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COLD INJURIES IN KOREA DURING WINTER OF 1950-51

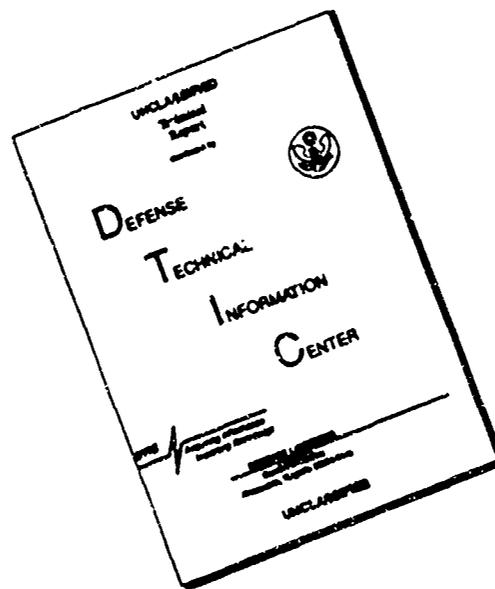
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SOLE INJURIES IN KOREA DURING WINTER OF 1950-51

by

Lt. Col. K. D. Orr, M.C.  
Capt. D. C. Fainer, M.C.

from

Army Medical Research Laboratory  
Fort Knox, Kentucky  
1 November 1951

Clinical studies carried out at the Osaka Army Hospital, Japan. Data were compiled and report reproduced at the Army Medical Research Laboratory, Fort Knox, Ky.

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## FOREFWORD

On 29 November 1950, Brig. General S. B. Hays, Surgeon, Japan Logistic Command, designated Osaka Army Hospital as a center for the treatment of cold injuries arising from the Korean conflict. The principal reasons for this action were: a) to afford the best professional and nursing care for frostbite and similar conditions, including trench foot, through the development of a skilled team, b) to develop criteria for decisions on evacuation to the United States and return to duty of patients of this type and c) to pursue research in the development of improved prophylaxis, diagnosis, treatment and general management of these conditions.

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The occurrence of frostbite is usually sporadic in civil life. It most commonly occurs among individuals stuporous from alcohol and in individuals whose occupations require prolonged exposure during very cold weather (1); however, war fought in cold climates may produce a staggering number of cold injuries.

The history of cold injuries has been reviewed by several authors (2, 3). The armies of Alexander experienced casualties from frostbite. Napoleon's Russian campaign resulted in a tremendous number of cold injuries. According to the official British history of World War I there were 115,361 cases of frostbite and trench foot among British forces. It has been estimated that 10 per cent of the German soldiers in World War II on the Russian front suffered cold injuries. Based on provisional data there were 55,331 cases of cold injury in the American forces during World War II.

Large numbers of cold injury casualties materially reduce the fighting strength of an army. This is particularly true in ground forces where cold injury casualties are usually among the frontline riflemen. During the winter of 1944-45 in Europe there were 46,000 cold injury casualties in the American fighting forces. These required an average hospitalization of 50 days. Wayne (2) has calculated this to amount to the loss of the effective fighting strength of 12 infantry divisions for 50 days, since almost all cases were riflemen.

Not only do these cold injury casualties reduce the strength of an army, but they result in disability to the individual. Even patients who do not lose parts may have pain, hyperhidrosis and intolerance to cold weather following healing of the initial lesion. They are handicapped for certain occupations and some must receive compensation on separation from the service.

Cold injuries include frostbite and the trench foot-immersion foot syndrome. Frostbite is further divided into ground-type and high altitude frostbite.

Ground-type frostbite may occur in ground troops, usually the frontline soldier, when the ambient temperature is below freezing. The duration of exposure is between 1 and 24 hours.

High altitude frostbite (5) may occur in aviators where the ambient temperature may reach minus 60 degrees Fahrenheit with the duration of exposure being from a few minutes to a few hours. The very low temperatures may be combined with winds of high velocity which increase the cooling rate of exposed parts. Hands are the most frequent site of injury. Contact of the skin with extremely cold metal accounts for some of the cases of frostbite among aviators.

Trench foot, a term generally adopted in World War I, may occur at ambient temperatures near or slightly above freezing following prolonged exposure of the feet to cold and moisture. It is usually accompanied by numbness and insensibility of the lower extremities.

... probably above freezing, usually ...  
... have been immersed in cool seawater for vary

These types of cold injuries have a similar clinical appearance. As pointed out by Whayne (2), separation into the various cold injury categories is based largely upon the degree of cold to which exposed, the period of exposure and the environmental factors which in conjunction with cold intensify the effect of low temperature. Under conditions of combat a mixture of trench foot and frostbite may be present in a single individual.

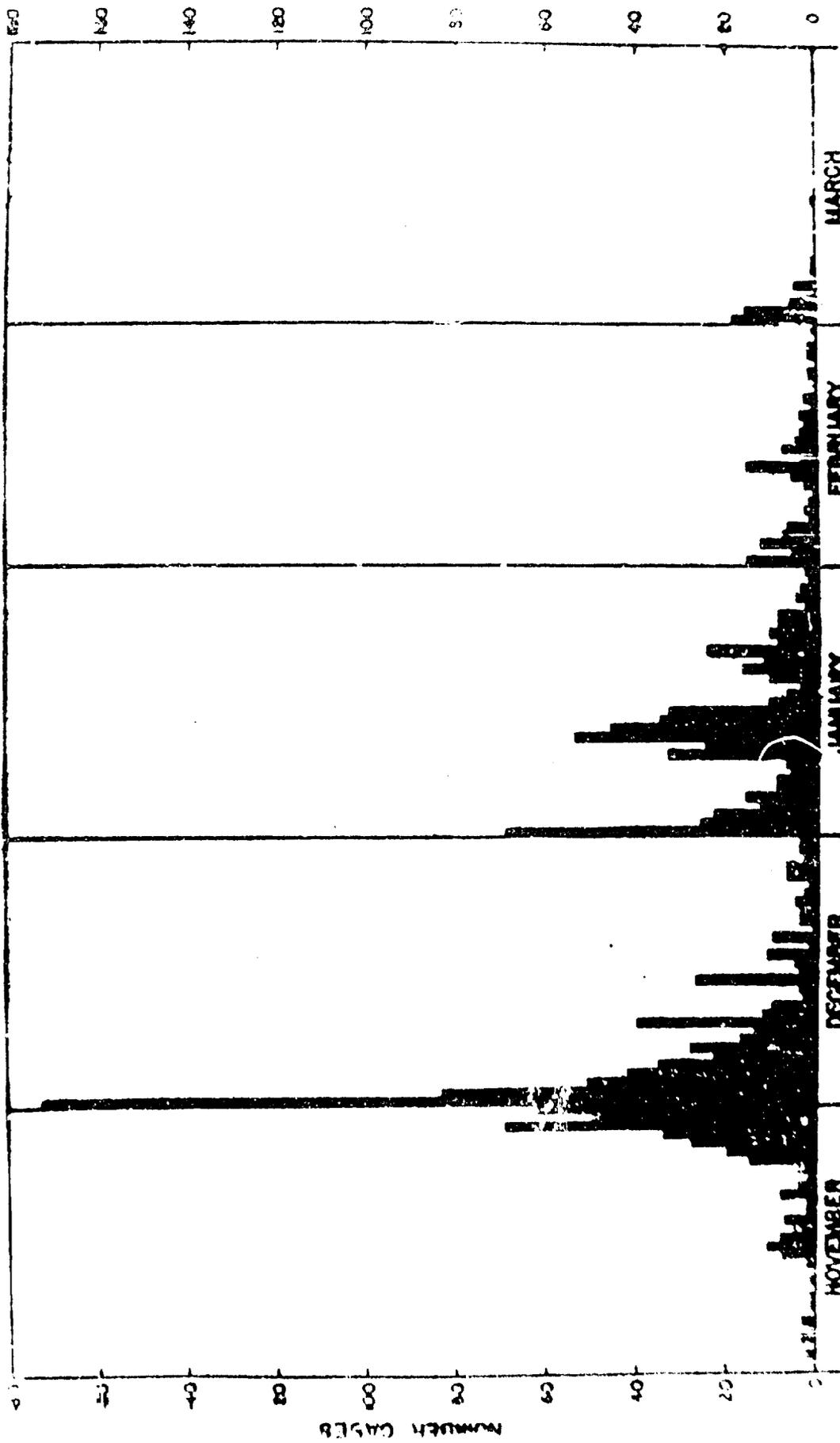
Although Lewis (4) has defined frostbite as actual freezing of the tissue, it is frequently impossible under combat conditions to determine if solidification has occurred. Among soldiers sustaining a cold injury in Korea during the winter of 1950-51, the affected part was rarely seen at a time when it could be determined if the part had been solidified. However, a history of ice between the toes or of socks or gloves frozen to the part was frequently given. Almost all cold injuries in Korea occurred when the temperature was below freezing.

The weather conditions in Korea probably were the most severe ever experienced by American fighting forces. On an average the temperatures were lower than those encountered in Europe or the Aleutian Islands in World War II or in Europe during World War I. Although American troops have been stationed in arctic and subarctic regions such as Alaska, Canada and Greenland, they have never been engaged in actual combat in those areas.

In Korea cold injuries were infrequent early in November 1950 (Fig. 1). In the latter part of November severe weather conditions appeared, the tempo of combat increased and a large scale retrograde movement by United Nations forces took place. Many cold injuries occurred. To accommodate these cold injury casualties a section of Osaka Army Hospital, Osaka, Japan was designated on 29 November 1950 as a center for the treatment of frostbite and similar conditions. Although not all cold injuries evacuated from Korea were sent to the Cold Injury Section of Osaka Army Hospital, a total of 4,216 patients were admitted with a diagnosis of cold injury. This represents more than one-half of the estimated total of men evacuated from Korea because of cold injuries.

At the close of the winter months, summaries of the clinical records of 2,257 of these patients were available. Serial photographs on over 100 patients also were available. On the basis of this material it has been possible to analyze certain clinical and epidemiological aspects of ground-type frostbite as it occurred in Korea during the winter of 1950-51. The case material is considered to be a sample of the frostbite population. All desired information was not available in each case history. The final diagnosis of the 2,257 cases on whom summaries were available indicated that 83.3 per cent were cold injuries. Most were considered to be ground-type frostbite.

The remaining 16.7 per cent, although admitted with a diagnosis of cold injury, failed to give a history of frostbite and failed to show the symptoms typical of frostbite. In these cases there was a history of being exposed to very cold and numb. Instead, a gradual onset of symptoms was reported.



THE DATES OF OCCURRENCE OF FROSTBITE DURING THE WINTER OF 1950-51  
IN 1710 CASES SUBSEQUENTLY HOSPITALIZED AT THE OSAKA ARMY HOSPITAL.

FIG. 1

anesthesia of the feet with erythema and maceration of the skin. The feet were usually cool to touch. There was no hyperhidrosis. No diagnostic title applicable to this condition is given in the Joint Armed Forces Diagnostic Nomenclature Manual. Therefore, the descriptive title "Ill Classified Condition of the Feet Manifested by Hyperhidrosis, Erythema, Maceration and Coldness" was given.

It is questionable if this condition is a true cold injury. Similar findings are present in men after long marches in months other than winter. However, the signs and symptoms of the Ill Classified Condition of the Feet as seen in Korea were of longer duration than the similar signs and symptoms seen following long marches in milder climates. Furthermore, the incidence of this Ill Classified Condition decreased when warm weather appeared. The condition may be very mild trench foot although hyperhidrosis is not a characteristic of early trench foot and immersion foot (6, 7). It was the result, in part, of physical irritation from trauma and chemical irritation from prolonged contact with perspiration in footwear impervious to water. These patients required only local foot care (potassium permanganate soaks) and bed rest.

