second attempt, supported by tanks, to reduce the pocketed enemy forces proved a difficult operation, but, by the night of 26 December, the divisional line had been straightened out. A strenuous attempt by the Germans to break through the lines at Menil did not succeed and ended by dark on 27 December. This battle is regarded as the operation that finally broke the German drive toward the Meuse River.

German forces engaged in the Battle of the Bulge were contained by both British and American forces. The Third U. S. Army struck from the Bastogne area in the south, the First U. S. Army counterattacked from the north on both sides of Manhay, and the British Corps operated to the west from Marche. Logically therefore, British forces took over the position of the 84th Division at the end of the defensive operation. The division then moved northward on 1 January 1945, to join the 83d Infantry Division and the 2d and 3d Armored Divisions under the First U. S. Army and to take part in a difficult counteroffensive in the Ardennes. The changeover was effected by a complex, sideslipping movement, over narrow, icy roads, but in spite of these difficulties the 84th Division managed, within approximately 36 hours, to complete its relief and concentration in a new area.

Cold injury.—Up to 25 December, although the combat was more intense than the division had ever before experienced, the incidence of trenchfoot remained low (table 41, chart 32). For this, there were a number of reasons:

1. Although the temperature range was favorable for the development of trenchfoot, very little rain fell.
2. The terrain was rolling and hilly, in contrast to the flat ground over which the division had fought on the approaches to the Roer River.
3. The many villages in the sector provided more protective shelter than had been available during the early experience.
4. The division had profited by its cold injury experience in November.

After 24 December, the mean daily temperature was below freezing (table 41, chart 32), and cold injuries, made up of both trenchfoot and frostbite, increased sharply. Up to this time, the division had not experienced frostbite, with which it was destined to become intimately acquainted during January.

3–16 JANUARY 1945

Tactical situation.—As a part of the First U. S. Army counteroffensive made from the north in the Battle of the Bulge, the 84th Infantry Division, teamed with the 2d Armored Division, spearheaded the principal advance. The attack, which was launched between the Ourthe and the Salm Rivers, had as its primary objective to take the ground between the rivers and reach the city of Houffalize, which was a key strategic point. The 84th Division was assigned the zone between the Ourthe River and the Houffalize road, which split the sector between the two rivers; this zone was cut by a small river, the Aisne. On the right of the division was the 2d Armored Division and on the left were the 83d Infantry Division and the 3d Armored Division. The secondary objective was to cut the vital crossroads at La Roche, which furnished the key to egress and ingress for German supply transportation. The first attack was largely an infantry effort, with armor in support. The type of terrain and the condition of the roads made the full use of tanks impractical. German opposing forces consisted of the *2d SS Panzer Division* on the right, the *560th*

Volksgrenadier Division in the center, and the *12th Volksgrenadier Division* on the left.

The 84th Infantry Division jumped off at 8:30 on the morning of 3 January 1945. For a few days, the 335th Infantry was on the right flank, bearing the brunt of the attack. The 333d Infantry on the left had easier going. The 334th Infantry was in reserve. Four days of fighting, the most difficult the men of the 84th Division had ever experienced, saw the capture of the villages of Beffe and Devantave and the ultimate occupation, on 7 January, of the commanding Consy Ridge and its village. The severe weather and the type of terrain continued to make the tanks largely ineffective, and the fighting was chiefly by the infantry.

On 11 January, the La Roche road was cut. On 13 January, the 333d Infantry captured Les Tailles and jumped off toward Dinez. On the same day, the 335th Infantry, which by this time had been fighting steadily for 8 days, captured Samrée, on the top of an 1,800-foot hill. By the end of the day, the same regiment had also captured Berismenil and Nadrin. These operations had denied the enemy access to the critical crossroads at La Roche. The morning of 15 January, Houffalize was made untenable by the 1st Battalion of the 335th, which had taken Hill 430, overlooking the city, and the 2d Armored Division moved in to occupy it.

From 11 January onward, elements of the 84th Infantry Division had been in the area in which they might expect to meet patrols from the Third U. S. Army. On 15 January, a 33-man patrol was sent out from the village of Filly, with the expectation of making a rendezvous with a similar patrol from that army. The original rendezvous point had been changed, however, and it was not until the next day, 16 January, that the patrol from the 84th Division sighted a United States soldier in the yard of a Belgian farmhouse and, upon challenging him, learned that he was with a patrol from the Third U. S. Army. As one of the histories of the 84th Division recorded, "The second rendezvous point was the home of a farmer with a pretty 22 year old daughter."

After 13 days of difficult and intensive combat, in extreme cold, over an unfavorable terrain, the 84th Division was given a 5-day rest, until 21 January, in the vicinity of Barvaux, Belgium. This period was also used for reorganization and for the servicing of equipment.

The terrain over which the fighting just described had occurred was rolling and heavily forested; some of the hills reached a height of 1,800 feet above sea level. There was a maze of tiny villages astride the roads and trails, each of which was a potential enemy strong point.

On the first day of the attack, snow, sleet, and rain fell. The temperature dropped, and snow in the hills in some areas was knee deep. Snow continued to fall during the first week, sometimes lightly but on two occasions with blizzard intensity. The temperature sometimes fell to 13° F. (−10.6° C.). The roads were icy. The woods were dense, and the trails became invisible. At times, the mist was so thick that visibility was limited to 30 or 40 yards.

The resistance of the enemy was heavy, and both weather and terrain favored their activities. They could fall back from one village to another, and from one prepared hilltop to another, which made attack doubly difficult.

The problem of cover was critical during this time. It took 2 hours to dig through the frozen crust of the ground and 5 hours to dig a foxhole 3 feet deep. Sleeping was an equally serious problem, because of the danger that exposed parts of the body would freeze. Water froze in the canteens and rations, and other supplies could be brought up to the front only in halftrack vehicles and by hand carry.

Under these unfavorable circumstances, the infantrymen of the 84th Division fought long and hard. Those who engaged in the reduction of Beffe and Devantave were in combat 96 hours without a break. The aggressiveness of United States forces in pushing attacks under such conditions eventually made German reliance on the weather a serious mistake. On several occasions, the enemy was taken completely by surprise, and once they were even found asleep when a village was taken by the Americans.

Cold injury.—During these 13 days of hard fighting, the 84th Division suffered no trenchfoot, but frostbite was in evidence in all combat units (chart 32). In the narrative history of the divisional operations for this period, it was noted that "frostbite was as dangerous as all Krauts and their guns put together." Five cases occurred on the first day of the attack (3 January), and between 1 and 16 cases were reported daily until 9 January. A precipitous rise to 57 cases occurred on this date, and a fluctuating point epidemic, with a high incidence of 62 cases on 11 January, was maintained through 12 January. Nine cases were reported on 13 January, but no more than six on any day thereafter until 16 January, when this period of fighting ended.

The absence of trenchfoot and the prevalence of frostbite during this period are readily explained. While the average precipitation reported for the First U. S. Army area is at variance with the divisional records for this time, precipitation as such, since it was in the form of snow, did not directly influence the incidence of frostbite. On the other hand, the deep snow which covered the already difficult terrain undoubtedly did interfere mechanically with operations, and, by increasing fatigue and prolonging exposure, it contributed, at least indirectly, to the occurrence of cold injury.

The point epidemic of frostbite which occurred between 8 and 14 January is chiefly attributable to below-freezing temperatures, the severe type of combat action, insufficient protective clothing (p. 144), lack of shelter, and the tactical impossibility of practicing rotation of troops. All divisions on the Western Front experienced cold injury when they were first exposed to extreme cold. The 84th Infantry Division was no exception. However, in view of its difficult mission and the moderate nature of the epidemic of frostbite which it sustained, it must be concluded that by this time this unit had become a seasoned and battlewise fighting force.

16–31 JANUARY 1945

Tactical situation.—After a rest period of 6 days, beginning 16 January, the 84th Division took the offensive on 22 January, with the specific mission of reducing the villages of Gouvy and Beho, midway between Houffalize and Saint-Vith. Two days of bitter fighting ensued, characterized by heavy resistance and hard enemy counterattacks, before the mission was completed on the night of 23 January. Mopping-up and defense operations occupied the troops until 27 January, when the division was moved to the vicinity of Harzé, Belgium. The rest of the month was spent here, in rest, reorganization, and maintenance of equipment.

At the conclusion of this phase of divisional operation, and upon the occasion of the detachment of the 84th Infantry Division from the VII Corps, the commanding general of the division received from Maj. Gen. J. Lawton Collins, Commanding General, VII Corps, a letter of commendation. In this letter, the general expressed his appreciation of the splendid combat record of the division and of the vital part which it had played "in closing out the ill fated attempt of the German Fifth Army to break through the Ardennes."

Cold injury.—Although the division entered combat after a rest period and although the tactical situation was not as intense as it was earlier in the month, cold weather and difficult terrain again caused an upsurge in the incidence of frostbite during this period (table 41, chart 32). Thirteen cases were reported on 24 January and ten on 27 January. For the remainder of the period of combat the daily number of cases was five or less.

2 FEBRUARY–5 MARCH 1945

Tactical situation.—On 2 and 3 February 1945, the 84th Infantry Division moved to a new assembly area in Holland, in the vicinity of Waubach. The period 4 to 6 February was spent in resting and in reorganization and maintenance of equipment. This was familiar territory, in which the division had seen its first combat. Its new mission was to prepare for crossing, and then to cross, the Roer River and to exploit the bridgehead toward the Rhine. The original plan was to cross the Roer on 9 or 10 February. With this in mind, rigorous training, with practice crossings of the Würm River, was carried out on 6–8 February. On 9 February, the crossing was postponed for 24 hours, and, on 10 February, it had to be postponed indefinitely because the enemy released the water behind the dams guarding the great reservoirs fed by the Roer. The result was the artificial flooding of the river in the area occupied by the 84th Infantry Division. The river rose to an excess of 11 feet on 10 February and remained at nearly 10 feet for the rest of the month.

During this time, training was intensified, and maneuvers identical to those involved in the actual Roer crossing were carried out several times by each unit, both in the forward area on small streams and in the rear on the Meuse, which in width, depth, and current is similar to the Roer River. Each battalion designated to make the crossing rehearsed for it completely six times. On 19 and 20 February, the final training was received on the Meuse River.

The 1st Battalion of the 334th Infantry crossed the Roer early in the morning of 25 February. By the end of the day, a two-regiment front, driving toward the north, had been established on the far shore, and armor had crossed and had been brought to bear against the enemy. Resistance was irregular and was only moderately heavy. Evidently, the Germans had been thrown off balance by the division's turning to the north when they had expected a straight eastward drive to the Rhine out of the Roer bridgehead. Soon afterward, as the enemy defense deteriorated and became disorganized, the division, in an aggressive attack, drove steadily northward and then turned east, reaching the Rhine by 5 March. The bridges in this sector had been blown up while the division was approaching the river, and therefore, after mopping-up operations, it entered a holding phase on the west bank of the river.

At the conclusion of Operation GRENADE (the crossing of the Roer River and the advance to the Rhine), Lt. Gen. W. H. Simpson, Commanding General, Ninth U. S. Army, sent a letter of commendation to the commanding general of the 84th Infantry Division. In this letter, note was taken of the three phases of combat operation in which the division had participated, beginning with the reduction of Geilenkirchen, going on through the Battle of the Bulge, and ending with the crossing of the Roer River and the advance to the Rhine. It was also noted that the 84th was one of the few divisions engaged in the operation which had fought all the way from the Roer River to the Rhine without ever losing momentum.

While training was in progress near Wauback, temperatures were above freezing, and the February thaw gave rise to much mud and wet. Though there was no great exposure after 4 February, cover was not adequate. Many of the men lived in tents, the dirt floors of which were always wet and muddy.

Cold injury.—Trenchfoot did not occur in the 84th Division during the training period of Operation GRENADE, although temperatures and environmental conditions were ideal for its development. There were no cold injuries of any kind during the advance to the Rhine, and only nine cases, all of which were frostbite cases, during the crossing of the Roer. It may be significant, as the divisional history notes, that "orientation, sanitation and trenchfoot prevention rounded out the training phase" of the Roer-Rhine action. It is probably also significant that, during this time, although there was some resistance which at times was moderately heavy, the stress of combat action was lacking.

ANALYSIS OF THE TOTAL EXPERIENCE

From the standpoint of cold injury, the experience of the 84th Infantry Division falls into three distinct periods.

First period.—During this period, in which the division experienced its first combat, the high incidence of trenchfoot demonstrates the great susceptibility of inexperienced troops to this type of cold injury, even when they have had training before combat in its prevention. This phase of the experience also shows that the incidence and severity of cold injury are considerably influenced by the type of combat, the availability or lack of shelter, and terrain. Finally, it demonstrates conclusively that, even among new troops, trenchfoot can be brought under control by good leadership, the vigorous application, collectively and individually, of appropriate preventive methods and procedures, and adequate supply of the proper clothing, and regular rotation of individuals and units.

The concern felt in both division and corps over the initial high incidence of trenchfoot led to prompt investigations to determine the causes of the outbreak. The surgeon of the XIII Corps listed the causes (stated them), as follows, in his annual report of medical department activities for 1944:

1. The terrain was extremely unfavorable because it was naturally soft and boggy. Rain fell nearly every day of the operation, and mud was deep and constantly present.

2. The tactical situation did not permit relief of troops from frontline duties, even for short periods.

3. The supply of overshoes was inadequate, and those which were available were often used incorrectly. Many men threw them away. In one regiment, they were taken away by order.

4. The supply of socks was inadequate. Many units had only one pair of socks per man.

5. Shoes had not been properly fitted. Many men were wearing sizes too small for military purposes, in that they would not comfortably accommodate a second pair of socks. Also, after the shoes became wet, shrinkage was sufficient to cause constriction of the circulation.

6. Tactical circumstances made it difficult or impossible for the men to remove their shoes and socks. Even when this was possible, many were afraid to take them off, for fear, that in case of an attack, they might not be able to get them on again quickly enough, if at all. Removal of the footgear, for that matter, seemed useless, since there were no facilities for drying shoes and socks.

7. Although the great majority of the troops were aware of the signs and symptoms of trenchfoot, appreciated its dangers, and had been taught how to prevent it, many of them failed to practice what they had been taught.

Once the responsible factors were fully understood, a vigorous campaign was initiated to reduce the incidence of trenchfoot. It was extremely effective. Components of the regimen were as follows: (1) Frequent rotation of frontline troops; (2) provision of drying rooms; (3) provision of overshoes; (4) provision

of dry socks daily, or as frequently as possible, by bringing them forward with the rations; (5) instruction of unit commanders by medical officers; (6) thorough indoctrination of the troops; (7) daily foot inspections or inspections as often as the tactical situation permitted; (8) diagnosis of trenchfoot only after a careful history has been taken and an equally careful examination has been made at the clearing station; (9) use of questionnaires in determining the causes in each individual case of trenchfoot; and (10) requirement that explanation of high incidence of trenchfoot in any unit be made by the commander of the unit.

Second period.—The second period of combat activity in the 84th Infantry Division provided additional evidence of the universal susceptibility of both experienced and inexperienced troops to frostbite (which was then the prevalent type of cold injury) when combat is intense. The rates, however, were never as high as those in the epidemic of trenchfoot in the first period. This phase of the experience therefore clearly demonstrates that, even under the most trying conditions of combat, terrain, and weather, a well-led unit, with high morale and good individual training, can function without unduly high losses from cold injury.

Third period.—In the third period of the 84th Division's combat experience, there were no cases at all of trenchfoot and only nine cases of frostbite. The circumstances and terrain were ideal for the production of trenchfoot. This was the period of the February thaw. Precipitation was moderately heavy. The terrain was low and muddy. The temperature ranged between 40° and 50° F. (4.44° and 10.0° C.). Most elements of the division were living without adequate shelter. Training was intensive. Many river crossings were necessary. Actual operations required the crossing of the Roer River, the establishment and exploitation of a bridgehead on the far shore, and a drive to the Rhine. The complete absence of trenchfoot under circumstances so highly propitious to the development of the condition seems to demonstrate conclusively the importance of the type of combat action and the psychological response of competent troops in aggressive and victorious tactics.

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CHAPTER XV

The Prevention and Control of Cold Injury

GENERAL CONSIDERATIONS

The fundamental principles of the prophylaxis of cold injury were in large part developed during World War I (p. 45). It is extremely unfortunate that they were not recollected and promptly put into practice in the United States Army in World War II. If this had been done, many thousands of casualties from cold injury would almost certainly have been avoided.

In World War II, the trenchfoot experience in the Aleutians (p. 83) was brief because the campaign itself was brief; as a result, no formal program of prevention and control was instituted. In the Mediterranean Theater of Operations (p. 101), it took a bitter experience in the winter of 1943–44 to demonstrate the need for the program which was put into effect, with excellent results, during the winter of 1944–45. In the European Theater of Operations (p. 127), the cold injury experience in the winter of 1944–45 was even more disastrous than the early Mediterranean experience. Eventually, an effective program of prevention and control was put into effect in the European theater, but only when it was too late to prevent the major losses from cold injury which had already occurred. Had the war in the Pacific continued into the winter of 1945, there seems little doubt that losses from this cause could have been kept at an acceptable level. The program of prevention and control which had been set up and which was in the process of implementation when the war ended was based on sound principles. It involved the cooperative efforts of the Quartermaster Corps, the Medical Corps, and command, and it incorporated the lessons that had been learned in the Mediterranean and European Theaters of Operations.

The key to the prevention of undue losses from cold trauma is full appreciation by all personnel, on all levels, of the fundamental fact that weather is a bitter enemy, quite as capable of causing casualties as is a human enemy. Measures of prevention and control must be based on this concept and on the additional concept that, even if military operations must be undertaken in winter, it is not inevitable that cold trauma of significant degree occur in association with them.

A brief experience in the Pacific showed that a certain type of cold injury may occur even in warm weather (p. 211). The danger of this form of trauma is therefore not imaginary when a war must be prosecuted in a theater located in a climate in which winter temperatures fall below 50° F. During certain periods of winter fighting in Italy and in western Europe, as has been pointed out

elsewhere, cold injury was second only to combat casualties as a cause of disability and a loss of man days. In some units, under some circumstances, losses from this cause were even greater than losses from combat injuries. On the Western Front, the numerical loss from cold injury amounted to about three divisions In terms of military effectiveness, the loss was nearer 12 divisions, since 90 percent of the casualties occurred in combat infantry riflemen, who made up about a quarter of each division. No fighting forces can afford such losses over any considerable period of time, particularly since the outlay of personnel, training effort, and time required for the application of preventive measures, in comparison with the outlay required to train combat replacements, is so small and gives such gratifying results.

Of course, not all losses from cold injury can be prevented, and the accomplishment of urgent objectives may sometimes be worth a high price in casualties from cold as well as in the more usual combat losses. It is quite possible, in fact, that on occasion the calculated risk may be worth the cost. That gamble was made at least once in World War II (p. 209). But the risk can be assessed, and the decision concerning it made, only by a command thoroughly appreciative of the danger from cold injury and of the possible scale of losses from it. The responsibility for such decisions clearly furnishes one more reason why there must be a full understanding, by all echelons of command, of the total implications of cold injury in all winter combat operations.

Attention has been called elsewhere (p. 181) to the vigorous program of preventive measures instituted by a regimental combat commander who happened to see, in the hospital in which he was a patient for another cause, precisely how serious trenchfoot can be. Another commander of an infantry regiment was wise before the event. An observer for the Army Ground Forces Board, NATOUSA,[1] quotes him as saying:

> I wrote a monograph at Benning in 1928–29 on the subject of the care of the feet. I thought it was an important subject then, though some other people did not. It is still one of the most important subjects for an infantry officer to know. Trench foot is one of the major causes of non-battle casualties and a non-battle casualty reduces your combat strength just as much as does a battle casualty * * *. The remainder of this regiment [he excluded the Japanese-American component, which for various reasons had a high rate] has consistently had the lowest trench-foot rate among the infantry of the division. This, I am sure, is largely due to the emphasis we have placed on care of the feet. I have personally conducted a school on care of the feet for the junior officers of the regiment. We require every man to go into combat with a clean, dry pair of socks inside his shirt and we require platoon leaders to see that their men change wet socks for dry ones, and massage their feet, whenever it is at all practicable. If Benning does not already have it in its officer-candidate course, it should include a short course on care of the feet. The instructor should be a competent doughboy who has done a lot of marching and knows how to take care of feet in wet, cold weather. I don't think that anything that Benning can teach its students is of more importance.