Some patients who demonstrated hyperhidrosis, erythema and maceration of the feet gave a history compatible with a cold injury and demonstrated hypesthesia. These patients are discussed under the Clinical Manifestation of first degree frostbite.

## II. CLASSIFICATION

Frostbite is best classified clinically into 4 degrees of severity. However, all degrees of frostbite may be present in a single extremity with the most distal part being the most severely injured.

First degree frostbite is characterized by numbness, erythema, swelling and superficial desquamation of the involved part. Numbness of the toes alone while exposed to cold does not constitute a first degree lesion. The toes may become anesthetic following exposure to 40 or 50 degrees Fahrenheit for a few hours with no subsequent damage. The presence of stinging or burning pain and swelling after rewarming is indicative of injury due to cold. Analysis of 1,880 clinical records of patients hospitalized at Osaka Army Hospital diagnosed as frostbite indicated that the most severe lesion in 16.7 per cent was first degree frostbite.

Second degree frostbite produces vesiculation of the skin. This degree of cold injury involves only partial thickness of the skin and does not extend into subcutaneous tissue. First degree frostbite is present proximal to the second degree lesion. Examples of second degree frostbite are shown in Figs. 2, 3, 4 and 12. Second degree frostbite was the most severe lesion in 33.6 per cent of 1,880 cases.

Third degree frostbite involves the entire thickness of skin, extending into varying depths of subcutaneous tissue. Vesicles may or may not appear. Second and first degree lesions surround the zone of third degree damage. Examples of third degree frostbite are seen in Figs. 5, 6, 15 and 16. Third degree frostbite was the most severe lesion in 43.6 per cent of 1,880 cases.

Fourth degree frostbite produces damage to the entire thickness of the skin and results in the loss of the part.



**Fig. 2 - Second degree frostbite of the heel, 7 days after injury.**



Fig. 3 - Second degree frostbite of the left middle finger, 4 days after injury.



Fig. 4 - Second degree frostbite of the ear, 4 days after injury.

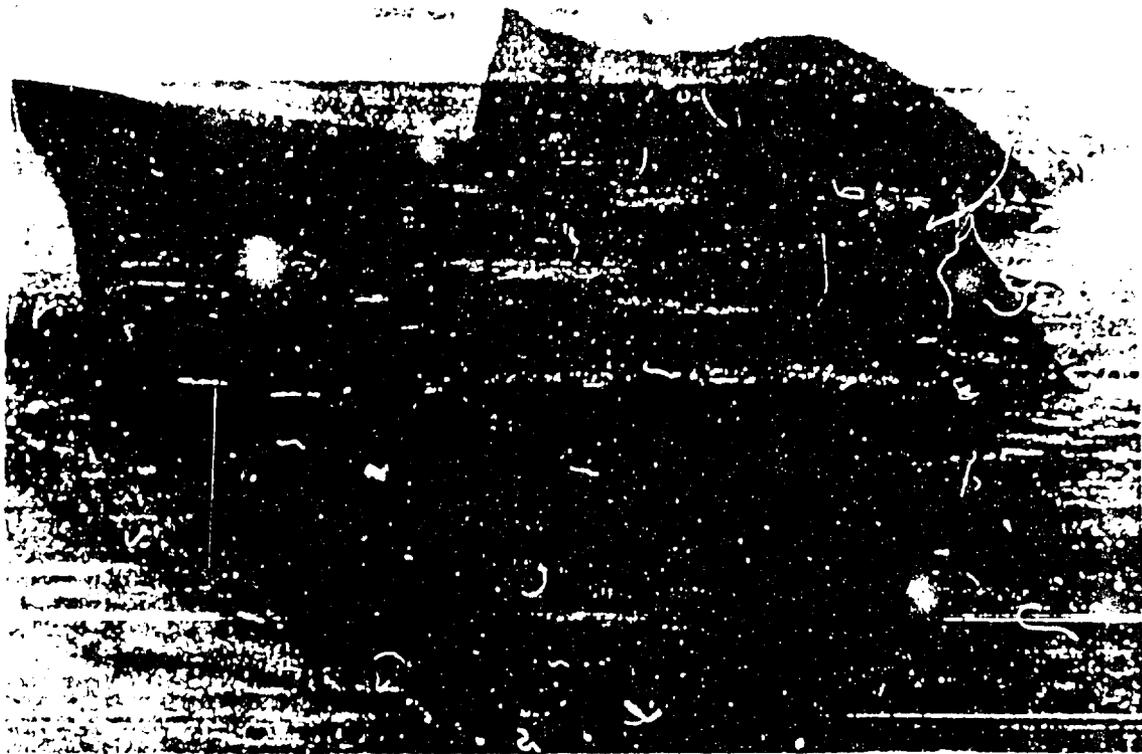


Fig. 5 - Third degree frostbite of the finger tips with second degree frostbite of the dorsa of the fingers, 13 days after injury.



Fig. 6 - Third degree frostbite of the heel, 5 days after injury.

are seen on the digits or parts which have incurred fourth degree damage. Thin-walled bullae are commonly present over the dorsum and sole of the foot at the proximal border of the severely injured part. This is illustrated in Fig. 7. The location of these bullae is of prognostic significance, usually indicating severe damage to non-vesiculated tissues distal to it. Further examples of fourth degree frostbite are seen in Figs. 8, 9, 23 and 26. Six and one-tenth per cent of the 1,880 patients had fourth degree frostbite.

Extremities were the most frequent site of injury in soldiers frost-bitten in Korea. In the 1,880 patients at the Osaka Army Hospital, 86 per cent of lesions involved the feet alone, 11 per cent hands and feet, 2.5 per cent hands alone, and 0.5 per cent other sites, including ears, face and knees.

### III. EPIDEMIOLOGY

Both agent and host factors are involved in the epidemiology of frostbite and other cold injuries. Environmental conditions such as temperature, wind, precipitation, terrain and ground conditions as well as the activity at the time of injury, the duration of exposure, environmental protection, physical fatigue or exhaustion, individual susceptibility, etc., are contributing factors. Several factors usually are responsible for any individual case of frostbite. While one or more factors may appear to be the most important, they cannot be entirely separated from other apparently less important factors.

Whayne (2) has analyzed considerable data regarding the epidemiology of cold injuries, particularly trench feet, as they occurred in World War II. The epidemiology of frostbite in Korea is in general in agreement with the findings of Whayne. However, much of his data concerned entire units. In the analysis of frostbite in Korea an attempt has been made to relate epidemiological factors to the individual.

#### 1. Agent factors:

Korea corresponds in size and in latitude to the Atlantic Coastal Plain of the United States from Wilmington, N. C. to Boston, Mass., and inland to the Appalachian Mountains, but its climates are much more diverse than the climates of this area of the United States. In the winter months the temperature corresponds to temperatures in areas much farther north. For instance, the mean monthly temperature for January at the 38th parallel in Korea roughly corresponds to the January temperature in northern New England. Since few people have lived continuously out-of-doors in the United States to the degree that troops must live under combat conditions, the comparison must be used with caution.

In the winter of 1950-1951 in Korea the temperature occasionally fluctuated more than 35°F during a 24 hour period. However, the mean temperature in combat areas was below freezing on almost all days of the winter months. The minimum temperatures were frequently near or below 0°F. Temperatures of -30°F or colder were recorded on occasion in several areas. The coldest weather occurred in the central mountainous regions of the peninsula.

The eastern, central and northern parts of Korea are covered by rugged mountains and hills. The highest mountains, with peaks reaching 8,000 feet above sea level, are located in the northern third of the country.



Fig. 7 - Fourth degree frostbite of the toes of the left foot and distal third of the right foot, 4 days after injury. A large bulla is present proximal to the areas of fourth degree frostbite.

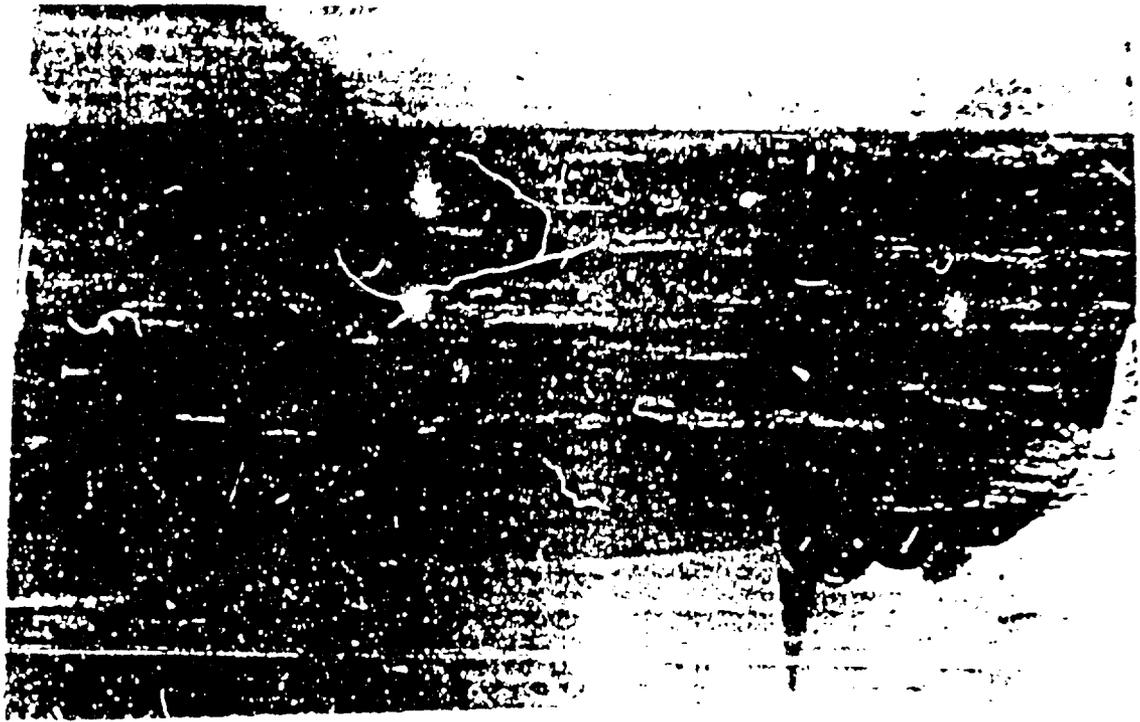


Fig. 8 - Fourth degree frostbite of the finger tips, 9 days after injury.



Fig. 9 - Fourth degree frostbite of both feet, 9 days after injury.

only large areas of continuous lowlands are along the coast. The combat occurred in the mountains and hills where shelter was rare and exposure to the elements common. The ground was usually frozen and sometimes snow covered.

There are many rivers and streams in Korea. Tactical situations required that these rivers or streams be crossed. It was often necessary for the soldier to wade free-running streams or rivers and sometimes the soldier fell through thin ice while crossing.

Most cases of frostbite occurred between sundown and sunup, particularly during the early morning hours. The daily temperature usually reaches a minimum at this time.

Clinical summaries were available on 320 patients from one unit (Second Infantry Division)\* who suffered cold injuries over a 90-day period (10 Nov. 1950 to 7 Feb. 1951). Temperatures were taken at 6:30 A.M. daily at the unit headquarters. While these temperatures are representative of the minimum temperature of the particular day, they are probably slightly higher than the temperature of the exact location where the individual soldier suffered his cold injury. Unit headquarters are usually located in more protected areas whereas the individual soldier may be on a hilltop or a ridge. However, a comparison of the number of cases occurring on any particular day with the 6:30 A.M. temperature recorded on that day shows that almost all cases occurred when the temperature was below freezing and most occurred when the temperature was near 0 degrees F. The comparison is shown in Table 1.