If this sort of down-to-earth concept of cold injury and of methods of preventing it had been common at all levels, casualties from this cause would

[1] Report on Infantry, Army Ground Forces Board, Army Ground Forces Headquarters, NATOUSA, 27 Mar. 1944.

promptly have been reduced to a minimum. Soldiers who contracted trenchfoot might have been ignorant of its dangers and of methods of prevention, but they were shrewd enough to figure out what they should have been taught, as the following letter shows. It was written to his ward officer by an enlisted man hospitalized with trenchfoot in a hospital in Italy: [2]

Not a single person I talked to, out of many in the hospital with trench foot, had ever heard of the ailment until he was told that he had it. Since it is putting so many men out of action, I think it would be well worth an effort on the Army's part to inform the soldier on the subject before and not after he has it. Printed matter on the subject is all right but too often printed matter is discarded, before reading, as nonsense. If not replaced by, printed matter on the subject should at least be supplemented by a talk given to soldiers by a medical officer.

Naturally, the talk should emphasize the ill effects of the ailment rather than describe it as a means of getting back to the hospital for a rest. Description should be made of its worst possible effects, such as damage to blood vessels and gangrene setting in making amputations necessary. If possible, show pictures of and describe worst cases, giving length of time confined (not walking) and possible discomforts of the feet after the war is over. Then the soldier should be told what he can do to keep from getting trench feet.

Although it would probably be a good thing to do, no soldier has much of an urge to take his socks off while in actual combat. However, he should be supplied with and carry at least one pair of socks with him and be urged to change them at the first opportunity. If socks to be carried in the pack could be sealed in a cellophane wrapper or canned in something like a ration tin, they would have a better chance of being dry when the change was made.

Back in a bivouac or rest area sleeping with shoes and socks on should be discouraged. Shoes and feet should be dried out. During the day, especially if the sun is out, feet should be aired * * *. Whenever it is practicable to get shoes off, whether at night or during the day, feet should be massaged to stimulate circulation. Because of differences in circulatory systems, some persons are, undoubtedly, more susceptible than others. Nevertheless, much can be done, as preventative measures, by the individual soldier.

The supply sergeant should make an honest effort to see that the soldier is frequently given a pair of clean, dry socks. During wet seasons, shoes should be waterproofed when given to the soldier. Even if his shoes are waterproof, the soldier should either change his socks or air and dry his feet and socks to rid them of dampness due to perspiration.

Officers and Non-coms should be held responsible for seeing that each soldier takes care of his own feet, both in beneficial practice and in making the best use of what supplies he has.

Company feet inspections would be more effective, as a preventative measure, than the individual reporting on sick book.

The soldier should first be informed, and then guided. Don't rely too much on the soldier's own initiative in the matter.

PREVENTIVE PRINCIPLES AND PRACTICES

The approach to the problem of prevention and control should be entirely realistic. The agent role of cold or wet cold in the production of cold injury is fairly well understood. The weather cannot be altered. If operations are planned under winter conditions, the weather must simply be accepted and compensated for. Similarly, once tactical objectives have been established, intensity of combat action and the terrain to be fought over must also be

[2] Report, Lt. Col. F. A. Simeone, to Surgeon, Fifth U. S. Army, subject: Trench Foot in the Italian Campaign 1943–45, 1945.

accepted. Little can be done to ameliorate their adverse effects. Shelter, like the weather, is largely fortuitous. Not much planned provision can be made for it.

What are those things about which something can be done? Several cold injury modifying factors (p. 366) can be influenced deliberately. It has been shown that the degree of training, the level of unit and individual discipline, the adequacy of supply and the extent and effectiveness of the rotation practice are readily amenable to good staff and command practices. The organization to accomplish these purposes likewise is readily established and easily directed.

Although it has been recognized since World War I that the prevention and control of trenchfoot are command functions, almost everything written on the subject in World War II appeared in the medical literature, and with few exceptions the directives, circular letters, and other official documents dealing with cold injury either originated in the Medical Corps or were inspired by medical officers. Quite early in the war, medical officers in the Surgeon General's Office (p. 57) and in overseas theaters became impressed with the necessity for adequate prophylaxis against cold trauma, an important reason for their concern being their realization that there were no rapid and effective methods of therapy. Summaries of preventive practices began to reach the literature soon after trenchfoot first appeared in the Mediterranean theater, and they continued to appear until the end of the war. Most of them, however, quoted or reflected official Army policy. Few represented new contributions.

By the end of World War II, adequate principles and procedures for the prevention of trenchfoot and other forms of cold injury had been formulated and published. These presentations, however, were applicable only to individuals and to small military units. There were no similar publications in which were set forth the organizational, administrative, and technical principles and practices applicable to the prevention and control of cold trauma in large military organizations. This need has not yet been met. This chapter, therefore, has two purposes, to outline the general principles of the prevention of cold injury and, in addition, to propose an organizational setup by which the mass prophylaxis of cold injury can be accomplished. The principles of prevention and control are, in themselves, simple. On the other hand, the organizational and administrative practices necessary to secure their implementation and continued application cannot be left to chance.

Elements of prevention and control.—Any discussion of the management of cold trauma should begin with the unqualified statement that neither prevention nor control can be accomplished without competent, interested command supervision. The success or failure of the effort depends upon this factor. When command supervision is available, as the experiences of both World War I and World War II make clear, the incidence of cold injury can be kept at an acceptably low level.

The essential elements of prevention and control include the following: (1) The provision of ample supplies of clothing and footgear which are properly sized, well fitted, correctly worn, and always readily available; (2) the mainte-

nance of good foot and clothing discipline; and (3) the rotation of the individual soldier within his unit and the rotation of whole units out of the line.

The maintenance of good foot and clothing discipline implies the training of the individual soldier in the personal prevention of cold injury. Each man must carry extra socks with him. He must change them once daily, and preferably oftener. He must remove his shoes when he goes to sleep. He must massage his feet at regular intervals. He must so fully understand the necessity for movement that he will automatically exercise his feet and legs whenever he can, even if he can do no more than tap his feet or wiggle his toes in his boots. He must also understand the necessity for seeking medical care promptly when he suspects that he has sustained a cold injury. Many of these things are difficult to do in frontline combat, and they will not be done in the absence of good discipline and constant command supervision.

The rotation of the individual soldier involves his removal from a frontline position to a dugout, a tent, the basement of a damaged building, or some other improvised shelter where he can rest for an hour or longer, change his socks, dry his clothes, and secure hot coffee or some other hot drink. If this sort of individual rotation can be carried out daily, or at least within the 48- to 72-hour period regarded as the incubation period for trenchfoot, the soldier will be out of the line for only brief periods and for only a few hundred yards, but the chances of his developing cold injury will have been considerably reduced.

The second type of rotation implies the rotation of a battalion, a regiment, or some other military unit out of the line into a reserve position in the division area or farther back in the corps or army area. This type of rotation concerns a total military organization, in contrast to individual rotation. Both types should be practiced on a planned and regular basis unless the combat situation absolutely forbids it.

It is the responsibility of command that the measures just outlined be planned and implemented. This implies command responsibility for the provision of clothing, for its ready availability, and for its proper utilization; for the provision of hot food and drink for the individual soldier as often as is possible; for the enforcement of foot discipline; for the provision of warming and drying devices and their utilization as often as is feasible; and for insuring that men with complaints referable to their feet, whether or not the symptoms are regarded as caused by cold trauma, be sent to the rear promptly for medical advice, as a prophylactic measure, or for medical treatment if that should be necessary.

If the indoctrination of all personnel has been properly carried out and if the simple measures just described are instituted and employed whenever the tactical situation does not absolutely prevent them, the incidence of cold injury in winter combat will be greatly reduced. Furthermore, once such a program is made an integral part of unit training and discipline, a minimum of command supervision will be required above battalion level. If the details are well carried out, company by company, platoon by platoon, and squad by squad, the

program will be certain to yield dividends, not the least of which will be the retention in combat of effective and essential personnel.

Clothing.—Clothing plays so important a role in the success of a program of prevention and control that, even at the expense of some repetition, certain points must be emphasized again:

1. Adequate supplies must, of course, be provided in the army and the division area, but their provision there is useless unless they are brought forward and made readily available to meet the needs of the individual soldier in the most advanced outpost.

2. Clothing includes more than the uniform. Shoes, shoepacs, gloves, socks, and sleeping bags must also be provided. Footgear fully adequate for protection may be canceled out by inadequate covering of other parts of the body, and vice versa. Footgear and clothing completely adequate for operations in cold temperatures and in dry snow offer little or no protection in valleys where the temperature is higher and where wetness as well as cold may produce numbers of casualties from trenchfoot.

3. The individual soldier must be taught how to wear the clothing provided so that it will furnish the most effective possible protection against exposure.

4. The daily sock exchange is an essential phase of the program of prevention. It requires the provision of enough socks, of proper sizes, to permit the exchange, which is best effected, as the World War II experience showed, by bringing the clean, dry socks forward with the daily rations.

5. Provision must be made not only for the original issue of clothing but also for the reequipment of men who may have lost or discarded parts of their uniform in combat. Reissue involves collection and salvage, as well as the issue of new clothing as necessary, and therefore has economic implications. The economic aspect, however, must be subordinated to a more important consideration, that the period of exposure of the combat soldier must not last any longer than is absolutely necessary.

Individual instruction.—The soldier should receive individual printed instructions concerning foot care in addition to the mass instruction in the prevention of cold injury which he receives as part of his training. The Preventive Medicine Section, Office of the Surgeon, NATOUSA, in its annual report for 1943 set forth the following essential facts concerning the prevention of trenchfoot which the individual soldier should know:

1. Trenchfoot is produced by standing or sitting about over a long period of time with cold, wet feet. Intense cold is not necessary for its development. It can occur when the temperature is 50° F. (10° C.) or higher. The most important causes are moisture, cold, and lack of activity. Trenchfoot is frequently associated with constriction of the limbs by boots and tight clothing.

2. In the early stages of trenchfoot, the feet feel heavy, wooden, and numb. They are insensitive to pain, touch, or temperature, particularly around the toes. At this time, they are usually cold to touch. They are swollen and

white except for a few scattered bluish areas. If they are warmed rapidly—which they should not be—they become first red, then purple, hot, greatly swollen, and painful. Sometimes blisters appear.

3. Once trenchfoot has been incurred, the patient should be sent promptly to a hospital where he can be treated adequately. In the meantime, he should not be permitted to walk. His feet should not be warmed. They should not be massaged. Instead, they should be kept cool and should be elevated above the level of the trunk. If trenchfoot is not handled according to these directions, serious disability and possible loss of the feet may follow.

4. Since the treatment of trenchfoot is far from satisfactory, it is of the utmost importance that this condition not be permitted to occur. It can be prevented by keeping the feet clean, dry, and warm. Under winter combat conditions, it is not always possible to achieve these objectives, but constant attention to certain preventive measures will reduce or prevent occurrence. Seeing that preventive measures are carried out is the responsibility of the commanding officers of units. Observing them is to the best interests of the individual soldier, as well as of his outfit.

Among preventive measures recommended in the report are the following:

1. Frequently (once or twice daily, at least) remove shoes and socks. Wash, dry, and massage the feet. Apply foot powder. If possible, put on clean, dry socks; if this is not possible, wring out the wet socks until they are as dry as possible.

2. No matter how cold it is, do not sleep with shoes on, particularly if shoes and socks are wet. This practice interferes with the circulation of the feet and also keeps them wet and cold.

3. If means are not available for drying socks and if fresh socks cannot be supplied, dry the wet ones by pinning them to the inner side of the overcoat or field jacket, or place them across the shoulders under the jacket during the day. At night, keep them in the sleeping bag.

4. Do not stand in cold water or mud unless it is absolutely impossible not to. Rocks, boards, brushwood, branches, and any similar material that is available will keep the feet out of the water, at least to some extent.

5. Keep the feet and legs in motion, particularly when they are wet as well as cold and when dry socks are not available. If troops must remain in one place, the individual soldier can mark time or can move his legs vigorously and frequently. If he can do nothing else, he can wiggle his toes inside his shoes. If he sits down, he can keep the feet higher than the buttocks.

6. Be certain that the shoes are not laced so tightly, and that clothing is not worn so tightly, as to interfere with the circulation of the feet and legs. Shoes should be laced loosely. Clothing should be worn loosely. Even moderate constriction of the blood supply, to a degree often unnoticed by the wearer, may reduce the circulation enough to cause trenchfoot. The first noticeable signs of interference with the circulation usually are numbness and

tingling sensations in the feet and legs. When these occur, exercise the legs and feet immediately until they feel normal and warm. Every means must be used to keep further constriction of the limbs to a minimum.

RESEARCH ON COLD TRAUMA

At the end of the war, knowledge of the several host factors which contribute to the production of cold injury (p. 377) was still grossly inadequate. This was all the more unfortunate because many of these factors are of such a character that they concern not only cold injury but also trauma in general. Some, in fact, are of sufficient importance to influence the total fighting effectiveness of combat soldiers.

Much more needed also to be learned about how to cope with the environmental factors of cold injury which can be influenced. The solution of these problems could no more await a mobilization day than can organization and training for the prevention and control of cold trauma be delayed until troops have been committed to battle or even until they have been sent to foreign theaters. Individuals immediately concerned with the problem were of the opinion that all knowledge at hand at any time should be used to the fullest possible extent. However, they also believed that the best possible results in the prevention and control of cold trauma would require additional research and the development of new equipment to indicate practices and to provide means for dealing with the intangible host and environmental factors involved in the problem.[3]

It was the consensus among authorities that full coordination of research and development required to meet the problems inherent in cold injury, as well as in other trauma, in any future war might be best directed toward the study of man as a whole in relation to his environment. Only from such an all-inclusive program can there come the fullest understanding of the factors involved in cold and other trauma. Whether a research program, and the organization necessary to carry it out, should be set up within the framework of the Armed Forces or under a civilian science foundation is a matter for discussion. The important consideration is the realization of the magnitude of the task and of the necessity for full coordination of research and development to meet the problem in future combat.

[3] Several investigations toward these ends have already been carried out. Important studies in clothing and equipment made by the Quartermaster General have greatly reduced the exposure sustained by infantrymen. The Air Force has conducted studies on survival in the Arctic and, within the limits of its research facilities, has supplemented them with basic studies. The Department of the Army has evaluated equipment in relation to environment at a post set up in a cold climate and has also studied special phases of cold trauma, such as hygiene, sanitation, acclimatization, and nutrition. Investigations of several host factors in cold trauma have been conducted under the auspices of the Medical Service Research and Development Board. In the winter of 1951–52, a research team was sent to Korea to study a program of prevention and control which, for the first time in United States Army history, was planned in advance of the expected cold injuries.

A COMPREHENSIVE PROGRAM FOR THE PREVENTION AND CONTROL OF COLD TRAUMA[4]

A satisfactory program for the prevention and control of cold trauma begins in the Zone of Interior and ends with the individual combat soldier in the foxhole of the winter frontline. Its basic components are organization, command support, indoctrination, training, discipline, and adequacy of supplies.

Zone of Interior

The foundation for the prevention and control of cold injury is naturally laid in the Zone of Interior, where potential losses from this cause must be taken into account in all strategic and tactical planning. In the past, too little attention has been paid to these considerations. Lack of appreciation of the dangerous potentialities of cold and wet cold and of their consequences was in large part responsible for the high casualty rate from these causes in World War II. There was also equally little appreciation (1) of the many factors in addition to weather that make up the total causation of cold injury and (2) of the possibility of modifying some of them, at least, to the advantage of an army fighting in winter. Trenchfoot and other forms of cold injury are not unexpected accidents, suddenly introduced into the course of military operations. They are so certainly a feature of campaigns in wet, cold climates that they necessarily enter into the total military plan.

The objective of indoctrination in the Zone of Interior is to inculcate upon command, staff, and service personnel, as well as future combat personnel, a full appreciation (1) of the cost of cold injury in combat troops, (2) of the responsibility of command echelons for its prevention and control, and (3) of the responsibility of every officer, noncommissioned officer, and enlisted man, both as an individual and as a member of a group, to carry out the simple, fundamental procedures that will protect individual soldiers and their organizations against cold trauma.

The strategic and tactical implications of cold trauma must be made part of the education of every officer in the United States Army. They must be presented and emphasized in all service and staff schools and at the United States Military Academy; in a general way, this has been done for the last several years in the series of lectures on medical matters delivered at West Point. Similarly, the training of Reserve and National Guard officers must include indoctrination on this subject. If command and staff are to be fully effective in time of war, their training and indoctrination with respect to cold injury must be undertaken in time of peace.

[4] The authors of this volume, on the basis of their personal experiences in World War II and after a thorough review of both the good and the bad practices in the control of cold injuries in this war, believe that the preventive principles outlined in the following pages should be adopted.

Broad policies for the prevention and control of cold trauma are formulated in the Zone of Interior. They should be embodied in recommendations and directives which should (1) be suitable for general application, (2) be based on the opinions that emerge from a pooling of staff and technical knowledge, on previous experiences, and on research data produced by agencies studying cold trauma, and (3) be limited to principles, methods, and procedures applicable to operations in a wide range of winter climates and terrain. These recommendations and directives should not be concerned with details. It would be impractical, in fact, to work out detailed programs in the Zone of Interior, since such programs necessarily vary with the place of operation, the type of combat mission, the degree of cold, the amount of precipitation, and the nature of the terrain.

Training aids, training literature, and training directives for general distribution should originate in the Zone of Interior. They should be provided in sufficient quantity, and should be kept current, so that they will always include the latest developments. All of these releases should be simply and clearly expressed and should be as brief as is consistent with completeness.

Whether or not training in the prevention of cold injury should be a part of the training of the individual soldier in the Zone of Interior during peacetime is a matter which training authorities must finally decide. Certainly, it would seem the part of wisdom that plans for unit training and for the indoctrination of commissioned and noncommissioned officers should be set up and kept current. Furthermore, since the enlisted components of the Army today will make up the small key cadres which will train the combat soldier of tomorrow, it would seem wise that the men who make them up should clearly understand their own responsibility in the prevention of cold trauma. In the light of present knowledge, such training should include the practice in the field, by individuals and small units, of preventive measures against cold, including care of the feet and the use and care of clothing assemblies designed to prevent exposure. As other preventive measures are formulated in the light of results of research, they should be incorporated in the training program.

Finally, the Zone of Interior has two other missions with respect to cold injury. One is the conduct of research and development, to improve methods and practices currently in use. The other is the provision of expert consultants wherever and whenever they may be needed and requested in overseas theaters.

Overseas Theaters

The difficulties which were connected with the indoctrination and training program for the prevention and control of cold injuries in World War II, and which were evident in both the Mediterranean and the European theaters, should not exist in future wars. In the European theater, while the program eventually set up was extremely effective, it was established too late, and it had to be implemented in the course of combat. In the Pacific theater,

the program set up was established well in advance of the need for it. It took full account of previous errors and covered all conceivable emergencies (appendix I; see also appendix H). On the other hand, except for the teams previously employed in the malaria-control program (p. 487), no administrative facilities existed for its implementation within the framework of the theater organization. Command, staff, and technical personnel all had to undergo comprehensive indoctrination along with enlisted components, and administrative facilities had to be developed before the training program could be undertaken. Neither the pattern of the program nor its effectiveness was tested in combat, but it is believed that, if there had been such a test, the results would have been satisfactory.

Cold injury indoctrination in overseas theaters should be simpler in the future because the groundwork for the full appreciation of the importance of cold trauma in winter operations will already have been laid in the Zone of Interior. Command will be aware of the necessity for early planning, organization, and training. Officers will have had their basic training. Noncommissioned officers and key enlisted men will have had sufficient training to make them generally familiar with the subject, and their period of indoctrination can be correspondingly shortened.

The program in an overseas theater has three components: (1) A central organization at theater level, (2) indoctrination teams at the theater level, and (3) control teams at the army level.