(Since temperatures were not recorded by other units in areas where cold injuries were actually occurring, further analysis of the relationship between the occurrence of frostbite and the temperature cannot be made. Temperatures from air strips cannot be considered adequate since they are usually located on flat lands or sheltered valleys often not near the areas of ground troop action.)

## 2. Host factors:

a. **Combat.** The incidence of frostbite among military forces in Korea was directly proportional to the tempo of combat. Local cold injuries were uncommon during periods when there was no contact with the enemy, but occurred with increasing frequency as the tempo of combat increased.

\* Does not represent all patients from Second Division frostbitten during this period, but only those hospitalized at Osaka Army Hospital on whom summaries of the clinical records were available at the close of the winter months.

TABLE 1

A COMPARISON OF THE NUMBER OF CASES OCCURRING IN ONE UNIT WITH THE TEMPERATURE RECORDED AT 6:30 A.M. AT THE UNIT HEADQUARTERS ON THE DAY THE INDIVIDUAL CASE INCURRED FROSTBITE

Temperature Degrees Fahrenheit	Number of Cases	Per Cent of Cases
Higher than 30	4	1.2
21 to 30	52	15.3
11 to 20	41	12.8
1 to 10	160	50.0
-9 to 0	19	6.0
-19 to -10	24	7.5
Lower than -10	20	6.2
<b>TOTAL</b>	<b>320</b>	<b>100.0</b>

Three hundred and twenty patients\* from one unit (Second Division) were frostbitten over a 90-day period (10 Nov. 1950 to 7 Feb. 1951) and were eventually hospitalized at Osaka Army Hospital. The day by day activity of this unit was known.\*\* On days when there was no enemy contact an average of 0.7 cases occurred. When enemy action was light, an average of 1.2 cases occurred per day. An average of 6.4 cases per day occurred when the action was moderate and an average of 9.3 cases occurred when the action was heavy. This is shown in Table 2.

b. Relationship between environmental temperature and intensity of combat.

As indicated above, the incidence of frostbite during winter operations increased as the intensity of combat increased. Cold injuries obviously will not occur during warm weather even with the most intense type of action. It is also true that cold injuries were uncommon in the presence of very cold weather but in the absence of contact with the enemy. This is illustrated in Figure 10. Cold injuries were most frequent during the periods when combat activity was heavy and the temperature low. At other times the temperature fell equally low, but in the absence of contact with the enemy, frostbite was uncommon.

\* Does not represent all patients from Second Division frostbitten during this period, but only those hospitalized at Osaka Army Hospital on whom summaries of the clinical records were available at the close of the winter months.

\*\* Command Reports of Second Inf. Div. (Nov. 1950 - Mar. 1951)

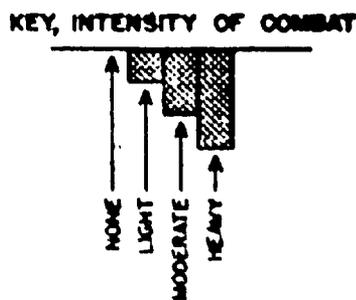
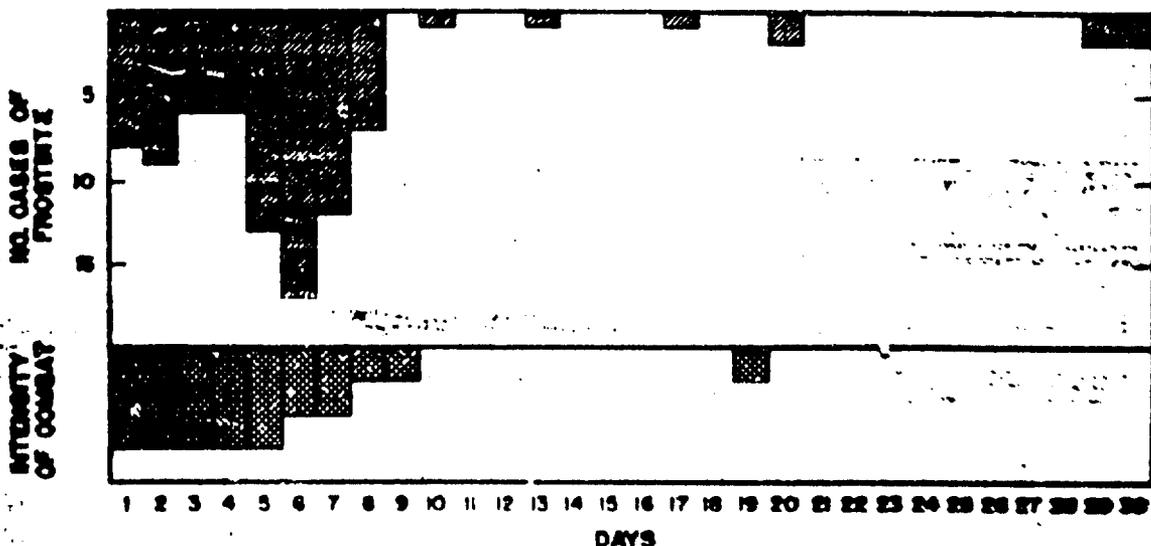
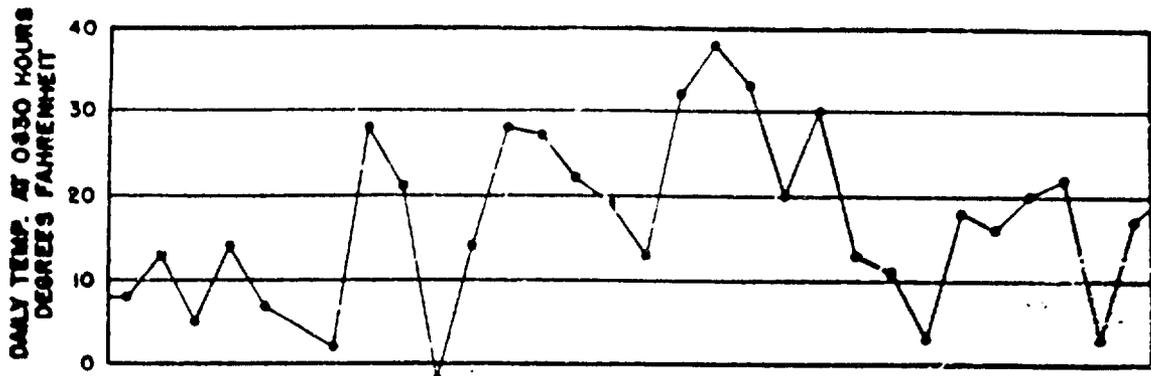


FIG. 10 THE RELATIONSHIP BETWEEN THE DAILY NUMBER OF CASES OF FROSTBITE WITH AN ESTIMATE OF DAILY COMBAT ACTION AND A DAILY TEMPERATURE TAKEN AT 8:30 A.M. THIS IS WITHIN A SINGLE UNIT ON 30 CONSECUTIVE DAYS.

TABLE 2

THE NUMBER OF CASES OF FROSTBITE OCCURRING IN ONE UNIT DURING A 90 DAY PERIOD COMPARED WITH THE TEMPO OF COMBAT ON THE DAY THE INDIVIDUAL CASE INCURRED HIS COLD INJURY

Tempo of Combat	Number of Days	Number of Cases	Average Per Day
None	26	18	0.7
Light	28	34	1.2
Moderate	23	147	6.4
Heavy	13	121	9.3

c. Activity at time of injury. - Frostbite in Korea usually occurred when the soldier was immobilized. As shown in Table 3, at the time of injury, 66.6 per cent were immobilized while pinned down by enemy fire or while in a foxhole, or sleeping or riding in a vehicle. Seventeen per cent reported themselves to be walking at the time of injury although the walking was interrupted by rest periods. Twelve and one-half per cent were standing guard and were relatively motionless. Three and one-tenth per cent received their cold injuries while held prisoner and 1.8 per cent while ill or wounded. A greater proportion of patients probably received frostbite directly or indirectly as a result of wounds but were not hospitalized at the Cold Injury Section of Osaka Army Hospital if the wound was more serious than the frostbite.

TABLE 3

THE ACTIVITY AT THE TIME OF INJURY IN 1,051 SOLDIERS FROSTBITTEN IN KOREA

Degree of Frostbite	ACTIVITY						
	Prisoner	Standing (Guard)	Walking	Riding	Sleeping	Pinned down or in Foxhole	Ill or Wounded
First	5	25	31	9	5	56	2
Second	3	58	70	27	12	160	5
Third	12	44	66	47	39	279	5
Fourth	13	4	12	2	4	49	7
TOTAL	33	131	179	85	60	544	19
Per Cent	3.1	12.5	17.0	8.1	5.7	51.8	1.8

The direct relationship between the incidence of frostbite and the tempo of action of the enemy is largely the result of the immobility occurring during periods of intense action. During periods of enemy action the soldier will move little in order to escape enemy fire, to prevent detection or to hold a line against an advancing enemy. When there is no contact with an enemy he is able to move about, will exercise to rewarm when cold and has greater opportunity to attend to individual foot hygiene.

... of exposure of ...  
 ... specific period of time ...  
 ... frostbite. Thus, it may be ...  
 ... riding in a vehicle, sleeping, etc. In Korea the duration  
 of exposure was usually measured in terms of hours. As shown in Table 4 more  
 than 80 per cent of 812 patients reported a duration of exposure of 12 hours  
 or less. The range was between 2 and 72 hours.

TABLE 4  
 THE DURATION OF EXPOSURE IN 812 SOLDIERS FROSTBITTEN  
 IN KOREA. THE RANGE IS BETWEEN 2 AND 72 HOURS.

Degree of Frostbite	DURATION OF EXPOSURE							
	0-6 hrs.		7-12 hrs.		13-18 hrs.		More than 18 hrs.	
	No.	%	No.	%	No.	%	No.	%
First	13	10.5	92	74.2	15	12.1	4	3.2
Second	23	9.3	198	79.8	1	0.4	26	10.5
Third	53	16.2	225	68.6	18	5.5	32	9.8
Fourth	20	17.9	36	32.1	48	42.8	8	7.1
TOTAL	109	13.4	551	67.8	82	10.1	70	8.6

e. Environmental protection. - Environmental protection includes  
 shelter and clothing. Shelter was rare for the rifleman in Korea. Some-  
 times warming huts were provided but usually not during periods of retrograde  
 movement and heavy action. During daylight hours men were sometimes rotated  
 to the rear to warm by fires but at times of enemy contact fires were pro-  
 hibited at night.

Information on body clothing of soldiers frostbitten in Korea  
 is scanty. It is believed that body clothing was usually adequate. The  
 role of body clothing in protecting against cold injuries of the extremi-  
 ties is important. The maintenance of circulation to the extremities is  
 partly dependent on the maintenance of general body warmth.

Since extremities, particularly the feet, were the most fre-  
 quent sites of frostbite, information was acquired on the type of footgear  
 and handgear worn. Second, third or fourth degree frostbite of the hands  
 rarely occurred when dry leather mitten shells with wool inserts or dry  
 leather glove shells with wool inserts were worn. Frostbite of the hands  
 most frequently occurred when handwear was wet, inadequate, or not worn.

Several types of footwear were available to soldiers in Korea  
 during the winter months. Most commonly worn were rubber sheepskin and  
 leather boots (2-buckle combat boots, combat boots lacing to top, para-  
 trooper jump boots). Some patients had no footgear when frostbitten,  
 particularly men frostbitten while held prisoner by the enemy or wounded  
 men ambushed while travelling to the rear in ambulances.