Central organization.—The central organization at the theater level is simple in constitution and economical of personnel. It consists of a board or commission made up of the assistant chief of staff, G–3 (operations and training), the theater quartermaster, and the theater surgeon, or their immediate deputies. These are the staff division and service chiefs who are most intimately concerned with the prevention and control of cold trauma and who must make the decisions and determine the policies which will achieve these objectives. Subordinates will not serve the purpose. Ideally, the chief of staff would be a member of the board and would serve as its chairman. If his responsibilities do not permit the assumption of this duty, or even his inclusion in the membership of the board, then it is essential that a deputy chief of staff serve in this capacity, so that the theater commander may be kept fully cognizant of its findings, decisions, and recommendations.

A cold-trauma board in an overseas theater of operations would necessarily keep fully informed as to (1) the general situation and the specific details of cold injury in its various phases and manifestations in the theater, including incidence, (2) the level of clothing supplies and the efficiency of their distribution to field units, (3) the status of training and discipline with respect to cold injury, and (4) the effectivness with which the cold injury program is being carried out by the major theater organizations. Other functions of such a board would be (1) to keep the theater commander advised on the general situation and its special phases; (2) to determine general theater policies and plans in advance of winter combat; (3) to advise subordinate commands on

cold injury policies and preventive measures; (4) to confer with army, base, and other organizational cold injury teams or expert personnel at such intervals as the situation might require; (5) to direct and supervise the utilization of joint indoctrination teams for theaterwide cold injury training before the beginning of cold weather; and (6) to authorize and direct special investigations of unusual outbreaks of cold injury. A cold-trauma board should also recommend policies and plans for all theater units, covering (1) the supply of clothing, footgear, and supplementary equipment; (2) individual and unit practices for the prevention of cold injury; (3) discipline; (4) rotation; (5) medical triage, evacuation, and care; and (6) whatever other measures might be required to improve the effectiveness of the theater program.

Men with the manifold duties and responsibilities of members of the cold-trauma board naturally could not be expected to do the traveling or to spend the time necessary to investigate personally the many aspects which cold injury may present. This difficulty would be overcome by providing the board with the advice and services of two or more technical consultants, who would serve as its eyes and ears. If desired, these consultants could be associate members of the board. One of them should be a highly qualified medical officer, trained in epidemiology and thoroughly familiar with all aspects of cold injury and with the particular responsibilities of the medical service for it. The other should be a Quartermaster Corps officer who, for his part, fully understands clothing requirements for combat in cold weather, clothing supply, and the correct utilization of clothing to minimize exposure.

The consultants to the cold-trauma board, in addition to their general duties as technical advisers, would have certain special duties. They would visit subordinate commands, especially army areas and replacement centers, as frequently as would be necessary to keep themselves fully informed on (1) all aspects of the cold injury problem, including incidence, (2) the status of supply, distribution, and utilization of clothing and footgear, and (3) the effectiveness of control practices. They would (1) advise and consult with army cold injury teams and officers in a liaison capacity; (2) work in close coordination with the parent agencies of the cold injury teams (that is, the office of the chief surgeon and the office of the quartermaster); (3) maintain liaison with G–3 and the quartermaster and surgeon of other major headquarters, such as subtheaters, bases, and army groups; (4) make plans and prepare directives for the over-all cold injury prevention and control program, for approval by the board and for publication and distribution through command channels; (5) advise on and assist in the preparation of technical bulletins and directives for distribution through technical channels; (6) aid in the planning and implementation of the theater cold-indoctrination program; (7) report on the theaterwide incidence of cold injury and maintain records of its occurrence by units; (8) investigate, for the information of appropriate command, the occurrence of cold injury in units in which the incidence is unduly high or in which investigation might be required for other reasons; (9) perform any other

technical duties which the development of the cold injury program of prevention might make necessary; and (10) assist in the planning and implementation of health education in cold injury by the use of all effective media, including newspapers and the radio, in order to reach the greatest possible number of soldiers.

There would seem to be no need to set up cold-trauma boards in headquarters of communication zones, subtheaters, bases, or army groups. In these headquarters, it would be better for the responsibility for the prevention and control of cold injury to rest with an officer of sufficient rank, qualifications, judgment, and technical competence to advise on special problems as they arise.

Indoctrination program.—If those responsible for the establishment of an overseas theater have given sufficient credence to the potential threat of cold trauma in winter operations, theater planning and organization will provide qualified personnel and satisfactory methods for its prevention and control. If planning has been adequate and if the correct organization has been set up in the first days of the existence of the theater, it is entirely possible that, when the time for it arrives, complete indoctrination can be executed within the resources of the theater. This will be possible, however, only if the theater command is interested and alert, if there is complete command support in all echelons, and if there is full utilization of the advice and assistance which the cold-trauma board, its consultants, and the cold injury control teams can supply. Both command and technical personnel have the responsibility for expediting the training when once it begins. Thereafter, command has the responsibility for the continuing execution of training doctrines.

Indoctrination teams might find permanent usefulness in any headquarters in which training activities are carried out. Replacement training centers, for instance, have special need for continuing technical advice and assistance in the preparation of inexperienced soldiers for combat.

The practical application of the program for prevention of cold injury in any special theater of operations is determined by the season at which combat operations are to begin, though, as just pointed out, the organization designed to carry out the program should be set up the day the theater headquarters comes into existence. Training and indoctrination for key command and staff officers should begin promptly thereafter, but, for practical reasons, intensive training of small units and of individual combat soldiers should precede by not more than a few weeks the time at which the training is to be used. When the proper time comes, the training program should have top priority. As a rule, this means that training begins in the late summer, just in time to be completed before autumn rains set in and the temperature falls to the range within which cold injury is likely to occur.

Key personnel for the indoctrination program are supplied by the chief quartermaster and the chief surgeon of the theater. The officers selected work in close coordination with G–3, and with the full support of command, during the period designated for the completion of the indoctrination program. They

also work with the technical guidance of the consultants to the cold-trauma board and with and through lower echelon team and unit resources.

The ultimate objective of a cold injury indoctrination program in a theater in which winter combat is being planned or is under way is the training of all personnel in the theater in the most efficient application of preventive and control methods and procedures. This includes the fullest possible utilization of clothing and equipment in order to reduce unit and individual exposure to unfavorable weather.

Indoctrination must be thorough. It must be based on general principles, but it must also include detailed instruction in all measures to be carried out by units and by individuals. It is essential that all elements have a complete understanding of the reasons for all parts of the program. They must also understand the limitations of clothing, rotation, and other measures to be applied to, or by, individuals and groups.

Indoctrination must include appropriate training for command, staff, and technical officer components on all levels. It can be assumed that command and staff officers of a field army will have had sound indoctrination in the Zone of Interior and will have come to understand, through programs carried out in the theater, the significance of cold trauma and the necessity for preventive and control measures. Training at the army level, therefore, would be directed chiefly to officers and enlisted men in smaller units. Because of their special exposure to cold injury, combat personnel require the most intensive and most comprehensive training.

With correct preliminary planning and the appointment of qualified personnel for indoctrination duties, it should be possible to carry out a theater-wide indoctrination program within from 6 to 8 weeks. It should also be possible to accomplish the total instruction required for any given combat unit within a period of from 3 to 6 days if, during this time, arrangements can be made for each component of the unit to receive from 3 to 6 hours of training, including both instruction and demonstration. Indoctrination of support and service personnel, who are less exposed to cold injury than combat personnel and who therefore require less intensive training, can be accomplished within shorter periods of time. If planning has been careful, it is perfectly possible to phase the training program for cold injury within an army in such a way that there will be little or no interference either with training in other subjects or with the planned commitment of units to combat.

Cold injury control teams.—The direct responsibility for guidance in the prevention and control of cold injury in a field army rests with the army trench-foot-control team. This team is made up of a line officer with combat experience and an officer from the Quartermaster Corps. It is not necessary for the team to include a medical officer, though the chief of the preventive medicine section in the office of the army surgeon should always be associated with the team in an advisory capacity.

Both officers on the cold injury control team must have a thorough knowledge of methods of prevention of cold injury, as well as an understanding of

tactics and of supply procedures, so that they can form precise judgments of the cold injury situation in combat units. They must have direct access to the chief of staff of the field army and must maintain close liaison with G–3, the quartermaster, and the surgeon. They must be provided with satisfactory transportation. Finally, to the extent that the combat situation and security considerations permit, they must have authority to enter unit areas down to, and including, regimental headquarters.

One of the specific duties of an army trenchfoot-control team is to keep fully informed on the incidence of cold injuries in the army, on the status of clothing supply, on foot discipline and rotation practices and the effectiveness of these measures, and on any other matters which might modify the cold injury situation. Other duties include making frequent, regular visits to corps, division, and regimental headquarters, in order to study the cold injury situation in these commands; acting in a liaison and consultative capacity to command and technical staffs of these headquarters; and surveying cold injury within subordinate units as may be necessary.

Trenchfoot-control teams should also perform the following functions: (1) Develop and maintain, with the support of G–3, a continuous indoctrination and training program; (2) carry out training, education, and indoctrination in cold injury prevention and control for selected cold injury control officers and noncommissioned officers by unit down to and including regiments; (3) keep the chief of staff of a field army, G–3, the quartermaster, and the surgeon fully informed of the cold injury situation by units; (4) maintain liaison with the cold injury consultants at theater level and with cold injury officers or boards at group level or at the level of other intermediate headquarters if a cold-trauma organization has been set up in them; and (5) maintain close liaison with S–3 (operations and training officer) and S–4 (supply officer), as well as with the surgeon of each unit.

The army trenchfoot-control team will find its greatest field of usefulness in the indoctrination and training of (1) officers who lead small combat units and (2) noncommissioned officers and key enlisted men in companies, platoons, and squads. Experience in the European theater showed clearly that the platoon and the squad are the key units through which individual preventive procedures can best be emphasized and toward which training should be directed to secure optimum results.

The trenchfoot-control directive issued in the European theater on 30 January 1945 (appendix G) specified trenchfoot-control teams only at army levels but did not forbid them in subordinate echelons. After their usefulness had become apparent, they were authorized in a few corps and in several divisions, and they were occasionally employed at regimental and battalion levels. Though this is entirely a matter for local command decision, it is somewhat doubtful that the mission of these teams justifies their routine use below the army level. A cold injury control officer would seem sufficient for an organization smaller than an army.

The effectiveness of cold injury control teams does not depend only upon their own performance. It rests in large part upon the performance of the carefully selected officers and noncommissioned officers in small units who act as receptor points for guidance in cold injury control. Obviously, a control team from an army or a corps cannot search out and instruct individual squads. On the other hand, it is perfectly practical for commanders of units below the regimental level to designate as trenchfoot-control personnel carefully selected junior officers and noncommissioned officers and key enlisted men to be sent to the rear of the regimental area for training in their duty by cold injury teams. In the European theater, it proved practical for one army cold injury control team of two officers to carry out successfully the training and instruction of trenchfoot-control officers and noncommissioned officers by regiments, even though these duties had to be performed during a period of intensely active combat. With correct advance planning, this particular situation should not occur again. Training in the future will be timed in relation to the combat situation, as it could not be in the European theater in the winter of 1944–45. In any event, the periods chosen must be satisfactory to regimental commanders.

After their formal training by the army cold injury control team, officers, noncommissioned officers, and key enlisted men designated as trenchfoot-control personnel have the responsibility of supervising in detail the protective measures to be carried out in the small units under their jurisdiction. Detailed supervision by company and platoon can be made the responsibility of an officer with special knowledge of cold injury prevention, while an enlisted man with interest in and knowledge of the subject can be extremely influential in inducing his squadmates to take the precautions and employ the measures which will protect them against cold injury.

The effective use of the trenchfoot control team system, in conjunction with cold injury control officers, noncommissioned officers, and key enlisted men, requires full acceptance of the prevention and control program by command and full command support in all echelons from the theater downward. This means, as already emphasized, that officers on the team must be able to establish prompt and effective liaison with commanding officers and surgeons in units. It also means that, in the interests of the program, line and medical officers, on their part, must supply all the information to which they have access. Officers on the team must not, of course, limit their contacts to designated trenchfoot-control officers, commanding officers, and surgeons. They must make general contacts with junior officers, noncommissioned officers, and enlisted men.

In the assessment of the cold injury situation in any unit, the team must give careful consideration to whatever recommendations the organization commander and the surgeon may make.

ALTERNATIVE PLANS

The experience of World War II amply demonstrates that the team method of trenchfoot control is necessary, is well adapted for the critical problem which it is designed to solve, and is justified by the results. This might have been expected. Earlier in the war, the team method had provided the solution for the equally critical problem of malaria in the North African theater and the Pacific areas. In both malaria and cold injury, the major emphasis must be placed upon preventive and control practices by individuals and units. Both conditions are potentially responsible for high casualty rates, and losses from both were dismayingly high until the institution of the team system reduced them to acceptable levels.

It must be conceded that the use of the team system means the setting up of a special organization to accomplish what should be accomplished automatically by ordinary staff and command methods. Furthermore, it might be argued that if a special setup is necessary for the control of cold injury it is also necessary for the solution of other problems. If such reasoning were carried to the ultimate limits, command could be plagued with a number of extraorganizational groups which, eventually, would disrupt routine processes and impair command control.

Such arguments are specious. Special organizations are not required to solve every special problem. The organization and operation of the team system are fundamentally the same whether the problem is cold injury, or malaria, or some other disease or condition. In the Pacific, plans were made to utilize the malaria-control teams, which had worked so effectively in the control of that disease in tropical combat areas, for the wet-cold indoctrination program. Such a plan would simply have required the transfer of abilities from one field to another. Men with background, training, and experience in malaria control would have needed only to master the principles of cold injury indoctrination and training to become immediately effective. Neither reorganization nor the setting up of new basic functions would have been necessary.

If it seems undesirable to establish specialist teams to cope with isolated special problems, the establishment of theater epidemiologic units is an alternative which has ample precedence in both the Army and the Navy. Epidemiology, as has been pointed out elsewhere (p. 2), is a broad subject which encompasses the mass characteristics of chronic diseases and trauma as well as of communicable diseases. Epidemiologic principles and methods of solution of individual and mass problems are the same for both disease and injury. They are just as applicable to an outbreak of cold injury as to an epidemic of typhoid fever.

The control of cold injury might therefore be vested in epidemiologic teams set up at theater levels. British Army Hygiene Units are an example of

this practice. So is the Special Epidemiologic Unit created by the United States Navy in World War II and used with such effectiveness that it was made a part of peacetime naval medical organization. The epidemiologic teams set up by the Army in World War II within the framework of general medical laboratories and field laboratories attached to armies were somewhat less effective than they should have been because they were not always utilized as it had been intended that they should be.

An epidemiologic unit would have as its province many epidemiologic problems. It could serve in the prevention and control of cold injury during the winter and of malaria during the summer. Venereal disease, gastrointestinal disease, and accidents would be its continuing concern. The flexibility of such an organization, therefore, as well as its expert personnel, would add to its advantages.

A PROPOSED BOARD FOR THE CONTROL OF TRAUMA

The over-all plan outlined, which in general is based on the experience of World War II and the lessons learned therein, provides a practical, comprehensive plan of cold injury prevention and control within the Military Establishment. It does not, however, provide the whole answer to the problem.

Singleness of purpose, avoidance of duplication, and coordinated direction of effort in the study of cold trauma could best be accomplished under the auspices of a board made up of representatives of command, training, and the several technical agencies involved. On the other hand, the scope of cold trauma, in spite of its dangerous potentialities, is too limited to justify the setting up of a board or commission whose sole function would be its prevention and control. The solution would be to make all trauma the function of the proposed board. This is reasonable. Cold injury is a part of the total field of trauma, and combat trauma is a constant wartime problem. Trauma from accidents of all kinds is also a growing peacetime military problem, which is greatly enhanced with the onset of war when cold trauma also becomes an urgent problem. The mission of the proposed board would be to determine needs, establish policies, and advise upon research, training, and general prevention and control measures for all forms of trauma, including cold trauma.

There is nothing revolutionary about such a proposal. Both World War I and World War II furnished illustrations of the medicomilitary fact that coordination of effort by several agencies is frequently most efficiently accomplished by the setting up of special boards or commissions whose scope and terms of reference go beyond the realm of routine staff procedures. Thus, in World War I, a board for the control of pneumonia performed a valuable service in mobilizing and applying all the resources then available for the management of pneumonia, which was the principal cause of death during the influenza epidemic of 1918. In World War II, the Army Epidemiological Board and the United States of America Typhus Commission, which brought

together the best talent available in these special fields, carried out invaluable research upon and contributed immeasurably to the practical field control of the diseases with which they were concerned. Both these boards were primarily medical organizations. The Army Committee on Insect and Rodent Control, which was an interstaff agency, had an important influence on the development and direction of research and practices directed toward insect and rodent control.

If the proposed board for the control of trauma were set up, it could profitably adopt at least two principles which have been well established. The first principle is that representatives assigned to the board be so highly placed that they speak with authority. Appropriate civilian experts might profitably sit upon the board for the control of trauma or might be assigned to it in a consultative capacity, but Army representatives must be chiefs, or deputy chiefs, of the agencies concerned, not their subordinates. The second principle is that similar boards be set up in the headquarters of the major operating echelons.

It is conceivable that the setting up of a board for the prevention and control of trauma, including cold trauma, might eventually lead to an even broader concept, the establishment of a board of preventive medicine. Such a board would be composed of command, staff, and service and technical experts. Its function would be to develop the organizations and outline the policies and practices necessary to meet the entire range of epidemiologic problems, such as acute communicable diseases, chronic diseases, abnormal psychology, and trauma, including, of course, cold trauma.

CHAPTER XVI

The Military Cost of Cold Injury

In every theater of operations in which combat operations were carried out during the winter in World War II, cold injury was responsible for large numbers of casualties and caused sufficiently heavy losses in man-days to interfere materially with military tactics. Some loss from cold trauma is inevitable during any winter fighting, and must be accepted as part of normal attrition. During World War II, however, losses from this cause exceeded expectancies in every theater in which United States forces conducted winter operations.

In order to avoid such losses in future wars, the reasons for this situation must be found, and the investigation must be comprehensive. Analyses of failures to cope successfully with cold trauma can be based in part on the study of cold injury in the individual soldier and in small units, but this is not enough. There must also be an evaluation of the policies of management which were laid down centrally and by theaters if a full appreciation is to be secured of the scope of the problem of cold injury in World War II. It is necessary to find out (1) what was done, (2) why it was done, (3) when it was done, and (4) why the policies and procedures instituted failed in conception, application, or both. Without this knowledge, it will not be possible to determine why cold injury was not kept within reasonable limits in the United States Army during World War II.

THE FACTS OF COLD INJURY IN THEATERS OF OPERATIONS

A review of the management of cold injury, including measures of prevention, by theaters necessitates some repetition of material presented elsewhere in this volume in more detail. The repetition is justified, however, since it affords a useful means of visualizing both the scope of the problem and the approach to its control. The repetition of the data also demonstrates that, while substantial understanding of how to manage cold injury had been achieved in Italy by the second winter of conflict and in the European theater by early 1945, the lessons were learned in both theaters chiefly in the hard school of experience. The losses from cold injury in the Aleutians provided warnings that could have set the pattern for an effective approach to the problem. As a matter of fact, these losses did initiate the activities in the Surgeon General's Office (p. 57). The Aleutian operations, however, were so small and remote

that they made almost no impression on the training program in the Zone of Interior, and they were not utilized as a guide for winter operations in Italy. The lessons learned from the 1943–44 winter campaign in Italy pointed the way to the control of cold injury during the 1944–45 campaign in that theater but they were not fully appreciated, nor were they utilized in the planning and training for the invasion of the Continent of Europe.

Army training and planning.—A partial explanation of the failure to learn these successive lessons can be found in the progressive development of the general military situation. In December 1939, the number of Army officers on active duty was 12,000, and Regular Army enlisted men numbered 212,000. Mobilization required the expansion of this small force to tens of thousands of officers and several million enlisted men. The mere expansion was in itself a gigantic task.

The first enemy action had focused attention on the Pacific and on the Tropics, and some time elapsed before the total military strategy was fully appreciated. Cold injury, therefore, did not immediately emerge as one of the basic problems.

The training of a large, raw military force, no matter where it was to fight, could not be expected to encompass, at once, all the special problems which later assumed special importance. It was proper, and to be expected, that the primary emphasis in training should be upon combat tactics and upon the technical and other military training of the individual soldier. Training authorities were besieged from all sides with requests that he be specially trained in a great number of subjects and skills. If the United States soldier could have been given, and could have retained, knowledge of all the subjects in which it was proposed that he be trained, he would indeed have been the epitome of military lore and efficiency. This was an obviously impossible ideal. There was not even sufficient time to train the troops in the prevention and control of such familiar causes of military casualties as malaria, the diarrheas, and the dysenteries.

In the light of these facts, it is easy to understand why cold injury, which had caused only a few United States casualties in World War I, in October, November, and early December 1918, should not have been appreciated as a potential source of heavy casualties in World War II. As a result of this lack of appreciation, planning, training, and the development and provision of clothing for protection against exposure to cold were not initiated early in the war. As a matter of fact, it was not until the potentialities of cold trauma had been demonstrated in the Aleutians and, more particularly, during the first winter in Italy, that a vigorous attack began to be made upon these problems.

The Aleutians.—While the great problems of mobilization, training, and general preparation for war were being wrestled with in the Zone of Interior, the course of events in theaters of operations began to proclaim the place of trauma from cold in winter warfare (tables 42, 43, 44, and 45). On Attu (p. 84), the experiences of a small and uninitiated task force demonstrated the role of cold and wet as agent factors, and also emphasized the importance of the

TABLE 42.—*Admissions for cold injury in the United States Army (including the Army Air Forces) by specific diagnosis and theater, 1942–45*

[Preliminary data based on sample tabulations of individual medical records]

Theater or area	Total cold injuries	Trenchfoot	Frostbite	Immersion foot (or hand)	Chilblains	Other effects of cold
All theaters and areas	82, 580	58, 355	18, 249	1, 361	901	3, 714
Continental United States	5, 133	290	4, 307	36	330	170
Total outside continental United States	[1] 77, 447	58, 065	13, 942	1, 325	571	3, 544
Europe	64, 008	48, 366	11, 974	436	179	3, 053
Mediterranean [2]	10, 397	9, 138	665	312	242	40
Middle East	33	22	11	----	----	----
China-Burma-India	35	7	12	----	15	1
Southwest Pacific	548	326	10	209	3	----
Central and South Pacific	129	26	31	63	1	8
North America [3]	2, 205	145	1, 220	295	131	414
Latin America	28	25	1	1	----	1

[1] Includes 64 admissions on board transports.
[2] Includes North Africa.
[3] Includes Alaska and Iceland.

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

modifying factors of duration of exposure, intensity of combat action, inexperience, and improperly designed and used clothing and footgear. The protective role of training was also brought out: One unit which had engaged in maneuvers in the cold and had received instruction in the prevention of cold injury suffered very little trenchfoot and frostbite during the whole of the Attu Campaign.

The Mediterranean (formerly North African) theater.—The signpost of Attu was not heeded in the preparation and management of troops and replacements for operations in Italy during the winter of 1943–44. The initial phase of the struggle was a series of fights for survival in precarious bridgehead footholds. Under these circumstances, cold injury had to be accepted because of the intensity of combat, the inadequacy of supplies, and the impossibility of rotation of troops and of execution of individual and unit control measures. On the other hand, there was no appreciation on the part of command and staff of cold injury as a potential cause of casualties as the bridgeheads were exploited, additional territory was conquered, supply lines were cleared, and it became obvious that winter operations in the Apennines were inevitable.

All of these facts are summarized in the Fifth Army Medical Service history for 1944, which read in part:

The Winter campaign for 1943–1944 found Fifth Army troops poorly equipped to meet the dangers of trench foot. Troops were provided only with the standard Army shoe or combat boot and a light wool sock. These shoes and boots became water-soaked and the light wool sock offered no protection against either wet or cold. The shoe or combat boot

TABLE 43.—*Incidence*[1] *of cold injury in the United States Army (including the Army Air Forces) by specific diagnosis and theater, 1942–45*

[Preliminary data based on sample tabulations of individual medical records]

Theater or area	Total cold injuries	Trenchfoot	Frostbite	Immersion foot (or hand)	Chilblains	Other effects of cold
All theaters and areas	90, 535	64, 590	19, 559	1, 451	971	3, 964
Continental United States	5, 203	315	4, 342	36	335	175
Total outside continental United States	[2] 85, 332	64, 275	15, 217	1, 415	636	3, 789
Europe	71, 038	53, 911	13, 134	506	204	3, 283
Mediterranean [3]	11, 192	9, 778	765	322	272	55
Middle East	33	22	11	----	----	----
China-Burma-India	35	7	12	----	15	1
Southwest Pacific	578	351	10	214	3	----
Central and South Pacific	139	26	36	68	1	8
North America [4]	2, 225	145	1, 230	295	141	414
Latin America	28	25	1	1	----	1

[1] Consists of both admissions for cold injury and cases in which admission was for other conditions but in which cold injuries appeared as secondary diagnoses. Data on secondary-diagnosis cases are not presently available for 1942 and 1943, and, for these 2 years, only admissions have been included in this table. It should be noted that cold injury admissions in 1942 and 1943 constituted but a small proportion of the World War II admissions for cold injury. For 1942 and 1943, admissions may be considered an approximation of incidence. During 1944–45, in the total Army the incidence of cold injury exceeded admissions by 11 percent.

[2] Includes 64 cases among admissions on board transports.

[3] Includes North Africa.

[4] Includes Alaska and Iceland.

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

fit so snugly that a heavy wool sock could be worn only by issuing a larger size shoe. Supplies were not adequate for such a readjustment, nor were heavy wool socks available for issue early in the winter. Apart from these deficiencies, neither officers nor enlisted men were alert to the dangers of trench foot, or adequately indoctrinated in preventive measures. Trench foot was a new experience to Fifth Army troops and the preventive measures urged by the Surgeon were difficult to put into effect.

There had been some early warnings of the possible hazards of cold injury (p. 101) but they were issued only a short time—a matter of days—before trenchfoot made its appearance in the theater. In the early winter of 1943–44, a number of command directives relating to the prevention and management of trenchfoot were published and disseminated (appendixes C and D), but they appeared only after the condition had become epidemic. Even after preventive measures had been described and ordered, their importance was apparently not fully realized. Whatever the reason, the Fifth U. S. Army, operating in the Mediterranean theater, learned about trenchfoot by experience in winter combat and paid for the experience with a high incidence of casualties from trenchfoot (tables 42, 43, 45, and 46).

The lessons learned during this period were summarized in the letter (p. 122) written in June 1944 to the Commanding General, NATOUSA, by the

TABLE 44.—*Incidence* [1] *of cold injury in the United States Army (including the Army Air Forces) by specific diagnosis and theater, 1942*

[Preliminary data based on sample tabulations of individual medical records]

Theater or area	Total cold injuries	Trenchfoot	Frostbite	Immersion foot (or hand)	Chilblains	Other effects of cold
All theaters and areas	1,305	77	1,022	3	154	49
Continental United States	913	55	717	1	110	30
Total outside continental United States	[2] 392	22	305	2	44	19
Europe	30	1	18	----	11	----
Mediterranean [3]	9	1	5	----	1	2
Middle East	4	3	1	----	----	----
China-Burma-India	----	----	----	----	----	----
Southwest Pacific	13	12	1	----	----	----
Central and South Pacific	4	3	----	1	----	----
North America [4]	323	2	279	----	32	10
Latin America	1	----	----	1	----	----

[1] Since secondary-diagnosis data are not available for 1942, admission data have been shown and may be regarded as an approximation of incidence in 1942. During 1944–45 in the total Army, the incidence of cold injury exceeded admissions by 11 percent.

[2] Includes 8 admissions on board transports.

[3] Includes North Africa.

[4] Includes Alaska and Iceland.

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

Surgeon of the theater, Maj. Gen. Morrison C. Stayer (appendix J). During the second winter in Italy, the application of preventive measures against cold injury became an integral part of the military operation. The result was a great reduction in the incidence of cold trauma as compared with the previous winter (tables 3 and 4) and a convincing demonstration that cold injury could indeed be prevented and controlled.

Losses from cold injury in Italy in the winter of 1943–44 increased the concern over this danger which was already felt in the Surgeon General's Office (p. 60). They also became a matter of concern to the War Department. In expectation of further winter operations, both in Italy and in western Europe, the available knowledge of cold trauma in military operations in the Arctics was brought together, and guiding command and technical directives were published (p. 63, and appendix A). These publications, however, appeared too late, and reached the European theater too late, to influence the epidemics of cold injury which occurred there during the winter of 1944–45.

The European theater.—Although representatives from the Chief Surgeon's Office had visited the Mediterranean theater in the winter of 1943–44, their observations on trenchfoot had been only incidental to the other purposes of their visit. An attempt to alert authorities in the European theater to the risks of cold injury had been made in the spring of 1944 (p. 161) but had not been successful.

TABLE 45.—*Incidence* [1] *of cold injury in the United States Army (including the Army Air Forces) by specific diagnosis and theater, 1943*

[Preliminary data based on sample tabulations of individual medical records]

Theater or area	Total cold injuries	Trenchfoot	Frostbite	Immersion foot (or hand)	Chilblains	Other effects of cold
All theaters and areas	7,481	2,224	3,645	459	317	836
Continental United States	2,520	60	2,220	15	135	90
Total outside continental United States	[2] 4,961	2,164	1,425	444	182	746
Europe	900	10	545	3	21	321
Mediterranean [3]	2,320	1,988	95	142	90	5
Middle East	28	19	9	--------	--------	--------
China-Burma-India	1	--------	1	--------	--------	--------
Southwest Pacific	4	1	--------	1	2	--------
Central and South Pacific	11	4	1	4	--------	2
North America [4]	1,661	142	761	290	69	399
Latin America	2	--------	1	--------	--------	1

[1] Since secondary-diagnosis data are not available for 1943, admission data have been shown and may be regarded as an approximation of incidence in 1943. During 1944–45 in the total Army, the incidence of cold injury exceeded admissions by 11 percent.

[2] Includes 34 admissions on board transports.

[3] Includes North Africa.

[4] Includes Alaska and Iceland.

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

Then came the successful landings in France and the rapid advance of the Allied armies across Europe. Morale was high. Victory was in the air. Many persons, some in high places, were convinced that the success of Allied arms would bring the conflict to a close late in 1944, before the onset of winter. Whatever the reasons, the important Italian signposts were lost sight of. Training during the long wait in England before the invasion of France did not include any emphasis on cold injury prevention, either by unit or by individual. Command had not been indoctrinated with the importance of cold injury in winter operations and did not comprehend its responsibility for prevention and control of this type of trauma. In the European theater, just as in Italy, command and technical directives were published, but the first cases of trenchfoot were occurring when they began to appear. In the surge across Europe toward Germany in the summer and early autumn of 1944, the need for such directives had not been appreciated (appendixes K and G).

As a result, United States forces were not prepared by training, nor did they have the proper equipment, to withstand cold injury at the beginning of the offensive in November 1944. Those in authority were therefore faced with the necessity of meeting this extremely serious development by expedients, and they were required to train and indoctrinate both commanders and troops during active, heavy combat, when trenchfoot was already epidemic.

TABLE 46.—*Incidence* [1] *of cold injury in the United States Army (including the Army Air Forces) by specific diagnosis and theater, 1944*

[Preliminary data based on sample tabulations of individual medical records]

Theater or area	Total cold injuries	Trenchfoot	Frostbite	Immersion foot (or hand)	Chilblains	Other effects of cold
All theaters and areas	40, 197	35, 555	2, 651	743	320	928
Continental United States	1, 210	75	1, 015	15	75	30
Total outside continental United States	[2] 38, 987	35, 480	1, 636	728	245	898
Europe	30, 525	28, 191	1, 080	350	60	844
Mediterranean [3]	7, 715	6, 962	394	174	144	41
Middle East	-------	-------	-------	-------	-------	-------
China-Burma-India	8	7	-------	-------	-------	1
Southwest Pacific	475	287	1	186	1	-------
Central and South Pacific	47	18	11	13	-------	5
North America [4]	195	-------	150	-------	40	5
Latin America	15	15	-------	-------	-------	-------

[1] Consists of both admissions for cold injury and cases in which admission was for other conditions but in which cold injuries appeared as secondary diagnoses.

[2] Includes 7 cases among admissions on board transports.

[3] Includes North Africa.

[4] Includes Alaska and Iceland.

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

The price paid in casualties in the European theater was far too high to justify the conclusion that cold injury losses of such magnitude could be accepted entirely as a calculated risk (p. 209). The incidence began to be reduced only after several weeks, and even then it fluctuated with the severity of the weather and the intensity of combat (table 47). A program of prevention was finally formulated, but only after a thorough epidemiologic study of cold injury had placed the proper emphasis upon its multiple causation and had stressed the relative weights of these various factors and their roles in the mechanism which produced this kind of trauma. By the time the program had become fully effective, the environmental hazards had almost entirely disappeared.

AN EVALUATION OF THE COSTS OF COLD INJURY

Preliminary data show that the total incidence of battle and nonbattle cold injuries of all types among United States Army (including Air Forces) personnel from 1942 to 1945 was 90,535 cases (table 43). These figures cover only soldiers excused from duty for treatment; patients who required only outpatient treatment are not included in them.

TABLE 47.—*Incidence*[1] *of cold injury in the United States Army (including the Army Air Forces) by specific diagnosis and theater, 1945*

[Preliminary data based on sample tabulations of individual medical records]

Theater or area	Total cold injuries	Trenchfoot	Frostbite	Immersion foot (or hand)	Chilblains	Other effects of cold
All theaters and areas	41, 552	26, 734	12, 241	246	180	2, 151
Continental United States	560	125	390	5	15	25
Total outside continental United States	[2] 40, 992	26, 609	11, 851	241	165	2, 126
Europe	39, 583	25, 709	11, 491	153	112	2, 118
Mediterranean [3]	1, 148	827	271	6	37	7
Middle East	1	--------	1	--------	--------	--------
China-Burma-India	26	--------	11	--------	15	--------
Southwest Pacific	86	51	8	27	--------	--------
Central and South Pacific	77	1	24	50	1	1
North America [4]	46	1	40	5	--------	--------
Latin America	10	10	--------	--------	--------	--------

[1] Consists of both admissions for cold injury and cases in which admission was for other conditions but in which cold injuries appeared as secondary diagnoses.

[2] Includes 15 cases among admissions on board transports.

[3] Includes North Africa.

[4] Includes Alaska and Iceland.

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

Data compiled during the period of combat from the different theaters, and recognized then as incomplete, showed that cold injury in the various theaters of operations was responsible for approximately 55,000 casualties. More complete study of losses from this cause since the war has brought the number up to more than 90,000. This figure has been arrived at by post-war sampling of individual medical records. Since it would be an impractical task to revise various detailed data by a review of individual medical records, certain of the discussions in this chapter are based on wartime data. It is obvious that some inaccuracies exist. It is equally obvious that these inaccuracies in no way invalidate the conclusion that the military cost of uncontrolled cold injury in World War II was enormous.

Since it would also be an impracticable task to revise unit data, or even data for armies or total ground forces for a theater, by a review of individual medical records, the cost of cold injury according to commands and armies has also been estimated from the wartime data.

Of the total of 90,535 casualties from cold injury (table 43), 82,580 were admitted to United States military medical facilities with the admission diagnosis of cold injury (table 42). Trenchfoot, with 64,590 cases, was the predominant type of cold injury, followed by frostbite with 19,559 cases. If only the theaters in which cold injury was a serious problem (that is, the Mediterranean and European theaters) are considered, and if the total cases

are limited to admissions with the primary diagnosis of cold injury, the total figure for trenchfoot is 57,504 cases (48,366 in Europe, 9,138 in the Mediterranean theater), and the total figure for frostbite is 12,639 cases (11,974 in Europe, 665 in the Mediterranean theater).

The mere statement of statistics does not tell the whole story. The true cost of any given number of cases of disease or trauma can best be calculated from the military standpoint in terms of total noneffectiveness; that is, in terms of the number of days lost from combat, support, and service duty because of the condition. The average number of days lost from duty because of cold injury in military populations in all areas was 83 per case. Provisional estimates made earlier in Italy had set the figure at 60 days.

An average loss of 83 days per case means that there was a total of 7,514,000 man-days lost from cold injuries for the total Army during the 1942–45 period: 6,265,000 days lost because of trenchfoot (97 days average duration), 1,134,000 days lost because of frostbite (58 days per case), and 115,000 days lost because of other cold injuries. This is 20,586 military man-years. If the loss is considered in terms of a hypothetical field army of 250,000 men, it represents the noneffectiveness of the entire field army for about 1 month. If it is considered in terms of a 15,000-man division, it represents the noneffectiveness of the entire division for about 16 months.

These losses, impressive as they are, still do not tell the whole story of the cost of cold injury in terms of military effectiveness. Cold injury is a malady of the frontline infantryman in direct contact with the enemy. Each infantryman in active combat at the front requires several other men to support him, keep him fed, clothed, supplied with ammunition, and provided with other services which he must have if he is to remain effective. The higher the echelon of the total command, the greater is the number of support and service troops not directly exposed to cold injury. Cold injury losses are therefore proportionately greater when they are calculated for small combat units, of battalion or company size. A battalion of infantry, for instance, has little overhead, and almost its whole strength is exposed to cold injury during combat. If each battalion is assumed to average 750 men, and if each infantry division is made up of 3 regiments of 3 battalions each, the population at actual risk is significantly smaller than the total population of the division; and the proportion of losses, based on the population at risk, is thus revealed in its true light.

Calculated on this more realistic basis, loss of time from cold injury for the division, instead of being 16 months, would be 37 months, or more than 3 years. These data require even more careful analysis to estimate the total tactical cost of cold injury. If, for example, the time factor is disregarded and the approximately 70,000 cases of cold injury in Europe in 1944–45 are used as basic data, it can be said that the equivalent of almost 5 divisions of 15,000 men each was lost to combat.

This still, however, does not give a true picture of the situation. Approximately 90 percent of all cold injury casualties were riflemen, of whom about

4,000 were in each infantry division. The loss of effective fighting strength from cold injury thus could be interpreted as more nearly 16 divisions than as 5 divisions. In the light of the facts just cited about the actual military populations at risk, the enormous impact of cold injury losses upon effective fighting strength is apparent.

As has already been pointed out, more complete data established by post-war sampling of individual medical records (tables 42 through 47, inclusive) show that wartime reporting was incomplete. The numbers of cases of cold injury by theater are significantly higher when data from all sources are consolidated and secondary diagnoses of cold injury are included. The total number of cold injury cases of all types during World War II approximated 91,000. The total time lost is estimated as 7,514,000 man-days, or 20,586 man-years, an average of 83 days per case. This estimate includes the seriously injured casualties who were returned to the Zone of Interior. These men often required many months of military care, and many of them could never be returned to military duty.

Losses according to commands and armies.—A breakdown of cold injury in United States Army forces by major commands and by principal field units in the European theater for the 6-month period ending with April 1945 (tables 48 and 49) showed that the annual rate per 1,000 men for total field forces was 75.9, as compared to the total theater rate of 46.6. The First and Third U. S. Armies had higher rates, 106.8 and 99.8, respectively. By comparison, the major field headquarters, the 6th and 12th Army Groups, had an annual rate per thousand men of 30.6. This rate would have been even lower except that a

TABLE 48.—*Cold injury incidence for United States Army Ground Forces, European theater (Continent only), by month, November 1944 through April 1945*

[Rate expressed as number per annum per 1,000 average strength]

Month and year	First U. S. Army		Third U. S. Army		Seventh U. S Army		Ninth U. S. Army		Fifteenth U. S. Army		XVIII Corps Airborne		Headquarters and attached troops, 6th and 12th Army Groups		Total	
	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate
1944																
November	2,715	110.9	4,544	224.4	1,420	94.5	622	47.5	(1)	(1)	------	------	27	16.1	9,328	125.2
December	5,184	164.0	4,306	170.0	2,236	106.4	1,193	67.8	(1)	(1)	------	------	105	35.4	13,024	132.2
1945																
January	5,047	203.9	3,626	135.9	3,012	144.7	252	18.9	94	187.5	1	78	108	35.3	12,140	136.0
February	3,194	144.5	1,848	75.4	2,423	99.3	224	11.7	47	49.0	4	5.5	277	49.8	8,017	83.4
March	734	23.9	1,097	35.9	592	19.5	132	4.3	5	.7	15	2.1	18	6.4	2,593	18.6
April	79	3.2	18	.7	84	3.5	0	0	0	0	0	0	0	0	181	1.6
Total	16,953	106.8	15,439	99.8	9,767	72.2	2,423	20.2	146	14.2	20	2.5	535	30.6	45,283	75.9

[1] Not in theater.