As shown in Table 5, 42 per cent of 1,111 cases of frostbite  
 were leather boots, 56.5 per cent were unboots and 1.5 per cent were no  
 boots when the limbs were frostbitten. Information on the type of footwear worn

Incidence of men who were in combat during the winter months is not available. However, a greater incidence of men with severe frostbite (fourth degree) in combat boots than those with mild frostbite (Table 5). Thus, 24.6 per cent of 138 first degree frostbite patients, 39.4 per cent of 358 second degree frostbite cases, 45.2 per cent of 527 third degree frostbite cases and 61.4 per cent of 88 fourth degree frostbite cases wore leather boots.

TABLE 5

THE TYPE OF FOOTWEAR WORN BY SOLDIERS AT THE TIME OF INJURY FOR 1,111 CASES OF FROSTBITE AND 275 CASES OF ILL CLASSIFIED CONDITION OF THE FEET MANIFESTED BY HYPERHIDROSIS, ERYTHEMA AND MACERATION (I.C.C.\*)

Degree of Injury	TYPE OF FOOTWEAR					
	Combat Boots		Shoepacs		None	
	No.	%	No.	%	No.	%
First	34	24.6	99	71.7	5	3.6
Second	141	39.4	214	59.8	3	0.8
Third	238	45.2	288	54.6	1	0.2
Fourth	54	61.4	27	30.7	7	8.0
<b>Total Frostbite</b>	<b>467</b>	<b>42.0</b>	<b>628</b>	<b>56.5</b>	<b>16</b>	<b>1.4</b>
<b>I.C.C.*</b>	<b>25</b>	<b>9.0</b>	<b>244</b>	<b>87.8</b>	<b>9</b>	<b>3.2</b>

Rubber shoepacs, which are impermeable to water, offer greater protection against the feet becoming wet with water or melted snow than do leather boots. Of 348 frostbite patients wearing combat boots, 37.7 per cent reported their feet and shoes to be wet with water or melted snow whereas only 10.7 per cent of 694 wearing shoepacs reported their feet and shoes to be wet with water or melted snow. (Table 6). Since water is a better conductor of heat than dry or dry footwear the presence of wet feet increases the incidence and severity of injury under conditions favorable to frostbite. As shown in Table 7, 15.2 per cent of 178 first degree cases, 17.9 per cent of 290 second degree cases, 29.8 per cent of 400 third degree cases and 66.7 per cent of 69 fourth degree cases reported their feet to be wet with water or melted snow. It is believed that the higher percentage of patients with severe frostbite who were wearing leather boots (Table 5) is due to the facts that leather boots offer less protection against wetness of the feet and melting snow (Table 6), and that wetness of the feet predisposes to severe frostbite (Table 7).

While shoepacs offer protection against water and melting snow because of their impermeability they permit socks to become wet with perspiration. Of 694 patients wearing shoepacs 69.0 per cent reported the feet to be wet with perspiration whereas 22.4 per cent of 384 wearing combat boots reported the feet to be wet with perspiration (Table 6). Eighty-eight and five-tenths per cent of 219 patients with the Ill Classified Condition of the Feet manifested by Hyperhidrosis, Erythema and Maceration reported their feet to be wet with perspiration (Table 7). Shoepacs were worn by 87.8 per cent of patients with this condition. As previously indicated, this condition is

believed to be secondary in part to prolonged contact of the feet with perspiration in impermeable footwear.

TABLE 6

THE CONDITION OF THE FEET DEPENDING ON THE TYPE OF FOOTWEAR IN 1,042 CASES OF FROSTBITE AND THE ILL CLASSIFIED CONDITION OF THE FEET MANIFESTED BY HYPERHIDROSIS, ERYTHEMA AND MACERATION

Condition of Feet	TYPE OF FOOTWEAR			
	Shoepacs		Leather Boots	
	No.	%	No.	%
Dry	141	20.3	139	39.9
Wet with perspiration	479	69.0	78	22.4
Wet with water or melted snow	74	10.7	131	37.7
<b>TOTAL</b>	<b>694</b>	<b>100</b>	<b>348</b>	<b>100</b>

TABLE 7

THE RELATIONSHIP OF THE CONDITION OF THE FEET TO FROSTBITE IN 937 CASES AND TO THE ILL CLASSIFIED CONDITION OF THE FEET MANIFESTED BY HYPERHIDROSIS, ERYTHEMA AND MACERATION (I.C.C.\*) IN 219 CASES.

Degree of Injury	CONDITION OF FEET					
	Dry		Wet with Perspiration		Wet with Water	
	No.	%	No.	%	No.	%
First	33	18.5	118	66.3	27	15.2
Second	97	33.4	141	48.6	52	17.9
Third	132	33.0	149	37.2	119	29.8
Fourth	17	24.6	6	8.7	46	66.7
<b>Total Frost-bite</b>	<b>279</b>	<b>39.8</b>	<b>414</b>	<b>44.2</b>	<b>244</b>	<b>26.0</b>
<b>I.C.C.*</b>	<b>8</b>	<b>3.7</b>	<b>194</b>	<b>88.5</b>	<b>17</b>	<b>7.8</b>

Twenty-six per cent of 937 cases of frostbite reported their feet to be wet with water or melted snow, 44.2 per cent reported the feet to be wet with perspiration and 39.8 per cent reported the feet and socks dry. This indicates that wetness of the part is not necessary for the occurrence of ground-type frostbite although there is no doubt that the presence of

wetness increases the incidence when the temperature is low and troops immobilized.

Individual foot hygiene is an important measure in the prevention of cold injuries. Unfortunately individual foot hygiene is often impossible or neglected during periods of heavy action. Also, during periods of heavy action the supply of socks may be inadequate. Information was obtained from 779 patients regarding the number of hours or days prior to frostbite that the socks had been changed. The time ranged between a few hours to more than a week and averaged more than 3 days. No data is available on the average time socks were changed among non-frostbitten soldiers in Korea.

f. Age. - As shown in Table 8, over 85 per cent of 2,114 cases of frostbite and the Ill Classified Condition of the feet were 25 years of age or less. No data are available on the age distribution of non-frostbitten soldiers who were present in Korea during the winter months. The high proportion of young men is probably representative of the age distribution of soldiers in Korea rather than of an increased susceptibility of young individuals to cold injury although the latter possibility cannot be eliminated on the basis of existing data.

g. Race. - The incidence of frostbite among Negro troops was apparently higher than among Whites. In one organization (25th Division), one unit of the organization was entirely Negro (24th Regiment) while two other similar units (27th and 35th Regiments) of the organization were entirely White. All units operated in the same area under similar circumstances of environment and combat. Yet the incidence of frostbite was approximately three times as high in the all Negro unit as in either of the all White units. Although this comparison indicates a higher incidence of frostbite among Negro troops it does not indicate whether the difference is due to actual increased susceptibility to frostbite or to differences in personal hygiene, motivation and training.

TABLE 8

THE AGE DISTRIBUTION IN 2,114 CASES OF FROSTBITE AND THE ILL CLASSIFIED CONDITION OF THE FEET

AGE	NO.	PER CENT
16 - 20	1116	52.8
21 - 25	695	32.9
26 - 30	204	9.6
31 - 35	57	2.7
36 - 40	31	1.5
41 - 45	11	0.5

Better information was obtained from another unit (9th Regiment) of another organization (2nd Division) to which both Negro and White troops were assigned. This unit was mixed, frequently down to squad level. Under these circumstances possible differences in motivation, personal hygiene and training was less marked. There were 167 cases of frostbite from this unit who were hospitalized at the Osaka Army Hospital and on whom summaries of clinical records were available. One hundred and thirty eight or 82.6 per

... of these cases were Negroes and 49 or 17.4 per cent were ...  
 the period from 17 November 1950 through 2 March 1951, 33 per cent of the  
 unit consisted of Negroes, ranging from a minimum of 26 per cent to a maximum  
 of 41 per cent during any one week period.

h. Rank. - As shown in Table 9, 99.8 per cent of 1,846 soldiers  
 frostbitten in Korea were enlisted men and 0.2 per cent were officers.  
 No officer above the grade of Captain was hospitalized at Osage Army Hos-  
 pital with frostbite. Of the 1,846 patients, 67.2 per cent were privates  
 or privates-first-class, 21.3 per cent were corporals, 11.4 per cent were  
 sergeants and 0.2 per cent were officers of the grades of Captain or less.  
 The distribution is similar for the 376 cases of Ill Classified Condition  
 of the Feet.

When the grade distribution of frostbitten patients is compared  
 to the grade distribution of a full strength infantry rifle company, it is  
 apparent that the proportion of frostbite patients of lower grades is greater  
 than the normal organizational distribution in a rifle company. For instance,  
 in a rifle company 50.5 per cent of men are privates or privates-first-class  
 whereas 67.2 per cent of frostbite patients were privates or privates-first-  
 class. The average private or private-first-class of a rifle company is more  
 exposed than the average soldier of higher grade and therefore has more  
 opportunity to incur frostbite. Furthermore, the usual private or private-  
 first-class may have less opportunity to attend to local foot hygiene than  
 does the soldier of higher grade.

TABLE 9

THE GRADE DISTRIBUTION OF 1,846 CASES OF FROSTBITE AND  
 376 CASES OF THE ILL CLASSIFIED CONDITION OF THE FEET  
 MANIFESTED BY HYPERHIDROSIS, ERYTHEMA AND MACERATION.

TYPE OF INJURY	GRADE							
	Pvt or PFC		Cpl.		Sgt.		Company Grade Off.	
	No.	%	No.	%	No.	%	No.	%
Frostbite	1241	67.2	394	21.3	211	11.4	18	0.2
I. C. C.	234	62.2	100	26.6	38	10.1	4	1.1
Distribution in Infantry Company*	50.5		25.2		21.0		3.3	

\* Personnel of Infantry Rifle Company T/O and E 7-17N, 15 Nov. 1950  
 (Unclassified)

i. Geographical origin. - The geographical origin and usual residence of 464 men was available from the records. Fifteen (3.2 per cent) were from states<sup>1</sup> in which the daily average minimum temperature for the month of January is 9.9 F or less. Eighty-eight (19.0 per cent) were from states<sup>2</sup> in which the average daily minimum temperature for the month of January is between 10.0° and 19.9°F inclusive. Two hundred and twenty-five (48.4 per cent) were from states<sup>3</sup> in which the average daily minimum temperature for the month of January is between 20.0° and 34.9°F inclusive. One hundred thirty-six (21.3 per cent) were from states<sup>4</sup> in which the average daily minimum temperature for the month of January is 35.0°F or greater.

j. Previous cold injury. - Information on previous cold injuries was obtained from 932 patients with frostbite. One hundred and thirty-nine or 14.9 per cent had a previous cold injury either before or during the winter of 1950-51. No information was available on the number of non-frostbitten men in Korea who had a past history of cold injury.

k. Smoking. - Since the smoking of cigarettes causes peripheral vasoconstriction, resulting in lower skin temperatures of the extremities, it might be suspected that the incidence of frostbite would be greater among smokers. As shown in Table 10, 17.2 per cent of 506 frostbite patients were non-smokers. Thirteen and one-tenth per cent of 237 men\* who had never suffered a cold injury were non-smokers. The difference is not statistically significant. This indicates that the incidence of frostbite among smokers probably was not greater than among non-smokers.

TABLE 10

THE AMOUNT OF SMOKING IN 506 PATIENTS WHO INCURRED FROSTBITE AND IN 237 MEN WHO HAD NEVER SUFFERED A COLD INJURY

	CIGARETTES					
	None		1 pack or less		More than 1 pack	
	No.	%	No.	%	No.	%
Frostbite	87	17.2	306	60.5	113	22.3
"Controls"	31	13.1	157	66.2	49	20.8

<sup>1</sup>North Dakota, Minnesota, Maine, New Hampshire, South Dakota, Vermont, Wisconsin, Wyoming, Montana.