TABLE 49.—*Cold injury incidence in major commands, United States Army, European theater (Continent only), by month, November 1944 through April 1945*

[Rate expressed as number per annum per 1,000 average strength]

Month and year	Ground Forces		Ground Force Reinforcement Command		Communications Zone		Air Forces		Total	
	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate	Cases	Rate
1944										
November	9, 328	125. 2	2	0. 3	10	0. 3	10	0. 7	9, 350	75. 1
December	13, 024	132. 2	115	17. 0	57	1. 5	20	1. 0	13, 216	80. 7
1945										
January	12, 140	136. 0	236	33. 1	122	3. 5	48	3. 1	12, 546	85. 3
February	8, 017	83. 4	176	25. 0	159	4. 3	13	. 8	8, 365	53. 1
March	2, 593	18. 6	86	8. 3	12	. 3	2	. 1	2, 693	12. 2
April	181	1. 6	19	1. 9	8	. 2	22	1. 2	230	2. 1
Total	45, 283	75. 9	634	13. 2	368	1. 8	115	1. 1	46, 400	46. 6

division attached to one of these headquarters, for guard, patrol, and similar duties, had to be thrown into combat during the German counteroffensive and in the succeeding weeks, when every possible resource was being utilized to bring the war to a rapid conclusion.

The Seventh and Ninth U. S. Armies had rates relatively much lower than those of the First and Third U. S. Armies, one of the explanations being that they had shorter periods of heavy offensive operations during the cold season. The explanation of the low rate for the Fifteenth U. S. Army (14.2) is similar: This army was not effectively in the theater until the end of December 1944, and its mission, except for a short period in the counteroffensive early in 1945, was to consolidate gains and hold and administer territory already overrun by the other armies of the 12th Army Group.

When the number of cases and the annual rates by weeks and months for the period from November 1944 to April 1945 are broken down for the First, Third, Seventh, and Ninth U. S. Armies (table 48), the high price of cold injury is further emphasized. Wide fluctuations are apparent in the weekly rates. At no time during the winter did the annual rate by months drop below 110 for either the First or the Third U. S. Army except for February 1945. Both of these armies were heavily engaged throughout this period. The Third U. S. Army experienced a sudden point epidemic in November 1944, which then leveled off somewhat. In the First U. S. Army, the buildup was slower, but the rate was maintained at a higher level for a longer period.

Examination of the rates for small individual units showed even higher rates for some periods than those just cited for larger bodies of troops. The

combat effectiveness of some of the smaller units, in fact, was reduced by more than half during some weeks of the November offensive.

Reinforcements.[1]—The loss of manpower through cold injury was costly not only in the prosecution of offensive actions, but also in the increased load it placed upon reinforcement and hospital facilities. During December 1944 and January and February 1945 (table 49) the Ground Force Reinforcement Command in the European theater had annual rates for cold injury of 17.0, 33.1, and 25.0, respectively. The annual rate for the November-April period was 13.2. These rates are an indication of the stress under which replacement facilities were operated to train and send forward men to compensate for those lost to the combat forces as the result of cold injury. A replacement had to be furnished for every soldier lost to the frontline combat organization, but, again, mere numerical statements do not tell the whole story. Every soldier requires from 8 to 15 weeks of basic training before he can be assigned to a combat theater. Then, because he is still raw and inexperienced, he must undergo several additional weeks of seasoning in battle before he reaches high combat efficiency. Every week of combat experience which a soldier has—short of the point of combat exhaustion—increases his value to the frontline commander and to the war effort. Unit records repeatedly show that it is not possible to measure quantitatively, much less qualitatively, the reduction in combat effectiveness of a unit that has experienced high casualties for any cause and that must operate with a large proportion of inexperienced replacements.

There is still another aspect to this problem. Certain intangibles cannot be discounted, such as morale, loyalty to one's unit, teamwork, and the comaraderie of men who have served with each other and with special units for long periods. It is a long time before replacements, no matter how well trained and experienced they may be, can take the place of men tried and trusted and with long periods of service. These intangible losses must therefore be added to the total quantitative and qualitative cost of cold injury.

Medical and hospitalization costs.—Cold injury is a burden to the medical services of the army. Medical costs begin at the frontline. Many casualties from this cause are not ambulatory and must be evacuated by litter carry, jeep, or ambulance. Later, patients with serious injuries must be evacuated to general hospitals in the communications zone, and finally, by hospital train, air, ambulance, or ship, to the Zone of Interior.

Each casualty from cold injury occupies a hospital bed for periods varying from a few days to several months. Most often, the period of hospitalization is long and the effect of new admissions is therefore cumulative (tables 50 and 51). Between 11 November 1944 and 29 June 1945, the average number of casualties in hospitals in the European theater because of cold trauma at the end of each week was 14,026. When the incidence of cold injury was high (from the week beginning on 25 November 1944 through the week ending on

[1] See footnote 49, p. 171.

6 April 1945), the average number of patients remaining under hospital care by weekly periods was 22,454. The maximum number remaining under medical supervision at the end of any single weekly period in the European theater was 35,424; this was for the week ending 9 February 1945 (table 51). Not all of these men, it is true, occupied hospital beds on any given day, but a large proportion of them did, and all of them, whether confined to bed or not, required medical supervision.

TABLE 50.—*Trenchfoot, immersion foot, and frostbite patients remaining in hospitals, and prevalence rates, United States forces, Mediterranean theater, 1943–45*

[Prevalence rates expressed as numbers remaining per 1,000 strength]

Period	Patients remaining at end of period		Rate at end of period	
	Trenchfoot and immersion foot	Frostbite	Trenchfoot and immersion foot	Frostbite
1943				
Aug.–29 Oct	------	------	------	------
30 Oct.–26 Nov	------	------	------	------
27 Nov.–31 Dec	136	------	0. 22	------
1944				
1 Jan.–28 Jan	573	------	. 92	------
29 Jan.–25 Feb	1, 697	------	2. 68	------
26 Feb.–31 Mar	1, 550	------	2. 31	------
1 Apr.–28 Apr	------	------	------	------
29 Apr.–10 Nov	------	------	------	------
11 Nov.–17 Nov	2	------	. 004	------
18 Nov.–24 Nov	349	11	. 70	0. 02
25 Nov.–1 Dec	298	16	. 59	. 03
2 Dec.–8 Dec	357	16	. 71	. 03
9 Dec.–15 Dec	398	11	. 80	. 02
16 Dec.–22 Dec	341	11	. 68	. 02
23 Dec.–29 Dec	359	14	. 70	. 03
1945				
30 Dec.–5 Jan	435	28	. 85	. 05
6 Jan.–12 Jan	537	22	1. 05	. 04
13 Jan.–19 Jan	583	25	1. 13	. 05
20 Jan.–26 Jan	537	31	1. 03	. 06
27 Jan.–2 Feb	514	61	. 99	. 12
3 Feb.–9 Feb	538	63	1. 04	. 12
10 Feb.–16 Feb	506	56	. 98	. 11
17 Feb.–23 Feb	567	47	1. 10	. 09
24 Feb.–2 Mar	539	56	1. 07	. 11
3 Mar.–9 Mar	481	39	. 98	. 08
10 Mar.–16 Mar	461	30	. 93	. 06
17 Mar.–23 Mar	428	22	. 86	. 04
24 Mar.–30 Mar	335	14	. 67	. 03

TABLE 50.—*Trenchfoot, immersion foot, and frostbite patients remaining in hospitals, and prevalence rates, United States forces, Mediterranean theater, 1943–45*—Continued

Period	Patients remaining at end of period		Rate at end of period	
	Trenchfoot and immersion foot	Frostbite	Trenchfoot and immersion foot	Frostbite
1945				
31 Mar.–6 Apr	283	11	0. 57	0. 02
7 Apr.–13 Apr	248	12	. 50	. 02
14 Apr.–20 Apr	206	11	. 42	. 02
21 Apr.–27 Apr	154	9	. 32	. 02
28 Apr.–4 May	135	9	. 28	. 02
5 May–11 May	110	8	. 23	. 02
12 May–18 May	72	6	. 15	. 01
19 May–25 May	40	4	. 09	. 01
26 May–1 June	24	4	. 06	. 01
2 June–8 June	24	4	. 06	. 01
9 June–15 June	10	1	. 03	. 002
16 June–22 June	6	3	. 02	. 01
23 June–29 June	7	2	. 02	. 01

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

Most of the general hospitals which received cold injury casualties found it convenient and practical to set up convalescent sections to carry out the rehabilitation program necessary to get the men back to duty. These sections required medical supervision and ancillary medical help. Whole convalescent hospitals were designated for the care of patients with milder cold injuries, who, it seemed reasonable to assume, might be returned to active service. Men with still slighter injuries were placed in such medical units as medical gas-treatment battalions (p. 308). Hospital-bed space was thus conserved, but the patients, nonetheless, needed considerable medical supervision.

In short, the medical cost of cold injuries required several types of medical facilities, the time of many busy medical officers, the labor of hundreds of personnel ancillary to the Medical Corps, and the utilization of many units of medical evacuation transport for millions of miles to bring casualties with cold trauma to medical installations in which they could receive appropriate treatment.

Cold injury–battle casualty ratio.—Battle casualties are the chief index of the cost of military operations. In terms of total cases, they represent the greatest single cause of loss of manpower to combat units. The ratio of cold injuries to battle casualties therefore furnishes a sound criterion of the military cost of cold trauma.

TABLE 51.—*Trenchfoot, immersion foot, and frostbite patients remaining in hospitals, and prevalence rates, United States forces, European theater, 1943–45*

[Prevalence rates expressed as numbers remaining per 1,000 strength]

Period	Patients remaining at end of period		Rate at end of period	
	Trenchfoot and immersion foot	Frostbite	Trenchfoot and immersion foot	Frostbite
1943				
31 July–31 Dec	-------	-------	-------	-------
1944				
1 Jan.–30 June	-------	-------	-------	-------
4 Aug.–10 Nov	-------	-------	-------	-------
11 Nov.–17 Nov	428	-------	0. 21	-------
18 Nov.–24 Nov	4, 171	3	1. 92	0. 001
25 Nov.–1 Dec	8, 636	28	3. 82	. 01
2 Dec.–8 Dec	10, 064	40	4. 26	. 02
9 Dec.–15 Dec	15, 676	78	6. 48	. 03
16 Dec.–22 Dec	17, 001	67	7. 05	. 03
23 Dec.–29 Dec	19, 463	232	7. 90	. 09
1945				
30 Dec.–5 Jan	20, 566	460	8. 19	. 18
6 Jan.–12 Jan	24, 085	1, 375	9. 50	. 54
13 Jan.–19 Jan	25, 238	3, 198	9. 77	1. 24
20 Jan.–26 Jan	26, 728	4, 753	10. 07	1. 79
27 Jan.–2 Feb	27, 654	6, 101	10. 43	2. 30
3 Feb.–9 Feb	28, 042	7, 382	10. 57	2. 78
10 Feb.–16 Feb	26, 338	7, 080	9. 75	2. 62
17 Feb.–23 Feb	23, 939	6, 552	8. 90	2. 44
24 Feb.–2 Mar	21, 517	6, 155	7. 98	2. 28
3 Mar.–9 Mar	19, 188	5, 526	7. 01	2. 02
10 Mar.–16 Mar	16, 397	4, 863	5. 94	1. 76
17 Mar.–23 Mar	13, 500	4, 024	4. 81	1. 43
24 Mar.–30 Mar	10, 615	3, 257	3. 74	1. 15
31 Mar.–6 Apr	8, 277	2, 541	2. 92	. 90
7 Apr.–13 Apr	6, 513	2, 070	2. 27	. 72
14 Apr.–20 Apr	4, 838	1, 559	1. 69	. 55
21 Apr.–27 Apr	3, 645	1, 252	1. 29	. 44
28 Apr.–4 May	2, 516	901	. 88	. 31
5 May–11 May	1, 828	691	. 63	. 24
12 May–18 May	1, 169	404	. 40	. 14
19 May–25 May	927	356	. 33	. 13
26 May–1 June	592	223	. 21	. 08
2 June–8 June	536	190	. 19	. 07
9 June–15 June	389	149	. 14	. 05
16 June–22 June	354	112	. 13	. 04
23 June–29 June	305	100	. 12	. 04

Source: Medical Statistics Division, Office of the Surgeon General, Department of the Army.

In the 22-day operation on Attu in May and June 1943 (table 52), which was a small operation, the ratio of cold injuries to battle casualties was approximately 1:1. Cold injury in this operation was responsible for 31 percent of the casualties from all causes, including, in addition to cold injury, both battle and nonbattle casualties and deaths in action. In the Fifth U. S. Army in Italy (table 52), for the period from November 1943 to April 1944, inclusive, the ratio of cold injury to battle casualties was 1:5. For the period from October 1944 to March 1945, inclusive, this same army, with the previous year's experience behind it, had a ratio of only 1:10. In the European theater in the winter of 1944–45 (table 52), the ratio of cold injury to battle injury in the First U. S. Army was 1:3.2, in the Third U. S. Army 1:4, and in the First and Third U.S. Armies combined, 1:3.6.

TABLE 52.—*Ratio of cold injuries to battle casualties by United States force or army, Attu and Mediterranean and European theaters*

Force	Period	Cold injuries	Wounded in action	Ratio of cold injuries to battle casualties
Attu Task Force	11 May 1943–1 June 1943	1, 200	1, 148	1:1
Mediterranean theater:				
Fifth U. S. Army	November 1943–April 1944	5, 752	27, 602	1:5
	October 1944–March 1945	1, 572	15, 864	1:10
European theater:				
First U. S. Army	4 Nov. 1944–16 Mar. 1945	16, 816	53, 611	1:3. 2
Third U. S. Army	do	15, 347	61, 905	1:4. 0
Total, First and Third U. S. Armies.	do	32, 163	115, 516	1:3. 6

The cost to a military force from cold injury is both tangible and intangible, as has already been pointed out. Some measure of the tangible cost can be arrived at by tabulation of the number of combat soldiers lost from this cause, as well as by the annual incidence rates resulting therefrom for the periods when it is a problem. Measurement by ratio of cold injuries to battle casualties is another effective index of cost. It is evident from the figures, rates, and estimates which have been cited that cold injury in military forces operating under winter weather conditions is expensive in trained and experienced combat personnel. That these costs can be reduced is inherent in the comparison between the ratio of cold injuries to battle casualties in the Fifth U. S. Army in Italy for the winter of 1943–44 and the winter of 1944–45.

ADVANCE PLANNING

Details of the program of prevention and control planned for the invasion of Japan, and planned well in advance of the daet set for it, are described in detail in the chapter dealing with the Pacific (p. 216). The picture there was indeed very different from the picture in Italy and in the European theater in the weeks before the launching of the massive assaults in those areas. The signposts of Attu, the Mediterranean theater, and the European theater had at last been read and heeded.

The program set up in expectation of the invasion of Japan represented a coordinated effort. Training personnel, Quartermaster Corps personnel, and medical specialists and organizations united in a common effort to meet the potential problem. In these endeavors, all the services were fully supported by command. Behind the entire effort was the approval and encouragement of the War Department. At last it had come to be realized that the combat soldier is just as noneffective when he is evacuated from the front because of cold injury as he is when he is sent to the rear with a combat wound. It had also come to be realized that it was just as important to teach the soldier the proper use of clothing and winter equipment to protect himself from cold trauma as it was to train him in the use of his rifle to protect himself in combat.

The end of fighting in the Pacific made the implementation of the planned program unnecessary. Such training estimates, however, as could be made before actual combat in winter weather gave promise of significant success and indicated that the measures which had been adopted would likely have been extremely effective.

APPENDIX A

War Department Technical Bulletin (TB Med 81)

TRENCH FOOT

War Department, Washington 25, D. C. 4 AUGUST 1944

1. DEFINITION. *a.* Trench foot is the term applied to the condition resulting from prolonged exposure of the feet to cold and moisture, usually associated with dependency and immobility of the lower extremities and with constriction of the limbs by shoes or clothing. The condition is closely related to immersion foot and shelter foot. Prolonged standing or long hours spent in an upright or crouching position in cold, wet trenches or foxholes, especially if they have previously become mud-soaked by rain and the weather then changes to frost, and the continual wearing of wet socks and footgear, are the most frequently responsible circumstances leading to the development of the syndrome. The period of exposure varies from several hours to several weeks.

b. Factors influencing the occurrence and severity of the condition include degree of cold, duration of exposure, and footwear which, although affording some protection during short exposure, causes constriction and is harmful after long exposure. Contributory factors are dependency and immobility which reduce peripheral circulation; body cooling as from wind and inadequate, damp, or wet clothing and footwear, resulting in loss of body heat and production of general vasoconstriction with consequent circulatory stagnation; trauma; and dehydration and nutritional and vitamin deficiency. Men over 40 and youths under 17 appear to be less resistant to the general effects of cold than those of intermediate ages. Racial hypersusceptibility to cold has not been definitely established, but it appears that individuals accustomed to a warm environment do not have the same defenses as those who have been accustomed to colder climates.

2. PATHOGENESIS AND MORBID ANATOMY. *a.* The essential vascular change during the period of exposure and hypothermia is peripheral vasoconstriction which involves predominantly the arteriolar vessels but may affect even the larger arteries and which results in a decreased blood flow to the part. This is induced both reflexly and as a result of the direct action of cold. The resultant ischemia causes anoxia of the capillaries with consequent increased permeability, exudation, and edema. Existing arterial disease or compression of the part by tight shoes or leggings may accentuate this mechanism. Direct thermal injury to the skin from prolonged exposure to cold may also be a factor as well as the traumata incurred from walking on the damaged feet.

b. Immediately after the part is exposed to warmth, there occurs an intense inflammatory hyperemia with excessive vasodilatation which may be due to several factors, including the release of histamine-like substances resulting from tissue injury by the cold, actual damage to vessels, and nerve injury causing vasomotor paralysis. This phase of hyperemia is accompanied by swelling of the tissues and edema. The transudation of fluid may be due either to mechanical factors or, in most instances, to increased permeability of the damaged capillary endothelium. A vicious circle is thus established, in which transudation contributes further to an already existing oxygen deficiency in the involved part. Involvement of peripheral nerves is suggested by paresthesias, dysthesias, anesthesia, and sudomotor disturbances. Meager histological studies have revealed mixed degenerative and regenerative changes in peripheral nerves. The significance of these findings is not

established but local interference with neurogenic control of peripheral blood vessels is probable. The tissues appear edematous and contain perivascular collections of lymphocytes, extravasated blood cells, and some polymorphonuclear leucocytes rather similar to any sterile inflammatory reaction. The exudates are fibrinous and the finer lymphatics may be blocked. The vessels themselves may show intimal thickening and vacuolization of the muscle fibers or more complete disorganization with extending thrombosis in the vessels adjacent to the traumatized area. In the more severe forms, histological studies made during the late stages of the condition, i. e., several months after exposure, show atrophy and thinning of the epidermis with much fibrosis and deposition of collagen around the nerve endings and blood vessels in the subcutaneous tissues. Fibrous infiltration of the muscles is also evident. This is believed to be the explanation for the late pain, rigidity, and weakness of the feet in this group of patients. The observation that these patients tend to improve spontaneously after 6 to 8 months, the time at which collagen ceases to contract, supports this belief.

3. CLINICAL MANIFESTATIONS. *a. Classification.* The clinical manifestations are variable. Depending upon the period of exposure and extent of tissue damage, the condition as it appears clinically during the period following admission may be classified according to degree as mild, moderate, and severe. The mild type is characterized by erythema, slight sensory changes, and little or no pitting edema. In addition to these manifestations, there are, in the moderate type, blebs, ecchymotic spots, and definite pitting edema. In the severe forms, these manifestations are more pronounced with evidence of massive extravasations of blood and incipient or actual gangrene.

b. Signs and symptoms. (1) During onset and period of exposure, there is first an uncomfortable sensation of coldness of the feet, and this is soon followed by numbness. There may be temporary tingling, and mild aching or cramping pain about the arches, ankles, and soles of the feet. In general, discomfort is not pronounced during this period, and the most prominent manifestations are numbness and a heavy wooden sensation of the feet. The patients complain of ataxia, walking is clumsy, and they feel as if they were "walking on blocks of wood." Swelling of the feet may occur after several hours or days but is usually not pronounced at this time. The skin, which is at first red, later becomes pale, "waxy white," "sickly yellow," mottled blue, or purplish. Blisters usually develop at a later stage.

(2) At the time of admission and after the shoes are removed, the signs and symptoms enumerated above are present and may be more pronounced. The feet are cold and may be anesthetic to pain, touch, and temperature. The peripheral pulses may be absent. The signs and symptoms during this period are considerably influenced from the standpoint of onset, duration, and degree by the method of treatment, as well as by the degree of damage which resulted before treatment was instituted. However, the condition progresses through three more or less distinct stages, each with characteristic signs and symptoms:

(*a*) *Prehyperemic or ischemic stage.* This may last for several hours or more. The feet remain cold, somewhat swollen, discolored, and numb. Areas of purplish discoloration may sometimes be observed particularly in or about the toes. Although in the milder cases there may be hyperesthesia, most cases are characterized by anesthesia of varying extent. In the more severe case, there is fairly extensive "sock anesthesia," and in the less severe forms, these areas involve the toes and extend around the margins of the foot and over its plantar aspect. In some cases in which exposure has been sufficiently prolonged, areas of incipient or even actual gangrene may be already apparent, particularly about the toes. Some patients experience a poorly localized, dull, aching sensation in the feet. The peripheral pulses may remain absent for some hours. As the feet grow warm, swelling increases rapidly, and a severe burning pain begins, marking the onset of the second stage.

(*b*) *Hyperemic or inflammatory stage.* This may last from a few days to a few weeks. Swelling increases rapidly, and the feet become red, hyperemic, hot, and dry. The peripheral pulses are full and bounding. Damage is greatest in the toes, the distal part of the dorsum

of the foot, and the ball of the foot. These parts remain edematous and hot and assume a livid cadaveric appearance. Blebs appear, except in the very mild cases, and may be filled with straw-colored fluid or extravasated blood. Patchy areas of ecchymosis are commonly found over the medial aspect of the first metatarsophalangeal joint, and of the longitudinal metatarsal arch, and over the sides of the foot. The rigid swelling, the redness, and the local warmth of the part indicate an intensive hyperemia. Superimposed damage to the peripheral vessels is suggested by the ulceration and actual gangrene which sometimes involves the more vulnerable parts, particularly the toes. The sensory disturbances are quite characteristic and may begin at once or be delayed for several days to a week. The initial anesthesia and hypesthesia are replaced by intense paresthesia. This has been described as an intense burning pain over the surface of the entire foot which seems to be relieved by cold and aggravated by heat or even by warmth. It is sometimes followed by intense, intermittent, stabbing, shooting pains beginning in the ankle joint or in the midtarsus and radiating to the tips of the toes. A generalized tingling sensation is often felt in the skin but is overshadowed by the burning pain. The periphery of the foot is usually anesthetic and this merges more proximally into areas of hyperesthesia and paresthesia. As these sensations subside, they gradually recede distally to the toes. The affected parts may ache or throb, and the pains are made worse by warmth and dependency. Anhydrosis or lack of sweating is evident and seems to coincide with sensory loss. The degree of edema varies with the extent of injury and, in the severe cases, may extend as high as the knee. Usually reaching its height by the fourth to sixth day, it gradually subsides to be followed by fine wrinkling of the skin. The red color slowly fades and usually within a week to 10 days may take on a waxy pallor. In the majority of cases, in which the injury has not been great, the skin assumes a normal color after some exfoliation. In a few cases, however, the feet become cold, blue, and sweaty. The subsidence of edema, heat, and redness marks the end of this stage.

Complications include localized infection, cellulitis, lymphangitis, and septicemia. Phlebothrombosis along the course of the veins of the dorsum of the feet and along the course of the saphenous veins has occurred and may be associated with petechiae in the nearby skin. Rarely transient hematuria and albuminuria, enlargement of the liver, and mild febrile reaction have been observed in cases of immersion foot but have not been reported in trench foot.

(*c*) *Posthyperemic stage.* The clinical manifestations during this stage vary and depend upon the degree of involvement and type of therapy. In the milder cases, the end results are satisfactory, and there is apparently complete recovery. In the more severe cases, there may be recurrence of pain, tingling, and swelling especially on walking, prolonged standing, or exposure to cold. In many of these cases, the transition from the second to the third stage is not sharp but occurs gradually and, during this period, the manifestations may vary from hour to hour or from day to day from those characteristic of the third stage to those characteristic of the second. In a few cases, deep-seated aching pain persists and may be associated with tenderness in the joints, usually the first metatarsophalangeal joint, or may be localized deep in the arch of the foot. This is usually worse at night. In still others, there may be limitation of motion in the joints, muscle weakness and wasting, and difficulty in walking. Some complain of hyperhidrosis of the feet, and anesthesia and paresthesia in the tips of the toes are not uncommon. The late pains, the paresthesias, and rigidity of the part may be due to compression of nerve endings and infiltration of muscle bundles with scar tissue. Hypocalcification or evidence of osteoporosis has been demonstrated in some of the cases and appears on the roentgenogram as diffuse or rounded areas affecting the distal part of the metatarsal bones and the proximal part of the phalanges. Occasionally, the extremities may become excessively sensitive to cold so that Raynaud's phenomenon or simple coldness may persist for hours after return to a warm environment. These sequelae have been observed for months or years after exposure.

4. PROPHYLAXIS. Prophylactic measures are directed toward conserving body heat and avoiding unnecessarily prolonged exposure of the feet to moisture, coldness, and other factors that decrease peripheral circulation.

a. Loose-fitting waterproof or water-resistant boots with replaceable thick felt innersoles and heavy woolen socks should be worn to provide good insulation as well as ventilation. The shoe-pac (rubber foot-piece, leather top type of footgear) is probably best for this purpose except on rough mountainous terrain. It is important, however, that the shoe-pac fits properly and does not constrict the toes or foot when the innersole and heavy woolen socks are used. If shoes are worn, they should be water-resistant, of relatively soft top construction, and sufficiently large to accommodate heavy woolen socks without constriction.

b. Every effort should be made to keep the feet dry and, if the socks or innersoles become damp or moist as a result of perspiration or prolonged immersion in wet mud or snow, they should be replaced by dry ones as soon as possible. An extra pair of dry heavy woolen socks should be carried by each soldier and others made available by an exchange service when troops are on duty in wet cold regions for periods longer than several days.

c. Standing in water or mud-soaked areas should be avoided as much as possible even though waterproof boots are worn. If the trench or foxhole contains water, it should be bailed out, if possible, and stones or branches of a tree placed at the bottom on which to stand.

d. The shoes should be removed at least once daily and the feet cleansed and dried. Innersoles and socks should be well dried before being replaced.

e. Cramped positions, prolonged immobility, and dependency of the extremities should be avoided. Frequent exercises and temporary elevation of the feet are desirable. If this is impractical, exercise of the toes and ankles within the shoes and elevation of the feet should be done as frequently as possible.

f. The upper part of the body should be kept warm and dry, and exposure to cold winds reduced to a minimum. Gloves should be worn, if possible.

g. Constriction by tight clothing, shoes, socks, garters, and leggings should be avoided.

h. Nutrition should be maintained at as high a level as circumstances permit. Whiskey and other alcoholic beverages should be avoided.

i. Whenever feasible, the feet should be inspected at least once weekly and injuries or infections properly treated.

j. Whenever circumstances permit, in cold wet weather, troops should be relieved from front-line action after several days exposure.

k. Unit commanders should be cognizant of the factors concerned in the causation and prevention of trench foot and of the importance of foot discipline and, in accordance with section IV, War Department Circular No. 312, 1944, are held responsible for the diligent application of the protective measures.

5. TREATMENT. The principles of treatment consist essentially of rest, avoidance of local trauma and infection, elevation of the feet to promote drainage of edema fluid, and reduction of metabolism in the affected part. The rationale of treatment is to reduce the metabolic demands of the part until edema subsides, extravasated blood is absorbed, and vasomotor tone is reestablished. Under these conditions, rapid tissue repair is favored. During the recovery stage, the reactive hyperemia, if too intense and if induced too rapidly, can be not only painful but also harmful. Therefore, rapid warming should be avoided.

a. Initial or emergency treatment. (1) As soon as the symptoms of trench foot appear, the patient should be sent to the hospital. He should be carried and not permitted to walk on damaged feet.

(2) Wet clothing should be removed and the patient wrapped in warm blankets leaving the involved extremities exposed to the air in a moderately cool room.

(3) The involved extremities should be handled very gently. The limbs should not be rubbed or massaged. If necessary, the feet may be cleansed carefully with plain white soap and water, dried, and then allowed to remain exposed, and elevated on pillows. While

it is desirable to warm the patient, the feet should always be kept cool by exposure to the room air.

(4) Strict asepsis must be maintained to avoid infection which may readily develop and rapidly spread in the damaged tissue of the feet. If sulfonamide drugs are available, they may be administered orally until the danger of spreading infection is past.

(5) Protection against pressure necrosis especially in the region of the heel is desirable and may be accomplished by frequent turning, by doughnut dressings, or by supporting the back of the legs down to the ankles on a pillow.

(6) During evacuation to the hospital, loose covering of the feet with sterile or, at least, clean towels or sheet is desirable in order to protect against bacterial contamination.

b. Definitive treatment. The same principles which underlie the initial treatment measures (that is, conservation of body heat and avoidance of trauma, infection, and heat to the involved part) are continued in the definitive treatment.

(1) Patients should be kept in bed, with the affected parts on a horizontal level with or elevated on pillows only slightly above heart level, and protected from external pressure either by complete exposure or by means of a cradle. Elevation of the extremities should be done only if there is evidence of inadequate circulation, that is, incipient gangrene, otherwise they should be maintained on a horizontal level. The period of bed rest is determined by the degree and rate of subsidence of edema.

(2) Massage or rubbing of any sort in the early stages must be avoided, and the part should be handled as little and as gently as possible. All antiseptics and ointments should be avoided, and blisters ordinarily should not be disturbed.

(3) Although the feet should remain exposed to the moderately cool room-air (65° F. to 70° F.), the body should be kept warm by means of blankets.

(4) In the early prehyperemic or ischemic stage when vasospasm is still evident and persists for longer than 6 hours, whiskey in 1-ounce doses may be administered for its vasodilating effect. Sympathetic block, using 1 percent procaine hydrochloride solution, may also be done for this purpose. These measures are not indicated after the hyperemic stage begins and should be discontinued.

(5) Maintenance of minimal tissue metabolism in the affected parts is important especially during the hyperemic type and may be accomplished by strictly avoiding the application of external heat and, if necessary, by actually cooling the limbs, in those cases in which persistent pain indicates the need for such treatment. In instances where the room temperature is not above 70° F., simple exposure of the parts may be sufficient. Cooling may be enhanced by directing the air from an electric fan against the exposed feet. Still greater cooling can be accomplished by spraying cold water from an atomizer through the fan blades. In the more severe cases with intense hyperemia and severe neuritic pains, these measures may be inadequate and greater cooling is required. This may be achieved through the application of ice bags or the use of a special refrigeration cabinet. If ice bags are to be used, sterile pledgets of cotton or gauze are placed between the toes and the whole foot loosely wrapped with sterile cotton batting and covered with a sterile sheet or towel. Carefully dried ice bags are then placed around each foot over the towel and the whole inclosed in an oiled-silk bag, around which, in turn, is wrapped thick layers of cellu-cotton or other equivalent insulating material. As an outer covering, a rubber pillowcase may be used, loosely tied about the upper calf. Ordinarily, it is sufficient to change the ice bags about every 4 hours. At this time, palpation of the toes may be done to make sure that the part is not too severely chilled. Ordinarily, a skin temperature of about 70° F. is optimum whether ice bags or a refrigeration cabinet is used. In cases with extreme hyperemia, more frequent changing will be necessary, but as hyperemia subsides, fewer ice bags will be needed to reduce the temperature of the foot to the required degree. It may be necessary to continue the ice-bag treatment for several days to 2 weeks. Care should be exercised to avoid wetting and maceration of the skin by the ice bags.

(6) Measures to prevent secondary infection including tetanus should always be instituted. Sulfadiazine by mouth should be used in cases with threatening infection. Blisters ordinarily should not be disturbed but, if opening becomes necessary, this should be done aseptically using a needle. Dressings, except when cooling is done by ice bags, and all local medication should be avoided. Areas of necrosis and ulceration which may subsequently develop should be treated conservatively as long as possible. In patients with gangrene, amputation should be delayed as long as possible and done early only in the presence of superimposed infection.

(7) A generally nutritious high protein, high vitamin diet should be supplied.

(8) After the hyperemia and edema have subsided, graduated vascular exercises should be instituted. These consist of: elevating the extremities 1 to 2 minutes at an angle of 30° to 50°; hanging the extremities over the side of the bed for 2 to 4 minutes during which the patient should flex and extend the toes; and assuming the supine position with the feet in the horizontal position for 2 to 4 minutes. This cycle is to be repeated for periods of 30 minutes, three to four times daily, for at least a week before the patient is allowed out of bed. Gradually, increasing activity should then be urged.

(9) Physiotherapy, including warm baths, massage, and passive exercises, is of value in the late stages and should be used, especially when the movement of the toes is limited by late fibrosis or edema.

(10) In cases with intractable edema and pain not controlled by ordinary measures, sympathetic block, using 1 percent procaine hydrochloride solution, compression dressings or an elastic bandage may be cautiously employed even though the value of these measures has not yet been established. Sympathectomy is indicated only in cases in which there is objective evidence of circulatory insufficiency or in which manifestations resembling Raynaud's phenomenon develop and persist months or years after the acute phase of the disease and can be shown to be relieved by "test" sympathetic blocks.

[A. G. 300.5 (27 Jul 44).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
Chief of Staff.

OFFICIAL:
J. A. ULIO,
Major General,
The Adjutant General.

DISTRIBUTION:
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TB MED 81 (Change 1)

3 OCTOBER 1944

TB MED 81, 4 August 1944, is changed as follows:

5. TREATMENT.

* * * * * * *

b. Definitive treatment.

* * * * * * *

(1) Patients should be kept in bed, with the affected parts on a horizontal level with or elevated on pillows only slightly above heart level, and protected from external pressure either by complete exposure or by means of a cradle. Elevation of the extremities should be done only if there is no evidence of inadequate circulation, that is, incipient gangrene, otherwise they should be maintained on a horizontal level. The period of bed rest is determined by the degree and rate of subsidence of edema for this form of treatment.

* * * * * * *

[A. G. 300.5 (21 Sep 44).]

BY ORDER OF THE SECRETARY OF WAR:

G. C. MARSHALL,
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ID 8 (60) : T/O 8–550.
ID 8 (45) : T/O 8–550S.
IB 5 : T/O 5–510S.
IB 8 (10) : T/O 8–650.
IB 8 (2) : T/O 8–520.
IR 5 (6) : T/O 5–251.
IR 5 (5) : T/O 5–21.
IR 8 (40) : T/O 8–560; 8–580.
IR 8 (30) : T/O 8–581.
IR 8 (20) : T/O 8–590.
IR 8 (15) : T/O 8–510.
IR 8 (10) : T/O 8–750; 8–760.
IR 8 (5) : T/O 8–572S; 8–780; 8–790.
IBn 3 : T/O 3–25.
IBn 4 : T/O 4–45: 4–145; 4–232.
Ibn 5 (2) : T/O 5–535S.
Ibn 5 (1) : T/O 5–55; 5–95; 5–275.
IBn 6 (2) : T/O 6–45.
IBn 6 (1): T/O 6–35; 6–55; 6–65; 6–75; 6–95; 6–175; 6–325; 6–355; 6–365; 6–395.
Ibn 7 (3) : T/O 7–95.
Ibn 7 (1) : T/O 7–85.
Ibn 10 (7) : T/O 10–95.
Ibn 10 (6) : T/O 10–125.
Ibn 10 (3) : T/O 10–175.
Ibn 11 (2) : T/O 11–15.
Ibn 11 (1) : T/O 11–25.
IBn 17 (3) : T/O 17–115.
Ibn 17 (2) : T/O 17–15.
Ibn 17 (1) : T/O 17–55; 17–125.
Ibn 18 (2) : T/O 18–35.

For explanation of symbol, see FM 21–6.

APPENDIX B

HEADQUARTERS, ARMY GROUND FORCES
Army War College
Washington 25, D. C.

710/111 (30 Jan 45) GNGBI. 20 JANUARY 1945

SUBJECT: Prevention of Trench Foot and Frost Bite.
TO: Commanding Generals,
All Armies,
All Corps,
XXXII Corps Atry,
Airborne Center,
Antiaircraft Command,
AGF Replacement Depots No 1 and No 2,
Replacement and School Command,
All Divisions,
1st Hq & Hq Det, Sp Trps, AGF,
All Replacement Training Centers.
Commanding Officers,
All Hq & Hq Dets, Sp Trps,
All Regiments,
All Groups,
All Battalions,
All Squadrons,
All Companies,
All Troops,
All Batteries.

1. The attached report is considered an excellent outline of a training program used by an overseas army for instruction in the prevention of trench foot and frostbite and the principles of wearing special cold weather clothing, sleeping warm and keeping dry.

2. This report is furnished for your information only. Reproduction and distribution are authorized.

3. Changes in training doctrine as enunciated in War Department publications which are necessary because of the information contained in observers' report will be published by the War Department. Change in training directives of this headquarters which are necessary because of information in observers' reports will be promulgated by this headquarters.

BY COMMAND OF THE COMMANDING GENERAL:

/s/ Holman Hamilton
/t/ HOLMAN HAMILTON,
Capt., A. G. D.,
Ass't Ground Adjutant General.

Inclosure 1

SEVERE WINTER WEATHER WILL SOON BE HERE TEACH YOUR MEN THESE PRINCIPLES AND PROTECT THEM FROM FROSTBITE AND TRENCHFOOT

Principles:

Body heat, not clothing keeps you warm. Clothing retains a layer of warm air around the body and prevents cold outer air from chilling the skin. In still air, warmth is equivalent to thickness of insulation.

Layers:

You get still air by wearing the windproof suit, which consists of jacket field M–1943, trousers field cotton OD and hood jacket field with *layers* of insulation underneath. The amount of insulation can be varied, for you can wear just a wool shirt under the jacket, or a wool shirt and sweater, or wool underwear and a wool shirt and sweater, or all these plus the jacket field wool. To get warmth you must wear the jacket field M–1943 on the outside, for the sweater and other layers of clothing lose their value when the wind blows through them.

As far as possible adjust the number of layers you wear to the temperature about you and your degree of activity. If you are cold, perhaps you should be wearing more layers. If you are sweating, you should take off one or more of the inner layers at the first opportunity to avoid making your clothing damp.

Avoid Overheating:

If your clothes become damp from perspiration, some of your body heat, normally used to keep you warm, will be diverted to dry out the damp clothing. In this way sweating makes you colder and in sub-freezing weather may help cause frostbite.

Clean Clothing:

Clean clothing is warmer than dirty clothing because grease or dirt helps conduct heat away from the body.

Loose:

In cold weather never wear anything that has a tight fit. Tight clothing or footgear restrict circulation and invites frostbite or trenchfoot. If a boot fits comfortably with one pair of socks, never wear it with two pair of socks. You may freeze your feet if you do, because the second pair will cause the boot to fit too tightly and restrict circulation. Similarly a field jacket which fits snugly and looks snappy when worn over a wool shirt alone will be too tight during cold weather when a sweater or wool jacket is also needed under the outer jacket. If your outer jacket already fits tightly, you may make yourself colder by putting on another layer under it, for you *restrict circulation.* In the same way, one pair of loose gloves is warmer than two pairs of tight ones. *If you want to keep warm in cold weather, keep your clothing loose.*

Food:

Food gives your body heat and keeps you warm. If you haven't eaten for several hours, your heat output is lowered and frequently you become cold. It this happens to you, eat a candy bar or some biscuits saved from your last K or C ration and you will immediately feel warmer and more alert. In cold weather always carry a few ounces of candy or other food in a pocket of your field jacket or parka. As far as possible, *eat little and often.*

Sleeping Warm:

Have as much insulation under you as over you. Your water repellent (not waterproof) case is windproof. Inside it you may use the mountain sleeping bag or wool sleeping bags for

insulation. As this insulation is compressed by the weight of your body, however, you need additional insulation under you. If they are dry, shelter halves, extra blankets, haversacks, field packs, web equipment, fiber ammunition or food containers (such as 10 in 1 ration boxes torn up), packboards, tree branches and bushes, or extra clothing, may be placed under your sleeping bag or blankets, for in general, the more insulation of this type you have under you, the warmer you will sleep. This is particularly noticeable in a mountain sleeping bag, whose down filling easily compresses under the body.