<sup>2</sup>Colorado, Connecticut, Illinois, Kansas, Idaho, Nevada, Massachusetts, New York, Iowa, Michigan, Nebraska, Utah.

<sup>3</sup>Indiana, Missouri, New Jersey, New Mexico, Ohio, Pennsylvania, Rhode Island, D. C., Kentucky, Maryland, Oklahoma, North Carolina, Arkansas, Oregon, Tennessee, Virginia, Washington, West Virginia, Delaware.

<sup>4</sup>Georgia, Arizona, Mississippi, South Carolina, Texas, Alabama, California, Louisiana, Florida

\* From training units at Ft. Knox, Ky.

1. Other factors. - Examination of the literature indicates contributory roles in the occurrence of frostbite in some men. Satisfying evidence is available.

Some men who incurred frostbite had been in Korea since July and August 1950 and thus were in the combat zone for 4 to 8 months. Other men were recent replacements and incurred frostbite shortly after arrival in Korea. No conclusions can be reached regarding the incidence of frostbite in combat veterans as compared to replacements. In 490 patients with frostbite 20.8 per cent reported themselves to have been in the combat zone for 1 to 30 days, 15.5 per cent for 31 to 60 days, 19.6 per cent for 61 to 90 days, 14.3 per cent for 91 to 120 days, 13.7 per cent for 121 to 150 days and 16.1 per cent for more than 150 days.

#### IV. PHYSIOPATHOLOGY

One of the first reactions of the body to cold is peripheral vasoconstriction. The temperature of the body core tends to remain constant. However, the temperature of the extremities falls. This is a normal physiological response. If the temperature of the extremities remains low for prolonged periods or if it falls to such a low level that freezing occurs, injury may result. Considerable controversy exists regarding the physiopathology of frostbite. The freezing temperature of human tissue is between twenty-eight and thirty-two degrees Fahrenheit but actual freezing (solidification) does not occur when the skin reaches this temperature because of the phenomenon of super-cooling (8) (the capacity of a tissue to go below its ordinary freezing point without solidifying). Freezing of the skin usually occurs when the skin temperature is between 25° and 14°F. Tissues that are actually frozen may be damaged as the direct result of ice formation within them. (9, 10). However, the course of frostbite subsequent to rewarming in the human and in the experimental animals (11, 12, 13, 14, 15) indicates that a vascular component plays a significant role in the physiopathology.

During the chilling period a peripheral vasoconstriction is present. When the tissues are actually frozen there is no movement of blood in the involved part. After rewarming, the vessels of the injured part are dilated and blood flows freely into the area as manifested by the resulting hyperemia. The part becomes edematous and vesicles or bullae appear within the first day after rewarming. The vesicles contain fluid which coagulates after a few days and is quite similar to plasma. Results of the analyses of fluid from the frostbite vesicles in three patients are shown in Table 11. During the first ten days after rewarming vesicles enlarge or refill if aspirated.

Thrombosis may occur resulting in an ischemic gangrene (pathological specimens removed weeks or months after injury show adherent thrombi in all vessels). Thrombosis of the vessels probably does not begin immediately after rewarming. The ischemic and cold injured tissue may dry and mummify or develop a wet, secondarily infected gangrene.

TABLE 11

THE CHEMICAL ANALYSES OF THE VESICLE FLUID IN 3 PATIENTS.  
THE FLUID IS SIMILAR TO PLASMA.

Patient	Days after Rewarming Vesicle Aspirated	Specific Gravity	Protein (gm/100 cc)			Chlorides Expressed as mgm NaCl per 100 cc
			Total	Alb.	Glob.	
N	5	1.020	4.6	3.7	0.9	710
T	6	1.022	5.2	4.2	1.0	685
W	20	—	3.5	2.0	1.5	610

## V. CLINICAL MANIFESTATIONS

The clinical manifestations of frostbite varied depending on the early management. Complications, particularly infection and pain, were more common when medical attention was not received early or when the cases were inadequately cared for.

In Korea it was extremely uncommon for soldiers to be seen by medical personnel while the part was still in the frozen state. Of 1,368 frostbite patients eventually hospitalized at the Osaka Army Hospital only 2.1 per cent were seen by medical personnel before hyperemia (as manifested by swelling or vesicles) appeared. However, a greater proportion of patients with severe frostbite were seen before the appearance of hyperemia than those with mild frostbite. The incidence of soldiers with various degrees of frostbite seen before swelling or vesicles appeared is shown in Table 12.

In 1,548 patients the average time between rewarming and evacuation to the rear was six days ranging from a few hours to more than three weeks. However, 57 per cent of the cases were evacuated to the rear in 3 days or less. Seventy-one per cent of 86 fourth degree frostbite cases were evacuated in three days or less.

TABLE 12

THE NUMBER AND PER CENT OF 1,368 PATIENTS WITH FROSTBITE WHO WERE SEEN BY MEDICAL PERSONNEL BEFORE THE APPEARANCE OF SWELLING OR VESICLES

Degree of Injury	Total Number of Cases	Seen by Medical Personnel before Hyperemia	
		No.	%
First	219	1	0.5
Second	464	1	2.2
Third	599	16	2.7
Fourth	86	11	12.8
TOTAL	1368	29	2.1

Some cases of second and third degree frostbite were treated early (frequently because of manpower shortages). They remained in this condition following opening of vesicles, or application of dressings, or no treatment. Following varying periods of time, evacuation to rear usually was necessary because of pain or infection. Some cases handled in this manner may have converted partial skin thickness vesicles into full skin thickness lesions as the result of infection.

The onset of freezing was not particularly painful. First, there was uncomfortable coldness in the part followed by numbness, which was sometimes accompanied by stinging or aching pain. While frozen the part was without feeling, "like a stump" or "like a block of wood." In cases of severe frostbite there was inability to walk. During this stage in some cases the socks were frozen to the feet or ice appeared between the toes. Before rewarming, the involved part had a waxy white appearance and some tissue may have been solidified.

In Korea, rewarming was usually accomplished by the individual soldier. In 655 patients with frostbite 60.3 per cent accomplished rewarming by walking or other physical activity, 21.4 per cent by holding the affected part near a fire, 12.7 per cent by massage, 0.9 per cent by immersion of the affected part into hot water and 0.9 per cent by rubbing with snow. At the time of rewarming there developed marked burning, stinging, aching pain and paresthesias.

Following rewarming the part became red and inflamed followed by grayish blue or purplish-red discoloration. This was more marked in cases of severe frostbite. Swelling began in less than three hours and vesicles or bullae appeared in six to twenty-four hours. Immediately after rewarming even the most severely injured parts were warm although parts which had sustained fourth degree frostbite became cold in two to three days.\*

The clinical manifestations and course subsequent to rewarming differed depending on the severity of the injury. However, the classification of frostbite into the four degrees of severity could not be made in the period before and shortly after rewarming during which time all cases may have a similar clinical appearance. The classification, and hence the prognosis and prediction of the subsequent clinical course, frequently could not be made until 24 or more hours after rewarming.

First degree frostbite was characterized by numbness, erythema and swelling. The usual sites of injury for first degree frostbite on the feet were the toes, heels and plantar surfaces, and on the hands, the finger tips.

In some cases there was anhidrosis initially. Other cases demonstrated hyperhidrosis and maceration. Part of the cases with hyperhidrosis and maceration represented first degree frostbite superimposed on the previously discussed Ill Classified Condition of the Feet Characterized by Hyperhidrosis, Erythema and Maceration. Other cases of first-degree frostbite who may have

\*Partly based on experimental rabbit frostbite, where parts which had become cold did not become cold until 60 hours after rewarming.

been anhidrotic initially were not hospitalized until after the injury. These patients may have developed hyperhidrosis as a result of the cold injury. Still other cases with a definite history of anhidrosis subsequently developed hyperhidrosis almost immediately.

Many soldiers in Korea suffered first degree frostbite of the finger tips or of the face which did not require medical attention. Numbness of the finger tips was present in many patients with frostbite of the feet but was so minor that it was frequently ignored. However, first degree frostbite of the feet usually caused symptoms severe enough to necessitate the soldier to seek medical attention and many of these men were evacuated from the combat zone.

Edema of the feet following first degree frostbite sometimes persisted for 10 or more days if the soldier remained on duty. It disappeared in less than five days if he was at bed rest or if he was not required to remain on his feet for long periods. Desquamation began in 5 to 10 days and continued for as long as one month in some cases.

Patients with first degree frostbite of the feet frequently continued to have a deep-seated ache or paresthesias in the toes and the balls of the feet when walking. The toes remained cyanotic in some patients. Most developed hyperhidrosis and complained of coldness of the feet.

Second degree frostbite produced partial skin thickness vesicles, superficial to the germinative layer. When the vesicle was shed the underlying skin was intact, although it was thin, soft, poorly keratinized and easily traumatized. The usual sites of second degree frostbite on the feet were toes, particularly the great toe; and the heels. The incidence of involvement of various parts of the feet is shown in Table 13. On the hands, the dorsa of one or more fingers were the usual sites of second degree frostbite although the ends of the fingers alone were sometimes involved as shown in Table 14.

In 19 cases of second degree frostbite the vesicles became dry, black and hard in an average of 14 days (range 11-20 days) after rewarming. The vesicles peeled away in an average of 24 days (range 17-36 days) after frostbite.

Edema of the affected part was not marked and disappeared in 3 to 5 days after rewarming if the patient was not ambulatory. The edema persisted for several weeks if the patient continued on his feet. Some limitation of motion of the part was usually present after rewarming, but disappeared in 3 to 5 days. Throbbing, aching or burning pain was present for 3 to 20 days. This pain was seldom severe enough to interfere with the patient's sleep provided he was not ambulatory.

Between 2 and 7 weeks after injury increased perspiration of the affected part was noted. At approximately the same time, many patients noted an inability to keep the feet warm. Cool or cold ambient temperatures caused stinging pain of the affected part.

Case History 1. - B. A., a 24 year old PFC, was frostbitten while sleeping in a foxhole during the night of 13 January 1951, with the ambient temperature being  $-20^{\circ}$  to  $-30^{\circ}$ F. On 14 January his feet were numb and he had difficulty in walking. A vesicle was found on the left great toe on the morning of 15 January.

THE SITES OF INJURY FOR SECOND, THIRD AND FOURTH DEGREE FROSTBITE OF THE FEET

Site of Injury	Second Degree Frostbite		Third Degree Frostbite		Fourth Degree Frostbite	
	No.	%	No.	%	No.	%
Great Toe	454	75	605	75	14	13.5
Second Toe	21	3.5	27	3.5	2	2
Fifth Toe	18	3	10	1.5	0	0
First & Second Toe	66	11	111	14	23	22
More than 2 Toes	14	2.5	14	1.5	2	2
All Toes	6	1	25	3.0	39	37
Heel	24	4	14	1.5	0	0
Distal One-third	0	0	1	.1	19	18
Entire Foot	0	0	0	0	6	5.5
<b>TOTAL</b>	<b>603</b>	<b>100</b>	<b>807</b>	<b>100</b>	<b>105</b>	<b>100</b>

TABLE 14

THE SITES OF INJURY FOR SECOND, THIRD AND FOURTH DEGREE FROSTBITE OF THE HANDS

Site of Injury	Second Degree Frostbite		Third Degree Frostbite		Fourth Degree Frostbite	
	No.	%	No.	%	No.	%
Tips - one or more Fingers	8	18.5	16	100	12	63
Dorsum - one or more Fingers	35	81.5	0	0	0	0
Entire Finger or Fingers	0	0	0	0	7	37
<b>TOTAL</b>	<b>43</b>	<b>100</b>	<b>16</b>	<b>100</b>	<b>19</b>	<b>100</b>

ing of 14 January and he was evacuated. Two days after rewarming he still had mild stinging pain of the toes and numbness and limitation of motion of the left great toe. There was a tense, amber color, 2 x 5 cm vesicle on the left great toe and only minimal edema (Fig. 11). On the third day, there was no pain, edema was gone and there was a full range of motion of all toes. By the 12th day the vesicle on the left great toe had dried into a hard, brownish-black eschar (Fig. 12). The eschar was removed on the 21st day revealing thin and poorly keratinized skin beneath (Fig. 13).