Many men make themselves cold by sleeping with too many clothes on:

This clothing, as they turn over in their sleep, restricts circulation at the shoulders and makes them cold. If they wore less clothing, not only would there be no constriction and they would sleep warmer, but the extra clothing could be used to advantage as insulation under them.

Brief exercise before entering the sleeping bag stimulates your circulation and causes you to heat the bag more quickly. A small man, however, may find the bag large and slow to warm. If so, he can fold part of the bag under him, in this way increasing insulation underneath and reducing the amount of air that his body must warm.

Waterproof and Water Repellent:

The raincoat is unpopular because it is *waterproof* and fits closely to the body. The man who marches in it sweats, and the sweat, condensing inside his raincoat, often gets him just as wet at the shoulders and back as if he wore no raincoat at all. For this reason the completely waterproof 2 piece, navy-type suit, called parka and trousers wet weather, is not issued to men who march, for they would soon be drenched with sweat. As organizational issue for special duties, however, this suit has many uses.

The jacket field M1943 and trousers field cotton are *water repellent but not waterproof.* Moisture vapor (sweat) can pass out through the fabric and does not condense inside. This means that you are more comfortable when marching in moderate rain if you wear the field jacket and not the raincoat. However, no water repellent will keep out water indefinitely and if you lie in water or stand for a long period in a heavy rain, you will gradually get wet even if you are wearing water repellent garments. Truly waterproof garments will not wet through no matter how much it rains, but you can get wet in them if water goes up your sleeve or runs off your helmet and down your neck.

Dry Feet Prevent Trenchfoot:

In cold weather care of the feet is as important as care of the rifle. When a man's feet are wet, cold and inactive for periods of more than one day circulation is reduced, and if it disappears, trenchfoot occurs. You can avoid trenchfoot and the amputation it often causes as follows:

1. *Do this:*

a. During wet cold weather wear properly fitted shoepacs for these reasons:

(1) The rubber shell and heavily oiled leather top will keep your feet dry.

(2) The shoepac is sized to fit over *2* pairs of heavy ski socks, insulation which you need for protection against winter cold.

(3) The shoepac has a high toe so that your toes are not constricted. Even if you are pinned down and can't move your body, you can wiggle your toes inside the shoepacs and in this way stir the circulation. In cold weather the ability to move your toes within your boots is important.

(4) The shoepac has a removable insole which adds insulation below the foot and absorbs perspiration.

b. Be sure that your shoepacs fit properly with 2 pairs of ski socks.

c. Be sure that you wear them for a few days before making long marches in them.

2. *Don't do this:*

a. During wet cold weather don't wear combat boots or service shoes without overshoes, for the following reasons:

(1) Leather boots quickly get wet, and unless they can be dried and fresh dubbing put on they will stay wet, making your socks wet, and gradually making your whole body cold.

(2) Combat boots and service shoes fit over one pair of socks wool light or one pair of socks wool heavy, which is insufficient insulation to keep your feet warm during the cold winter months. (Never wear them with ski socks, which will restrict circulation.)

(3) Combat boots and service shoes have a low toe which prevents movement of the toes to restore circulation.

(4) Combat boots and service shoes do not have removable insoles to add insulation under the foot.

b. Never wear ski socks inside combat boots or service shoes. If you do, you will restrict circulation and help cause frostbite.

c. Never keep your boots or shoepacs on for periods of several days without taking them off. Each consecutive day you wear them without taking them off, circulation becomes worse and frostbite or trenchfoot more likely. Whenever practical during cold weather, take off your boots or shoepacs for at least 3 minutes every 24 hours and rub your feet before putting footgear on again.

3. *Other information:*

a. Dubbing, which is another name for shoe waterproofing, lasts only a day under conditions of continual wet, but is effective under conditions where it rains only occasionally. Unless leather boots can be dried, which is frequently impossible, dubbing cannot be applied in a satisfactory manner. Therefore, dubbing, which works well under conditions of occasional rain will not keep your feet dry during cold wet winter months in the line.

b. *Dry Socks:*

If you are wearing wet *combat boots* that you can't dry, the issue of dry socks will be of limited value to you, for almost as soon as you put them on, the wet leather pressing against your socks will wet them through. By changing your socks you at least dry your feet and improve the circulation, which helps, but your wet boots will soon return your feet to their previous condition.

If you are wearing *shoepacs,* dry socks will help you for this reason: You replace socks somewhat damp from perspiration with dry socks. Unlike dry socks used in wet combat boots, these socks will not become wet from the outside.

As dry socks are warmer than damp ones, alternate two sets of socks and insoles. While wearing one set, dry out the other by body heat or any other available means. (One good method is to let body heat dry them at night in the sleeping bag.)

4. *Summary:*

a. Wear properly fitted shoepac with 2 pairs of ski socks.

b. If possible break them in for 3 or 4 days before making long marches.

c. Alternate 2 sets of ski socks and insoles in order to keep feet dry and warm.

DON'T GET TRENCHFOOT THIS WINTER

REPRODUCED BY: K.F.B.
HQ FOURTH ARMY (Surgeon)
29 January 1945

APPENDIX C

HEADQUARTERS FIFTH ARMY
Office of the Surgeon
A. P. O. #464, U. S. Army

24 NOVEMBER 1943

MEDICAL CIRCULAR
NUMBER 6

TRENCH FOOT

1. Approximately 200 men have been admitted to army hospitals in tne past five days suffering from trench foot.

2. Most of those afflicted report having worn wet socks and shoes for 3 to 14 days without change. Some, but not all, have been exposed to near freezing temperatures.

3. The symptoms include first numbness or loss of sensation. Later, some swelling develcps. Some who have removed their shoes have been unable to get them on again. At first the feet appear white, perhaps slightly wrinkled and furrowed, and quite cold and insensitive. If the feet are rubbed or warmed, more swelling and pain develops. Heat, walking or any trauma to the feet increases the escape of fluid and blood into the tissues. Later, vesiculation may develop. Anesthesia is replaced by hyperesthesia and paresthesia. The patient complains of shooting pains in the ball of the foot or on the dorsum of tbe foot. A varying degree of arythema appears. The foot is hot and the posterior tibial pulse is full and bounding. In the more severe cases anesthesia persists in some areas and necrosis of those parts may occur.

4. Management of this problem is directed primarily toward prophylaxis. However, proper treatment, once the condition has developed, will do much to lower morbidity and will return more of these men to duty. The following regime is suggested:

a. Those patients should be hospitalized.

b. The feet should not be exposed to heat, and the men are best kept out of heated tents or buildings.

c. The shoes should not be removed until the patient is recumbent and the feet slightly elevated.

d. All walking and other trauma is to be avoided.

e. The feet are gently washed with cold water and soap, using pledgets of cotton. They are then carefully dried, small pledgets of dry cotton placed between the toes, and a light dressing of sterile gauze applied.

f. The feet are kept elevated and are not covered with blankets. The patient is kept in a cool room or tent. In very severe cases, and when ice or snow is available a heavier dressing is applied and ice bags are applied. The ice bag covers must be kept dry.

g. Vesicles should not be opened.

h. The cold treatment is kept up for several days to several weeks depending upon the amount of swelling, vesiculation, and necrosis.

i. Vitamin B and Vitamin C should be given orally as vitamin deficiency may be an etiological factor.

j. Exercises should be started as soon as swelling has disappeared and open lesions have healed. These exercises should be carried out at hourly intervals consisting of toe flexion and anterior tibial setting. The length of the initial period of exercise should be governed by the comfort of the patient, increasing as tolerance permits.

k. Paravertebral novocaine block of the sympathetic trunk should not be done.

For the Surgeon:

/s/ C. O. BRUCE
/t/ C. O. BRUCE,
Lt. Col., Medical Corps,
Executive.

APPENDIX D

HEADQUARTERS
NORTH AFRICAN THEATER OF OPERATIONS
UNITED STATES ARMY

21 DECEMBER 1943

SUBJECT: Trench Foot.
To: Commanding General, Fifth Army, APO 464.
Commanding General, Seventh Army, APO 758.
Commanding General, Peninsular Base Section, APO 782.

1. Trench Foot, Immersion Foot, or Shelter Foot which was a very common disabling injury of the feet encountered during the winter months of World War I, is beginning to occur in troops of this theater. This is a very serious but preventable condition and all organization and unit commanders must become familiar with the measures required for its prevention.

2. When troops are subjected to exposure, frequent inspections will be made to ensure that they are taking proper care of their feet. Insofar as the situation permits, all deficiencies found will be the cause for immediate corrective action.

3. Trench foot is produced by standing or sitting about over a long period of time with cold wet feet. Intense cold is not a necessary factor, as the condition can develop at temperatures as high as 50 degrees F. The most important factors are moisture, cold, and lack of activity. Frequently, there is an associated history of constriction of the limbs by boots and clothing.

4. Individuals experiencing this condition usually first complain that their feet feel heavy, woody and numb, and are insensitive to pain, touch, or temperature. The insensitive areas are most marked around the toes. At this stage the feet are usually cold to touch, swollen and waxy white in color with a few scattered bluish areas present in the skin. When the feet are warmed up they become markedly swollen, red, hot and painful. Blisters may develop and the feet may turn purple in color.

5. Once trench foot has developed, *the feet should not be massaged* or warmed up but should be kept cool and elevated above the level of the rest of the body. The patient *should not be permitted to walk* and should be promptly sent to a hospital where adequate treatment can be given. If this type of injury is not handled in this manner it may lead to serious disability and possible loss of the feet.

6. The prevention of this condition is of great importance and consists primarily in keeping the feet clean, dry and warm. Under winter combat conditions it is often difficult to fulfill these requirements but constant attention to the following will minimize or prevent the occurrence of this condition.

a. The necessity of frequently removing shoes, leggings, and socks in order to wash, dry and massage the feet, apply foot powder and to put on dry socks if possible.

b. Improvised methods of washing and drying socks and shoes. For instance, in wet weather when nothing else is available, socks can be dried by pinning them to the inner side of the overcoat or field jacket or placing them over the shoulders under the jacket.

c. The necessity to *keep moving* when feet are cold and wet and dry socks and shoes are not available. If troops have to keep in one place they should *mark time* or make vigorous, frequent, movements of the legs. When sitting down they should elevate the feet higher than the buttocks, being careful that nothing is constricting or interfering with the circulation

of the legs. (If the circulation is normal the legs will not develop a numb or tingling sensation). If these sensations occur, the legs and feet should be exercised until they feel normal and warm.

d. The fact that regardless of how cold it may be it is important not to sleep with shoes on if feet are wet. If this is done there will be interference with the circulation, and the shoes, socks and feet will be prevented from drying.

By command of General EISENHOWER:

J. K. ROBERTS,
2nd Lt., AGD,
Asst Adj Gen.

APPENDIX E

Cir 108

26 Oct 1944

HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY

CARE OF THE FEET

1. General. Proper care of the feet is of the greatest importance for the maintenance of an effective command. A great amount of personal discomfort, as well as actual disability and loss of manpower, can be prevented by the constant attention of unit commanders and individual soldiers to the application of measures for foot care.

2. Responsibility. It is the responsibility of each unit commander to insure that all men of his command are equipped with adequate and properly fitting footwear, within availability of stocks; to inspect the feet and footwear of the members of his command at regular intervals; and to make certain that each individual soldier understands and practices the essentials of foot care.

3. Footwear. a. Supply: Footwear for field use will be that issued by the Quartermaster. Adequate well-fitted footwear is of great importance at all times; however, in cold, wet weather special equipment is needed and particular attention to foot hygiene is required. For added protection during the cold season there will be available from Quartermaster stocks:

Item	*Unit*	*Maximum Allowance*
Boots, service, combat	pr	2 per EM
or		
leggings, canvas, M–1938	pr	2 per EM
and		
Shoes, service, Type III	pr	2 per EM
Socks, wool, cushion sole	pr	3 per EM
Socks, wool, light, or socks, wool, heavy	pr	3 per EM
Overshoes, arctic	pr	1 per EM

b. Fitting: Shoes must be fitted so that no undue constriction or pressure will occur at any point when the foot is expanded by the weight of the body and pack. Because of individual variations in feet, shoes can be properly fitted only by actual personal fitting. The fitting will always be made over wool socks for the service shoe; or, for combat boots, over the sock, cushion sole, or sock, wool, heavy, or two pairs of socks, wool, light. Particular attention will be given to the provision of adequate foot room in the fitting of the footwear referred to in subparagraph a, above. For wear in wet, cold weather, a definite looseness of fit is preferable to a "snug" fit. Fitting may be made by the shoe fitting machine or by hand. In each instance, fitting will be made with the individual bearing full weight.

(1) Shoe Fitting Machine. When available, the shoe fitting machine will be used in strict accordance with the instructions issued with the machine.

(2) Fitting without Shoe Fitting Machine. The important consideration in shoe fitting is the provision of adequate length and width. A shoe of proper length will allow a thumb width (¾″) between the end of the great toe and the end of the shoe when the wearer bears full weight. Proper width may be judged by the wearer by a definite feeling of freedom of the foot in the shoe. In addition, a shoe of proper width will allow the fitter to demonstrate a looseness of the leather in front of the instep over the ball of the foot with the shoe laced,

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and, with the shoe unlaced, will allow him to insert one of his index fingers under the lower part of the tongue and over the base of the toes.

c. Care: (1) The uppers will be kept soft and pliable and the shoes as waterproof as possible. Both of these conditions may be maintained by the use of dubbin and polish. Dubbin will be worked into the leather by rubbing and moulding with the fingers. Particular attention will be given to the application of dubbin at the junction of the sole and the upper. The authorized allowance for dubbin, 2 oz cans, is 250 cans per 1,000 men per month.

(2) Even under ordinary conditions, shoes will become moist on the inside from sweating of the feet and must be allowed to dry out at least once every 24 hours. When two pairs are available, they will be worn on alternate days. When shoes become wet from outside causes such as rain, mud or snow, they will be dried slowly and not exposed to direct heat such as from open fires. In the field, ways for drying must be improvised. Broken up hay or straw, thoroughly dried over a fire and dumped into the shoe, will hasten drying; pebbles may be heated in a can and shaken about in the shoes for the same purpose. If dry paper is available, it may be torn into bits and stuffed into the shoes to absorb moisture. Well heated grain shaken about in the shoes is particularly effective.

d. Sock: Woolen socks, only, will be worn for marching or field duty. In cold, wet weather, cushion sole socks, or heavy wool socks, or two pairs of light wool socks will be worn (see Par 3a, above). Darned socks or socks with holes will not be worn on the march since they will cause abrasions or blisters.

4. Care of the Feet. a. General: The feet will be washed and thoroughly dried at least once a day. This is especially important on a march. As soon as possible after reaching camp after a march, the feet will be washed (not soaked) with soap and water, dusted with foot powder, and clean socks and spare shoes will be put on. (Unless the feet are well hardened, foot powder will be applied again in the morning before the march.) The dirty socks will be washed and hung to dry. The shoes worn during the day will be placed where they will have the best opportunity to dry.

b. Blisters: If blisters appear on the feet, they will be painted with iodine or alcohol and emptied by pricking at the lower edge with a pin, the point of which has been heated in a flame. The skin will not be removed. The blister will then be covered with adhesive tape or a Band-Aid until new skin has formed (2–4 days). The application of foot powder to the edge of the adhesive will prevent its sticking to the sock. Small cuts, scratches, and skinned places will likewise be cleaned with alcohol and covered with adhesive tape or a Band-Aid. Infections, serious cuts, large skinned areas and painful ingrown toe nails will be treated at the dispensary or aid station.

c. Ingrown: The toenails will be kept short and clean. If they are cut straight across and not on a curve, most of the trouble from ingrown toenails will be avoided.

d. Athlete's Foot: Athlete's Foot, a fungus infection of the feet, occurs commonly and if neglected may lead to considerable disability. The best methods of prevention are the maintenance of clean, dry feet, and frequent use of foot powder. If the infection does occur, it will be treated at the aid station or dispensary. Socks once contaminated with infecting agent may be a source of reinfection. Laundering in Quartermaster laundries will control this agent, and if this facility is not available, washing in soap and water and thorough sunning (inside and out) for a minimum of an hour each will be quite effective.

e. Trench Foot: (1) This is a serious condition resulting from the long exposure of the feet to moisture and cold. Extreme cold is not a necessary factor, and conditions may occur at temperatures as high as 50° F. The most important factors are moisture, cold and the lack of activity, such as occurs when standing or sitting for long periods of time. Tight footwear and leggings also contribute to the development of trench foot. Experience in other theaters indicates that a large number of troops may suffer from this condition during

the winter months unless the proper precautions are taken. In one active theater during the cold months, almost one half as many casualties resulted from trench foot as from battle injuries. A large percentage of those affected were unable to do combat duty thereafter.

(2) In addition to coldness of the feet, the first symptom of trench foot is often a feeling of numbness. There may also be tingling and aching of the feet, toes and ankles. Usually the condition does not cause acute discomfort in the early stages, the most common complaint being that of a feeling of "woodeness of the feet" and difficulty in walking. Swelling follows the other symptoms and the skin becomes white or mottled in appearance. Blisters may develop later. Unless proper care is sought early, serious damage to the feet may be the result.

(3) The prevention of trench foot is of great importance and consists, mainly, in keeping the feet clean, warm and dry. Under bad field conditions in the winter this is hard to do but the constant attention and effort of each individual to the measures outlined below can be very effective:

(*a*) Adequate, properly fitted footwear (see Par 3a above) must be worn.

(*b*) Do not constrict the lower legs, ankles, or feet by the tight lacing of leggings or shoes.

(*c*) Avoid standing in cold water, mud or snow.

(*d*) Whenever possible, keep moving when feet are cold and wet. If troops are to be kept in one place, they should mark time at frequent intervals or make frequent vigorous movements of the legs. Check for numbness of the toes by wiggling them frequently.

(*e*) Do not sit with feet lower than the buttocks.

(*f*) Loosen the shoe laces or buckles at every opportunity and move the feet around in the shoes as much as possible.

(*g*) Frequently (once or twice daily) remove leggings, shoes and socks in order to wash, dry and massage the feet, applying foot powder, and, if possible, putting on dry socks. If dry socks are not available, wring out the wet ones thoroughly before replacing.

(*h*) Make every effort and use all possible means for drying socks and shoes. (Socks may be dried by wearing them flat under the shirt above the belt when on the march or while sleeping).

(*i*) Do not sleep with the shoes on, if the feet are wet. The feet will warm up faster out of the shoes (they may be wrapped in a piece of cloth or an extra shirt), and the shoes will dry much more readily off than on.

(4) When trench foot is suspected, the patient will be handled as a non-ambulatory casualty and transported at once to the nearest aid station or dispensary. It is important to remember that the patient will not be allowed to walk and the feet will not be massaged or warmed. All constricting footwear and leggings will be removed, and the feet kept cool and elevated above the rest of the body. Failure to comply with these simple first aid procedures may lead to serious disability and possible loss of feet.

5. Inspection of Feet and Footwear: Each unit commander will inspect the feet and footwear of each individual in his unit at regular intervals (at least twice monthly) and, if possible, before a march which is to be of more than two hours duration. At these inspections, close attention will be given to the adequacy and condition of the footwear of each individual. The feet will be examined for the presence of blisters and reddened areas, corns, callouses, and other evidence of improperly fitted or poorly repaired shoes or socks and for improperly trimmed or ingrowing toenails. Deficiencies found on inspections will be corrected immediately so that each man will, at all times, have his feet in the best possible condition and adequate well-fitted footwear in his possession.