Fig. 11 - Case B. A. Second degree frostbite of great toe, 3 days after injury.



Fig. 12 - Case B. A. Second degree frostbite of great toe, 4 days after injury.

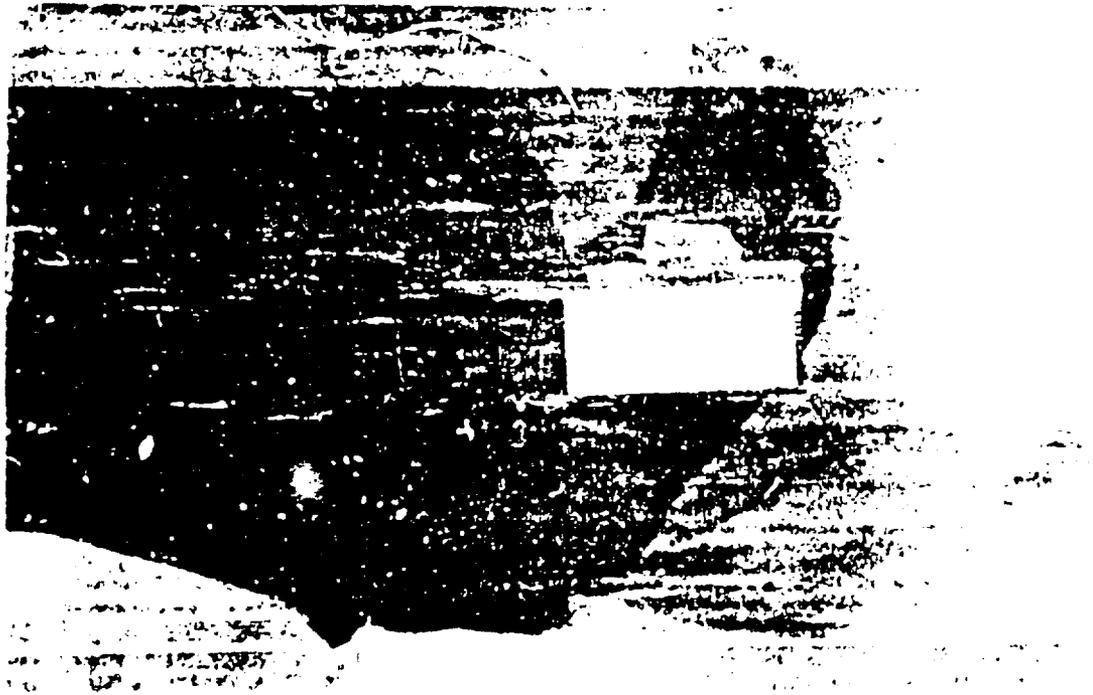


Fig. 13 - Case B. A. Second degree frostbite of left great toe, 30 days after injury.



Fig. 14 - Case B. A. Second degree frostbite of left great toe, nine months after injury.

... into the subcutaneous tissue. In the 10th day after injury hyperhidrosis of the feet and an inability to keep the feet warm were observed after injury (Fig. 14) the patient had no complaints referable to the feet.

Third degree frostbite produced ulceration through the skin into the subcutaneous tissue. Vesicles were sometimes present in third degree frostbite but partial skin thickness (second degree) vesicles usually were present at the periphery of the third degree frostbite. Third degree frostbite produced a variety of lesions, ranging from a vesicle on the end of a digit which resulted in a small ulcer when the vesicle was shed to involvement of the skin and subcutaneous tissue of an entire digit. In the most severe cases, although viable tissue was present, healing of the part occasionally was so poor that deep surgical debridement or amputation of the distal phalanx was required. The usual sites of third degree frostbite of the feet are shown in Table 13. Like second degree frostbite, toes and heels were the most frequent site, with the great toe predominating. Third degree frostbite of the hands occurred on the tips of the fingers, although large second degree vesicles usually were present proximally over the dorsa of the fingers (Table 14).

In addition to marked swelling and redness of the digits involved in third degree frostbite, edema of the entire foot or hand occurred. With general supportive care, including bed rest, this edema disappeared in an average of 6 days (range 3-10 days) after rewarming. Swelling of the third degree injured parts lasted a few days longer. There was marked limitation of motion of the digits. Mobility of the digits returned at approximately the time edema of the part disappeared.

Burning or stinging pain was present in the first few days after third degree frostbite, but was minimal unless the surroundings were warm. Total anesthesia of the part usually decreased after the first week and was associated with the appearance of paresthesias. Although a few patients experienced only mild burning or stinging pains after the first week, most patients with third degree frostbite had burning, aching, throbbing or shooting pains beginning on the 5th to the 17th day. This pain usually lasted for 2 to 5 weeks after injury but sometimes persisted for as long as 8 weeks after injury. The pain occasionally was severe enough to interfere with the patient's sleep but seldom required narcotics.

The skin overlying third degree frostbite formed a black, hard and dry eschar whether a vesicle was present or not. This eschar desquamated spontaneously, or required debridement because of purulent drainage between the second and eighth week after injury, depending on the severity of the lesion. In cases receiving only general supportive care, about 15 per cent would not heal and required surgical intervention, usually because of purulent drainage.

Ulceration through all layers of skin was always present. The ulcer may have granulation tissue at its base or an adherent hard eschar may reform. The ulcer epithelializes at the rate of about 2.0 mm (range 0.9 - 3.0) per week from all borders. In 155 cases not requiring surgical intervention, healing occurred in an average of 68 days (range 23 to 127 days). The site of the healed ulcer was scarred and indurated. The surrounding area of second degree frostbite showed thin, soft and easily traumatized skin.

Hyperhidrosis and an inability to keep the affected part warm were observed between the 4th and 10th week after injury.

The course of third degree frostbite is illustrated by the following two cases.

Case History 2. - J. S., a 22 year old white PFC, was pinned down by enemy small arms fire for 6 hours on the morning of 3 March 1951. The feet became numb. Following rubbing and massage the feet became red and swollen. A vesicle was noted on the tip of the right first toe on the morning of 4 March and the patient was evacuated. The patient reached Osaka Army Hospital 4 days after rewarming (Fig. 15). The dorsum of the right foot was slightly edematous. A 3 x 5.5 cm. yellow, full skin thickness vesicle surrounded by erythema was present on the end of the right great toe. The left foot was warm and dry and the toes were hypesthetic. There was mild burning pain of the toes of both feet. On the 11th day the vesicle ruptured and was superficially debrided on the 25th day, revealing a 2 cm. x 2 cm. area of granulation tissue at the center of the vesicle (Fig. 16). The ulcer gradually filled in (Fig. 17) and was healed on the 58th day after injury. The patient experienced very little pain during his hospital course. Forty days after injury the feet were perspiring and cold. Seven months after injury (Fig. 18) the patient still complained of hyperhidrosis and itching of the toes.

Case History 3. - J. N., a 17 year old Negro soldier illustrates a more severe third degree frostbite. His socks were wet with perspiration on 3 January 1951 when he was immobilized in a foxhole, with an ambient temperature of zero degrees Fahrenheit. The feet became cold and numb. On 4 January the left foot was swollen and a vesicle was present on the left great toe. He arrived at the Osaka Army Hospital on 6 January (Fig. 19). At that time the right foot showed no abnormality. Total anesthesia of the toes of the left foot was present and pitting edema extended above the ankle. All toes appeared cyanotic but were warm. A 3.5 x 4 cm. tense vesicle was present on the dorsum of the left great toe. The tip of the left great toe was firm and non-pliable. On the fourth day after frostbite the tip of the left great toe was cool. Six days after entry he was able to move the toes of the left foot and the edema had disappeared. Shooting pain was present in the left foot from the sixth through the twelfth day. Except for tenderness and occasional mild burning pain, the patient had no further symptoms. The vesicle on the left great toe had collapsed by the twentieth day after injury (Fig. 20). Because of purulent drainage superficial debridement, including the toe nail, was performed on the 26th day after injury. A hard, black, adherent eschar on the end of the left great toe gradually became demarcated (Fig. 21) and continued to drain. A roentgenogram taken 42 days after frostbite revealed no bony abnormality of the left great toe. Fifty-one days after injury surgical debridement of the left great toe was performed including a portion of the distal phalanx which was found to be infected (Fig. 22). The patient was returned to the Zone of Interior.

Fourth degree frostbite produced damage to the entire thickness of the part including bone and resulted in loss of the part. One or more digits were the most common sites of fourth degree frostbite. On the feet, 76.5 per cent of lesions involved one or more toes, 18 per cent the distal 1/3 or distal 1/2 of the foot and 5.5 per cent the entire foot (Table 13). On the hands, fourth degree frostbite involved the tips of one or more fingers in 63 per cent of cases and one or more entire fingers in 37 per cent of cases (Table 14). Fourth degree frostbite extending above the ankle or wrist was not seen in patients at the Osaka Army Hospital although such lesions may have occurred



Fig. 15 - Case J. S. Third degree frostbite of right great toe, 5 days after injury.



Fig. 16 - Case J. S. Third degree frostbite of right great toe, 10 days after injury. Ulceration into subcutaneous tissue.



Fig. 17 - Case J. S. Third degree frostbite of right great toe, 48 days after injury.



Fig. 18 - Case J. S. Third degree frostbite of right great toe, 48 days after injury.



Fig. 19 - Case J. M. Third degree frostbite of left great and second toes, 4 days after injury.



Fig. 20 - Case J. M. Third degree frostbite of left great and second toes, 4 days after injury.



Fig. 21 - Case J. N. Third degree frostbite of left great and second toes, 47 days after injury. End of second toe healed.



Fig. 22 - Case J. N. Third degree frostbite of left great and second toes. Tip of great toe suppurating and necrotic.

patients with wounds of the extremities are based upon the following:

There were no, or only small, vesicles over the site of fourth degree frostbite. As previously indicated, vesicles or bullae were commonly present at the proximal border of the fourth degree injured part and were of prognostic significance, indicating severe damage distally.

The parts which were eventually lost were always cold in patients entering 3 or more days after rewarming. It was impossible to produce warmth of these parts by sympathetic ganglion blocks or by vasodilators such as oral prisone, intravenous alcohol or intravenous procaine.

Edema of the entire foot or hand occurred, extending proximal to the area of fourth degree frostbite. With fourth degree frostbite of the feet, pitting edema frequently extended proximally as high as the knee. In 22 cases of fourth degree frostbite the edema proximal to the area of severe injury disappeared in an average of 10 days (range 7 to 20 days).

Mild to severe burning pain occurred in the first few days after rewarming. Beginning 3 to 13 days after rewarming, shooting, throbbing and severe aching pain may appear. This persists for 15 to 30 days. In 23 patients with fourth degree frostbite this pain was severe enough in only 9 cases to require codeine. Two of the 23 patients experienced no pain after the mild burning pain of the first few days following rewarming.

Nine to 15 days (average for 12 patients was 12.5 days) after rewarming the most distal part of the involved extremity became black, dry and shriveled. Subsequent to this, the clinical manifestations were exhibited in two ways;—the process continuing as dry gangrene where the affected tissue became black and dried hard, or mummified; or the affected tissue becoming wet, soft and purulent.

When fourth degree frostbite involved only digits the parts usually mummified. Occasionally, inter-digital joint spaces became purulent but this did not interfere with the drying of the lesion if superficial debridement and cleansing were performed. Wet, soft and purulent gangrene was more likely to occur when the lesion extended proximal to the web of the toes involving the distal one-third, one-half or entire foot. In 14 cases with fourth degree frostbite extending proximal to the web of the toes, 7 became dry and mummified and 7 became soft and wet. These cases received general supportive care but no drug therapy alleged to influence the course of frostbite. It was not possible to predict whether wet or dry gangrene would occur until 12 to 34 days after injury.

Dry mummification was desired since it permitted patients to be transported. The presence of dry gangrene from frostbite was not painful. Operation could await the appearance of a definite line of demarcation thereby preserving the greatest possible amount of tissue and retaining maximum function. When wet, purulent gangrene occurred and lymphadenopathy and signs of general sepsis appeared, operation had to be performed as an emergency or semi-emergency procedure. The site of amputation was through normal tissue, at a point proximal to all necrotic tissue.

When dry gangrene occurred the vesiculated and non-vesiculated tissues proximal to the fourth degree injury formed a superficial dry eschar. In 12 patients developing dry gangrene, this eschar was superficially debrided in

... of 26 days (range 15 to 34 days). The approximate time of demarcation became apparent in an average of 36 days (range 21 to 45 days). These patients were evacuated to hospitals in the Zone of Interior where surgery was performed. Demarcation was allowed to proceed down to bone at which time gangrenous tissue was surgically removed. The average time of operation after injury was 78 days (range 56 to 129 days).

Wet gangrene became apparent in an average of 19.5 days (range 12 to 34 days) in 10 patients. The ends of the toes were usually mummified. There was ulceration, softness and infection of the tissue behind the toes. The extension of the process was uncontrollable by vigorous local therapy, antibiotics and chemotherapeutic agents. Because of local infection, lymphadenopathy and signs of general sepsis these patients were not considered transportable. They were operated upon in an average of 9.5 days (range 1 to 29 days) after wet gangrene became apparent.

The clinical course of dry gangrene is illustrated by the following case.

Case History 4. - P. R., a 21 year old soldier of Mexican extraction, was frostbitten on the evening of 6 January 1951. The temperature was plus 10 degrees Fahrenheit. He walked 15 miles to an aid station the following morning at which time the right foot was swollen. A bullae appeared on the dorsum of the right foot on the afternoon of 7 January and became enlarged on 8 January. Four days after injury (Fig. 23) the entire right foot was edematous. A large bullae was present on the dorsum of the right foot behind the toes. There were a few small vesicles on the toes. The distal one-third of the foot was blue and toes 1 to 4 were cold. There was third degree frostbite of the left great toe. Edema of the foot disappeared by the ninth day after injury. The tips of the toes began to mummify on the tenth day. Mild aching and shooting pains began 8 days after injury and lasted until the twentieth day. The vesicle on the dorsum of the right foot slowly dried (Fig. 24) and was superficially debrided on the twenty-fourth day. There was no evidence of infection and the first 4 toes of the right foot continued to dry. A line of demarcation appeared by the thirty-fifth day (Fig. 25). He was returned to the Zone of Interior on the forty-ninth day. Surgical removal of the entire first and second toes and the distal phalanx of toes three and four was performed on the eighty-second day at which time the line of demarcation had extended down to bone.

The clinical course of wet gangrene is illustrated by the following case.

Case History 5. - W.E.G., a 17 year old Negro soldier suffered frostbite of both feet on 3 January 1951 when pinned down by enemy fire for 12 hours. The feet were wet and the ambient temperature was zero degrees Fahrenheit. He rewarmed his feet by walking. On 4 January, following removal of his boots, his feet swelled to such an extent that he was unable to replace the boots. He was evacuated 4 January. Six days after injury (Fig. 26) he complained of "shooting" pains in the feet. There was marked pitting edema of the feet and ankles. Bullae were present behind the toes. Moderate shooting and aching pains and paresthesias continued for approximately 7 weeks. Edema had subsided on the tenth day after injury. Mummification of the tips of the toes was apparent on the twelfth day. Fourteen days after injury a necrotic ulcer was present at the base of the toes of the left foot (Fig. 27). Forty days (Fig. 28) after injury many toes had become mummified.

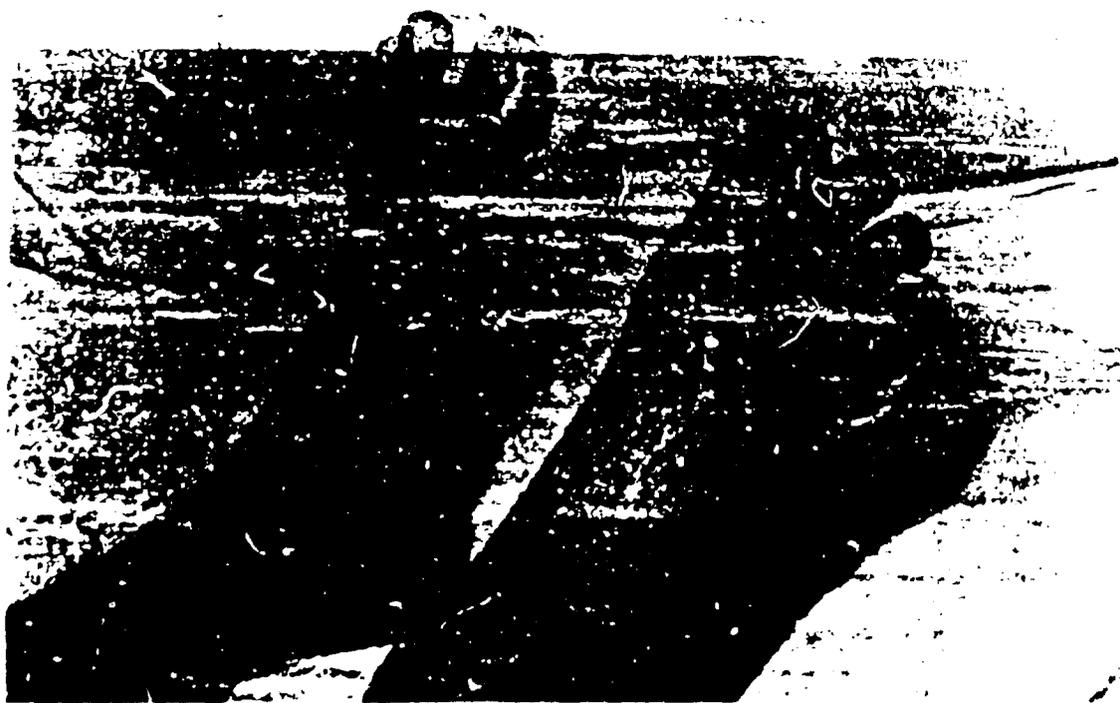


Fig. 23 - Case P. R. Fourth degree frostbite of the toes of the right foot, 4 days after injury.

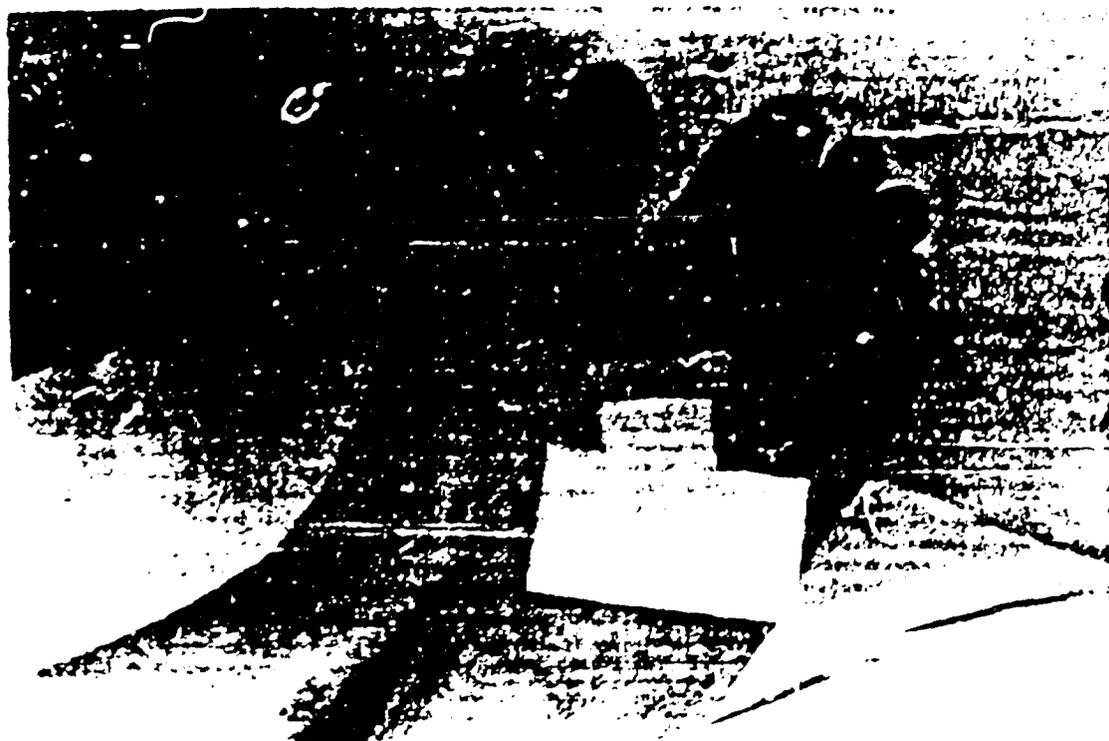


Fig. 24 - Case E. R. Fourth degree frostbite of the toes of the right foot, 4 days after injury. Right of foot marked with 'R'.



Fig. 25 - Case P. R. Fourth degree frostbite of the toes of the right foot, 50 days after injury. Necrotic tissue of proximal part of foot debrided.

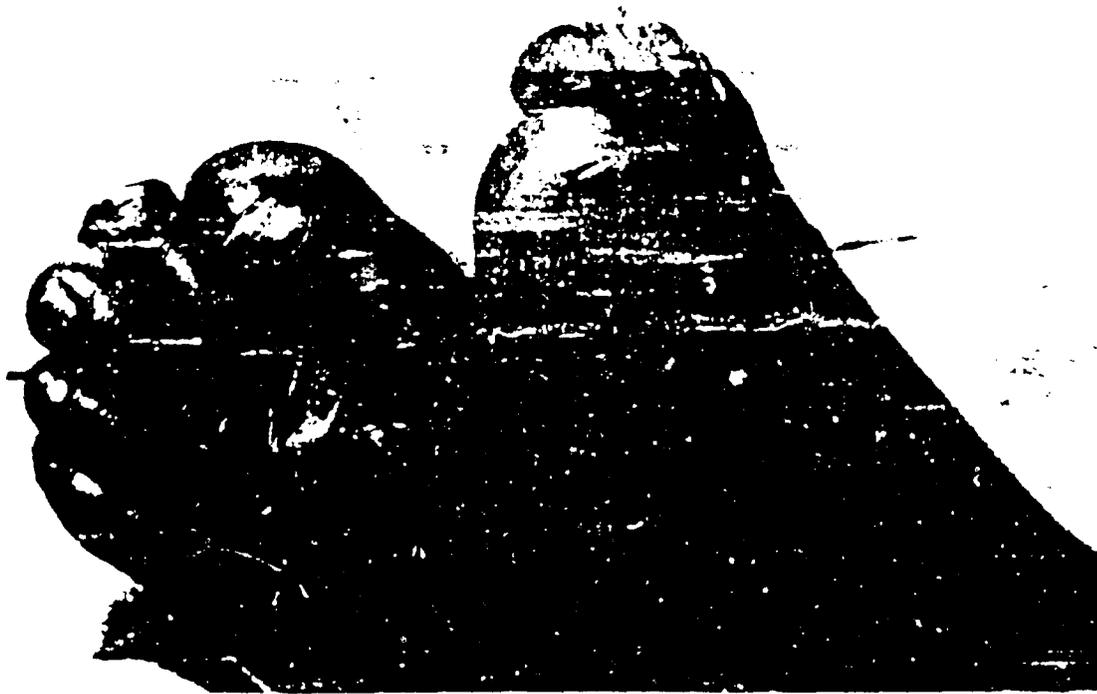


Fig. 26 - Case W. E. G. Fourth degree frostbite of both feet, 7 days after injury.