6. Instructions: Each unit commander will provide complete detailed instructions in foot care and hygiene to all enlisted personnel of his command. This instruction must be continuous and its application by the individual soldier checked at frequent intervals. This

directive, or pertinent extracts therefrom, will be posted in each unit for the information of the enlisted personnel. Supplementary information and source material for instruction may be found in these publications:

a. AR 40–205; AR 856–125; FM 8–40; FM 21–10; and FM 21–100.

b. See IV, Cir 312, WD, 22 Jul 1944. (AG 727.3 PubGD)

By Command of General EISENHOWER:

R. B. LORD,
Brigadier General, GSC, Deputy Chief of Staff.

R. B. LOVETT
Brigadier General, USA, Adjutant General

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APPENDIX F

HEADQUARTERS
THIRD U. S. ARMY
APO 403
U. S. ARMY

21 NOVEMBER 1944

MEMORANDUM:

TO: Corps and Division Commanders.

1. The most serious menace confronting us today is not the German Army, which we have practically destroyed, but the weather which, if we do not exert ourselves, may well destroy us through the incidence of trench foot.

2. If the prevention of trench foot were impossible, I would not mention it, but prevention is perfectly practicable and is a function of command.

3. Trench foot is due primarily to two causes, both of which produce a reduction in the blood supply of the foot. The first cause is due to the feet being cold and wet, which naturally shrinks the small blood vessels. The second cause is due to reduced flow of blood to the foot due to tight socks, and/or tight shoes, and tight leggings.

4. If company officers and non-commissioned officers did their full duty, there would be no trench foot. The onus of their failure rests on you. You must see to it that the following points are brought home to all members of your command:

a. First, each man is personally responsible for the health of his feet. He has to live with them, and if, through carelessness, he becomes a victim of trench foot he may well become a cripple for life.

b. Second, company officers and non-commissioned officers must see to it that the men care for their feet.

5. This care should be exercised along the following lines:

a. Where men have arctics, they should be worn in wet and cold weather.

b. Before putting the arctics on, the shoe should be dried and two pair of dry socks worn inside it. Size of shoe must be large enough to permit this to be done without constriction. Lace shoe as loosely as possible. Same procedure applies when no arctics are available.

c. The shoe should also be treated with dubbin, particularly where the upper joins the sole. One treatment of dubbin is not sufficient; it should be repeated daily.

d. Men should carry one extra pair of socks in their helmets. This will not only keep the top of the head warm but will dry the socks.

e. Whenever opportunity affords—and certainly each night—the galoshes, shoes, and socks should be removed, and the feet massaged vigorously for at least five minutes by the watch. The men should then put on a pair of dry socks next to the foot and preferably a second pair of dry socks outside the first pair. If only one dry pair is available it should be worn next the skin.

6. Orders have been issued that all new shoes be treated with dubbin before issue. Unit supply officers are responsible to check that this is done.

7. When possible a pair of dry socks will be issued with the daily ration and the wet pair turned in for laundering and drying.

8. We are going to have weather conditions from now on until the end of the war which will be conducive to trench foot. To win the war we must conquer trench foot. You have conquered every other obstacle—I am sure you can conquer this.

/s/ G. S. PATTON, Jr.,
Lieut. General, U. S. Army,
Commanding.

APPENDIX G

HEADQUARTERS
EUROPEAN THEATER OF OPERATIONS
UNITED STATES ARMY

RBL/PRH/mgc
APO 887
30 JANUARY 1945

AG 210.453 OpMS
SUBJECT: Trench Foot Control Officers.
TO: Commanding Generals,
First US Army
Third US Army
Seventh US Army
Ninth US Army
Fifteenth US Army

1. The Allied forces in the Pacific area had to lose four divisions from malaria before an energetic program was instituted to control the disease. In the European Theater of Operations the US Army has lost more than 2½ divisions because of trench foot. The trend of the disease is downward, but judged by the current incidence, a more energetic program of prevention is necessary.

2. The Supreme Commander has noted with growing concern the high incidence of trench foot in this theater. Letter, Supreme Headquarters, Allied Expeditionary Force, file AG 727.3-1 MED-AGM, subject: "Control of Trench Foot," dated 24 January 1945, states in part: "It is desired that higher unit commanders impress upon all ranks the necessity for unremitting attention to this command responsibility".

3. Trench foot is a preventable disease. The methods to be practiced in its control have been set forth in War Department Circular 312, dated 22 July 1944, Circular 108, this headquarters, dated 25 October 1944, and Circular Letter No. 126, Office of the Chief Surgeon, this headquarters, dated 18 October 1944. As evidenced by the continued excessive loss of manpower from this cause, the results thus far attained have not been satisfactory.

4. In order to carry out more effectively the provisions of the directives cited above, it is desired that these measures be instituted without delay and that they be continued until 15 April 1945:

a. Each army will provide a team of two officers; one officer from the line and one from the Quartermaster Corps, designated as the Trench Foot Control Team, to work in close cooperation with the representative of the Army Surgeon concerned with the prevention of trench foot. The duties of this team will be:

(1) To determine periodically the existing frequency of trench foot and of frostbite in regiments of the command and in separate units.

(2) To determine the factors contributing to excessive numbers of cases in particular units.

(3) To provide information to non-commissioned trench foot control officers as indicated in sub-paragraph 4b, below, in the methods of prevention of injuries resulting from cold (trench foot and frostbite).

(4) To recommend to unit commanders the necessary measures for improved control.

(5) To advise the army commander on observed deficiencies, on the existing status of trench foot in the command, and on the necessary remedial measures.

b. Unit commanders at company level, or the equivalent for separate units, will appoint trench foot control non-commissioned officers, selecting men of demonstrated ability and experience in order to insure that the duties outlined below are executed with energy, initiative and originality:

(1) Determination by personal inve tigation of the extent and satisfactoriness with which foot discipline is practiced in the company, and to encourage improved performance through personal instruction and by force of example.

(2) Determination of shortages in equipment and supplies essential to the prevention of trench foot.

(3) Institution of a program of small group discussion and demonstration designed to acquaint all members of the company with the measures which the individual soldier must practice in the prevention of trench foot and in keeping warm in winter weather.

By command of General EISENHOWER:

R. B. LOVETT,
Brigadier General, USA,
Adjutant General.

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APPENDIX H

GENERAL HEADQUARTERS

UNITED STATES ARMY FORCES, PACIFIC

APO 500

AG 353 (18 July 45) GC — 18 JULY 1945

SUBJECT: Wet-Cold Indoctrination Program.

TO: Commanding General, United States Army Forces, Western Pacific, APO 707.
Commanding General, United States Army Forces, Middle Pacific, APO 958.
Commanding General, Sixth Army, APO 442.
Commanding General, Eighth Army, APO 343.
Commanding General, Far East Air Forces, APO 925.

1. A Wet-Cold Indoctrination Program will be established in this theater to acquaint troops with adequate means of self-protection against winter weather conditions.

2. Troops in this theater have been subject only to tropical climates. For that reason particular attention will be given to preparing troops for cold weather conditions. Experience in the European theater, where troops were already acclimated to temperate climate, proved conclusively that unless vigorous emphasis was placed on the dangers inherent to sustained exposure to winter weather necessary under combat conditions, high casualty rates invariably resulted.

3. Many troops in this theater are unfamiliar with standard items of cold weather clothing and equipment. In order to cause such clothing to be utilized with the maximum benefit, it is necessary that strong emphasis be placed on the use of cold weather clothing.

4. The Commanding Generals, United States Army Forces, Western Pacific and United States Army Forces Middle Pacific are charged with technical and administrative control of the program as it applies to troops for which each of these commanders is logistically responsible. Tactical commanders are charged with the responsibility of insuring that the information included in this program is appropriately disseminated to personnel of their commands. Direct contact between Commanding General, United States Army Forces, Western Pacific, Commanding General, United States Army Forces, Middle Pacific and tactical commanders concerned is authorized for the purpose of carrying out the objectives of the Wet-Cold Indoctrination Program.

By command of General MACARTHUR:

/S/ H. W. ALLEN
/T/ H. W. ALLEN
Colonel, A. G. D.,
Asst. Adjutant General.

Copies to:
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438404°—58——36

APPENDIX I

HEADQUARTERS

UNITED STATES ARMY FORCES WESTERN PACIFIC

OFFICE OF THE COMMANDING GENERAL

TRAINING MEMORANDUM No. 1 — APO 707, 2 AUGUST 1945

WET-COLD INDOCTRINATION PROGRAM

1. *PURPOSE.* This indoctrination program is designed to establish universal appreciation and full recognition of wet-cold weather problems, together with the value of training in the proper use of individual wet-cold weather clothing and equipment.

2. *OBJECTIVES:*

a. The major requirement is the eventual qualification of every individual in this command in the correct employment of wet-cold weather procedures and equipment.

b. A second requirement is the qualification of appropriate supply personnel as experts in technical matters of supply and storage, care and maintenance, fitting and issue and the presentation of clothing and equipment.

c. Incident to the above requirements, a further objective to the establishment of definite command responsibility toward insuring that:

(1) Training in the proper use of wet-cold clothing and equipment is a continuing proposition, to be carried on subsequent to initial indoctrination.

(2) All officers and key enlisted personnel fully comprehend the capabilities and limitations of clothing and equipment in winter weather so that they may utilize the knowledge in exercising all possible precautions against weather-caused casualties.

3. *PRIORITIES OF INSTRUCTION:* First priority will be given to combat units scheduled for earliest staging in any forthcoming operation. Other units will be phased in accordance with mounting out schedules.

4. *COURSES:*

a. *Indoctrination in Proper Use of Clothing and Equipment.* All individuals, officers and enlisted men, will be given a two (2) hours course of instruction to include:

(1) Principles of how to live in wet-cold climates;

(2) Demonstration and explanation of fitting, wearing, care and designed purpose of wet-cold weather clothing;

(3) Training aids and training film to exhibit the dangers of wet-cold weather combat;

(4) A period reserved for answering questions.

b. *Supply Course.* Unit supply personnel and Quartermaster Class II and IV personnel will be given a minimum of one (1) hour additional instruction in the issuing and proper fitting of each individual article of the uniform.

c. *Refresher Training.* Constant review of the indoctrination course will be given.

5. *INSTRUCTIONS:*

a. *Wet-Cold Instructional Team.* A team of officer instructors will be attached to subordinate commands, as indicated in separate instructions to the commanders concerned. Full advantage will be taken of the services of these instructors as lecturers to personnel and for the training of unit instructors for supplementary indoctrination. Particular attention should be paid to the assistance the officer instructors can render to supply personnel.

b. Each major unit of this command will utilize the team referred to in subparagraph (a) above to train sufficient instructors within each major unit to centralize supplementary indoctrination.

6. *WET-COLD CLOTHING AND EQUIPMENT:*

a. Special indoctrination is required to obtain the maximum benefit from wet-cold clothing. Such individual clothing includes:

(1) Cap, field, cotton, O. D., with visor.
(2) Jacket, field, M–1943.
(3) Hood, jacket, field, M–1943.
(4) Jacket, field, wool, O. D.
(5) Sweater, high-neck.
(6) Trousers, field, cotton, O. D.
(7) Trousers, wool, O. D.
(8) Suspenders, trousers.
(9) Glove-shells, leather.
(10) Glove-inserts, wool.
(11) Shoe pacs, M–1944 with two felt insoles.
(12) Socks, wool ski.
(13) Overshoes, Arctic M–1945.

b. Individual equipment in the wet-cold classification includes:

(1) Bag, clothing, waterproof.
(2) Bag, sleeping, wool.
(3) Case, water repellant, for bag, sleeping.

c. Special purpose items of clothing and equipment in Class IV category for which indoctrination will be required are the following:

(1) Parka, wet-weather.
(2) Trousers, wet-weather.
(3) Overcoat, parka type, pile lined.
(4) Boots, knee, wader.

d. Training kits containing sample items of wet-cold clothing and equipment will be distributed to major commands by the team referred to in paragraph 6a above. Additional kits will be distributed as required.

7. *TRAINING AIDS AND REFERENCES:* The following training aids and references will be given a limited initial distribution as they become available. Requisitions will be filled as promptly as possible under limitations of availability. Reproduction of training aids will be accomplished by the major echelons to the maximum extent possible.

a. *Manuals, Wet-Cold:*

(1) TM 10–275 Principles of Cold Weather Clothing.
(2) FM 70–10 Mountain Operations.

b. *Manuals, Extreme Cold:* (For consideration only; indoctrination in extreme cold is not part of the program sponsored by this memorandum) TM 70–15 Operations in Snow and Extreme Cold.

c. *Printed Matter:*

(1) Letter, Hqs Army Ground Forces, (file 710/111 (20 Jan 45) GNGBI) subject: "Prevention of Trench Foot and Frostbite." (To be furnished by WETCO officers.)
(2) WD Circular 312, 1944—Trenchfoot, Cause and Prevention.
(3) AR 850–125—Fitting of Shoes.
(4) AR 850–126—Fitting of Clothing.

d. *Bulletins on Fitting and Sizing:*

(1) SB 10–236 Size Tariffs.

(2) SB 10.191 Fitting and Issuing Jacket, field, M–1943.

(3) SB 10–194 and Change 1—Supplement Tariffs.

(4) TB 10–275 (1) Lengthing of Sleeping Bags, Foot. Measuring and Fitting of Shoes and Socks.

e. *Cartoons:* (To be prepared for automatic distribution)

(1) How to Use the Sleeping Bag.

(2) How to keep dry.

f. *Training Films:*

(1) FB 180 Trenchfoot.

(2) Combat FB 30 through 42.

(3) FS 142–3–4–5 Cold Weather Clothing.

g. *Special "Wetco Outlines":*

(1) 1—Wet-Cold Clothing and Equipment Indoctrination Course. (To be furnished by WETCO officers.)

(2) 2—Supplement for Supply Personnel to Wet-Cold Clothing and Equipment Indoctrination Course.

(3) 3—Accelerated Acclimatization. (To be furnished by WETCO officers.)

8. *REPORTS:*

a. Unit Status of Training Report. All USTR submitted to this headquarters prior to operational commitment will contain a statement as to the number of hours of Wet-cold Indoctrination accomplished per individual and the rating by unit commander as to the units proficiency in this subject.

b. *Classification Card Remark.* Hours of indoctrination accomplished per individual will be entered on Individual AGO Form 20 and Form 66–1 cards, (Example: Wet-Cold Indoctrination _____ hours on (day) (month) 1945). (GSC 353)

BY COMMAND OF LIEUTENANT GENERAL STYLER:

EDMOND H. LEAVEY,
Major General, USA,
Deputy Commander and Chief of Staff.

OFFICIAL:

S/LEONARD S. CARROLL,
Lt. Col. A. G. D.,
Asst. Adj. General.

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APPENDIX J

HEADQUARTERS
NORTH AFRICAN THEATER OF OPERATIONS

Office of the Surgeon
APO 534

6 JUNE 1944

710.
SUBJECT: Trench Foot.
TO: Commanding General, NATOUSA.

1. The total cases of trench foot as shown on hospital bed status reports from 12 Nov. 43 to 30 Apr. 44 was 5,670. The total battle casualties for Fifth Army for the same period was 21,674, giving a ratio of trench foot to battle casualties of 1 to 3.8. Trench foot accounted for 9% of all disease admissions from Fifth Army for the period 1 Nov. to 30 April.

2. Information available indicates that 20% of trench foot cases return to duty in 3 to 6 weeks, the remaining 80% have a prolonged hospitalization period with a probable return to full duty of not over 60%. The remainder must be used in limited assignment or evacuated to the ZI. Those cases returned to duty are much more susceptible to further injury due to cold. One battalion surgeon reports that out of 281 cases of trench foot evacuated from his battalion (Hawaiian) 29% were recurrences.

3. The prevention of trench foot is primarily a training problem which must depend entirely upon the education and discipline of the individual soldier. The problem is complicated during combat by the fact that the most susceptible group, the infantry, has a rapid turnover in personnel. We must teach the recruit how to keep from becoming a trench foot casualty at the most tense moment in his life, namely, when he is about to engage the enemy in close combat for the first time. To date there is repeated evidence that replacements in this theater have not received instruction in the prevention of trench foot prior to joining the combat division.

4. British troops in the beachhead had less trench foot than US troops. This was probably due to:

a. Better foot discipline and training in care of the feet.

b. Heavy wool socks.

c. Shoes large enough so that no constriction of the feet was caused by wearing heavy wool socks. (US troops tend to fit shoes too small for cold weather when heavy socks or two pair of light socks must be worn).

d. A pair of clean dry socks for each man daily, issued with the ration.

e. More frequent shifting of personnel in the line.

5. It is apparent from the above that trench foot is a serious problem. Foot disabilities experienced in warm weather are not as serious as trench foot but because of their prevalence they greatly affect troop efficiency. The solution of these problems can be obtained by proper training and equipment.

6. Studies in equipment requirements have been made and appropriate recommendations made to the War Dept, radio to AGWAR, ref. No. F53022, 31 May 44:

"Training in care of the feet and foot discipline has not reached the required standard. It is therefore recommended:

1. All units be issued the NATOUSA pamphlet on care of the feet and that it be used as a basis for unit training.

2. All unit training programs include at least 4 hours instruction in care of the feet.

3. That special training in care of the feet be given to unit commanders and NCO's and that they be taught the fundamentals of foot inspection by medical officers of the unit.

4. That unit commanders and NCO's be held responsible for foot casualties. A high incidence of these conditions to be indicative of lack of leadership.

5. That frequent inspections of feet and foot gear be made by the officers of combat units. That following such inspections immediate action be taken to correct deficiencies found in training, equipment or physical condition of individual's feet.

6. That all Replacement Depots conduct a school in care of the feet and certify that all individuals furnished to combat units have completed such a course."

7. Laundry facilities for socks should be provided for combat divisions during cold wet weather. Under such conditions one pair of dry socks should be furnished each individual daily with the ration.

8. In addition to the above measures commanders should arrange, during cold weather, for men in front lines to be released frequently. If this is not done they will lose one man with trench foot for each 3 to 4 battle casualties.

MORRISON C. STAYER,
Major General, USA.,
Surgeon.

APPENDIX K

HEADQUARTERS
GROUND FORCE REPLACEMENT SYSTEM

European Theater of Operations

CIRCULAR
No. 55

APO 887
13 DECEMBER 1944

1. *PREVENTION OF TRENCH FOOT*—1. References: War Department Circular 312, 1944; Circular 108, European Theater of Operations, 1944; Medical Bulletin 25; Circular Letters 126 and 134, Office of Chief Surgeon, European Theater of Operations, 1944.

2. Trench Foot has recently come to the fore-front as a major cause of casualties among combat troops in this Theater. This serious condition is largely preventable, provided the individual is instructed and takes certain basic measures to prevent it.

3. All members of the Ground Force Replacement System must be made fully aware of this problem. The Replacement System can and will make a material contribution towards its solution by properly indoctrinating replacements during the time they are under this command. Each man who is thereby spared the development of this condition is one more fighting man with his unit, and one fewer casualty that requires replacement.

4. It is urgent that each replacement passing through the Ground Force Replacement System is given adequate instructions to inform him of the individual measures for successfully preventing this disability. Instructions will be concerned with effective measures to be taken under field conditions and will be presented in such a manner as to impress the man with the seriousness of the condition.

5. Depot Commanders will designate instructors in sufficient numbers to give small group instruction to replacements under their control. Instruction in this will be included in the initial orientation given all incoming replacements, and in addition the training program given all replacements during their stay in the Replacement System will include a minimum of 1 hour each week on this subject.

6. The following points will be stressed:

a. The seriousness of the condition to the individual, both as to immediate dangers and the permanent injuries that may result therefrom.

b. The seriousness of the problem to the War Effort in this Theater.

c. Factors contributing to its development, with special emphasis on the role of conditions causing impairment of the circulation.

d. The preventable nature of the condition with practical preventative measures, including class demonstrations and practice by each individual. Included will be examinations to see that shoes and socks are properly fitted and the shoes or boots are habitually laced loosely; massage of the foot; exercise of the toes and ankles, both with and without shoes on; postural exercises of the foot.

7. The instructors to be used for this will secure the advice and assistance of the unit medical officers. It is recommended that men designated as instructors visit hospitals in the vicinity of the depot in company with some of their unit medical officers, and there see actual cases of Trench Foot so that they may be more conversant with and aware of the seriousness of this condition.

By command of Brigadier General MATCHETT:

CHARLES H. VALENTINE,
Colonel, G. S. C.,
Chief of Staff.

OFFICIAL:
F. G. GARRISON,
Major, A. G. D.,
Adjutant General.
DISTRIBUTION: "C."
Less Non-GFRS Units.

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