Fig. 27 - Case W. E. G. Fourth degree frostbite of both feet, 14 days after injury. Large necrotic ulcer on left foot.



Fig. 28 - Case W. E. G. Fourth degree frostbite of both feet, 40 days after injury. Necrotic areas and tendons exposed.

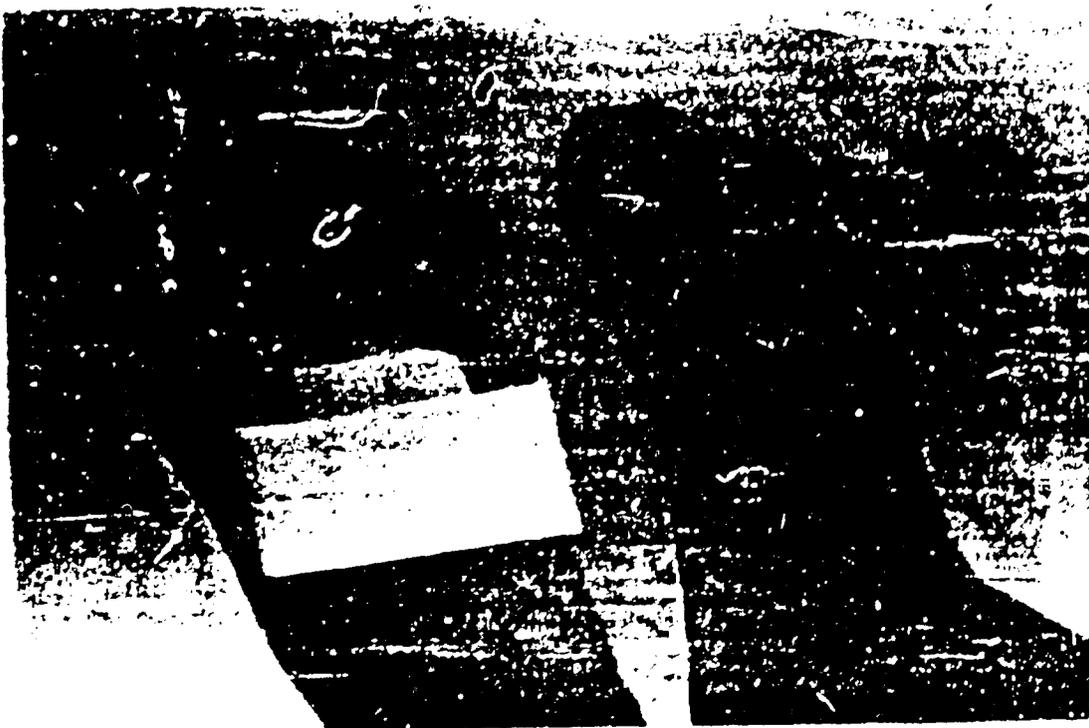


Fig. 29 - Case W. E. G. Fourth degree frostbite of both feet, 51 days after injury, 8 days after operation.

... wet, necrotic areas extended across the dorsa of both feet. ...  
... odor was present. Tendons leading to the right second, third and  
fourth toes were exposed. The patient's daily temperature ranged from 98.0  
to 99.4 degrees Fahrenheit. Slightly tender, moderately enlarged lymph nodes  
were present in each femoral triangle. Forty-three days after injury all  
toes except the left 4th and 5th were removed. Eight days after operation  
(Fig. 29) healthy granulation tissue was present at the site of operation.  
The patient was returned to Zone of Interior on the fifty-second day after  
injury. Ninety-nine days after injury a primary closure was performed on  
the left foot and a split thickness skin graft applied to the right foot.

## VI. DISPOSITION

Eighteen per cent of the 4,216 patients admitted to the Osaka Army  
Hospital were evacuated to hospitals in the Zone of Interior. The incidence  
of patients evacuated to the Zone of Interior during any specific period  
varied, depending on the evacuation policy. During December patients who  
would have required more than 30 days of hospitalization were evacuated to  
the Zone of Interior after preliminary treatment and when considered trans-  
portable. During this period 35 per cent of patients on whom disposition  
was made were sent to the Zone of Interior. In January all patients who  
would have required more than 90 days of hospitalization were evacuated.  
During this period 12 per cent of patients on whom disposition was made were  
sent to the Zone of Interior. In February and March, the evacuation policy  
permitted 120 days in hospitals of the Far Eastern Command. During these two  
months 7 per cent and 13 per cent respectively were sent to hospitals in the  
Zone of Interior.

Patients not evacuated to the Zone of Interior were returned to full or  
limited duty\* or were transferred to other hospitals in the Far Eastern Com-  
mand. Patients transferred to other hospitals included recovered allied mili-  
tary prisoners of war, United Nations troops other than American, and some  
U. S. Navy and U. S. Marine Corps personnel. Exact final disposition of these  
patients is not known.

Data on disposition was available on 1,327 patients with either frost-  
bite or the III Classified Condition of the Feet Manifested by Hyperhidrosis,  
Erythema and Maceration who were not returned to hospitals in the Zone of  
Interior. Seven hundred and eighty-two or 58.9 per cent were sent to general  
duty and 545 or 41.1 per cent were sent to temporary or permanent limited  
duty. Approximately 80 per cent of the patients sent to general or limited  
duty received physical reconditioning at a special reconditioning center.  
The remainder were sent directly to full or limited duty.

The disposition of patients by degree of injury is shown in Table 15.  
Essentially all cases of fourth degree frostbite were evacuated to the Zone  
of Interior. Sixty-four per cent of third degree frostbite patients and 16  
per cent of second degree frostbite cases were sent to the Zone of Interior.

\* Limited duty in most patients was temporary with the specification that  
the patient not be returned to a combat area where he would be exposed to low  
environmental temperature because of a possible increased susceptibility to  
cold injury. (Assignment to "Limited" duty was accomplished by re-profileing  
the patient with a profile 3 on the lower extremity.)

Almost all cases of first degree frostbite and the Ill Classified Condition of the Feet were sent to general or limited duty. The per cent returned to general duty was 81 and 86 per cent respectively. Slightly more than one-half of the second degree frostbite cases not evacuated to the Zone of Interior were sent to temporary or permanent limited duty. Over 80 per cent of the cases of third degree frostbite not evacuated to the Zone of Interior were sent to temporary or permanent limited duty.

TABLE 15  
THE DISPOSITION OF PATIENTS BY DEGREE OF INJURY

DISPOSITION	DEGREE OF INJURY									
	First Degree		Second Degree		Third Degree		Fourth Degree		I.C.C.*	
	No.	%	No.	%	No.	%	No.	%	No.	%
General Duty	201	81	225	41	47	6	0	0	309	86
Temporary or Permanent Limited Duty	42	17	232	43	223	30	1	1	46	13
Zone of Interior	5	2	88	16	473	64	104	99	2	1
*TOTAL	248	100	545	100	743	100	105	100	357	100

\* Ill Classified Condition of the Feet Manifested by Hyperhidrosis, Erythema and Maceration.

#### VII. DURATION OF HOSPITALIZATION

Six hundred and thirty-four patients returned to hospitals in the Zone of Interior were hospitalized for an average of 19.8 days (range 4 to 98 days) before evacuation (Table 16). During this period preliminary treatment was begun. The duration of hospitalization covered the period from the beginning of evacuation from frontline medical facilities until transferred from the Osaka Army Hospital. Accurate data is not available for the duration of hospitalization in hospitals in the Zone of Interior. It is estimated that it is in excess of 100 days. Between 25 and 35 per cent of the patients evacuated to the Zone of Interior have required or will require separation from the service (16).

Patients with frostbite who were not evacuated to hospitals in the Zone of Interior but who were returned to full or limited duty from the Osaka Army Hospital were hospitalized for an average of 32.4 days (range 4 to 127 days) as shown in Table 17. Patients with first degree frostbite returned to duty were hospitalized for an average of 16.6 days, patients with second degree frostbite returned to duty were hospitalized for an average of 29.3 days and patients with third degree frostbite returned to duty were hospitalized for an average of 54.9 days.

Patients with the Ill Classified Condition of the Feet Manifested by Hyperhidrosis, Erythema and Maceration were hospitalized for an average of 100 days.

TABLE 16

THE NUMBER OF DAYS OF HOSPITALIZATION AT OSAKA ARMY HOSPITAL OF PATIENTS SUBSEQUENTLY EVACUATED TO HOSPITALS IN THE ZONE OF INTERIOR. HOSPITALIZATION COVERS THE PERIOD FROM THE BEGINNING OF EVACUATION FROM THE FRONTLINE UNTIL RELEASED FROM OSAKA ARMY HOSPITAL

Degree of Injury	Number of Cases	Average Number of Days Before Return to Z. I.	Range of Days Before Return to Z. I.
Second	86	15.7	7 - 33
Third	457	20.0	4 - 98
Fourth	91	22.7	5 - 58
TOTAL	634	19.8	4 - 98

TABLE 17

THE DURATION OF HOSPITALIZATION OF PATIENTS RETURNED TO FULL OR LIMITED DUTY FROM OSAKA ARMY HOSPITAL. HOSPITALIZATION COVERS THE PERIOD FROM THE BEGINNING OF EVACUATION FROM THE FRONTLINE UNTIL RELEASE FROM OSAKA ARMY HOSPITAL

Degree of Injury	Number of Cases	Average Days of Hospitalization	Range of Days of Hospitalization
First	224	16.6	4 - 55
Second	446	29.3	8 - 97
Third	264	54.8	10 - 127
Total Frostbite	994	32.4	4 - 127
Ill Classified Condition	351	17.5	3 - 45

As previously indicated, approximately 80 per cent of the patients returned to duty received physical reconditioning at a special reconditioning center. An analysis of the records from the reconditioning center, of 182 patients with frostbite or the Ill Classified Condition showed the average stay at the center to be 16.2 days. The average time lost from duty may be estimated in the following manner: 20 per cent (average days of hospitalization) + 80 per cent (average days of hospitalization + average days at reconditioning center). For frostbite:  $0.2 (32.4) + 0.8 (32.4 + 16.2) = 45$ . For the Ill Classified Condition of the Feet:  $0.2 (17.5) + 0.8 (17.5 + 16.2) = 30$ . Thus, patients with first, second and third degree frostbite not returned to the Zone of Interior lost an average of 45 days from duty. Patients with the Ill Classified Condition of the Feet lost an average of 30 days from duty.

## VIII. TREATMENT

The treatment of frostbite depends on the time after injury, the severity of the injury, the presence of complications and the area affected. In military operations treatment is influenced by the tactical situation as well as the facilities available for evacuation of the wounded.

In military operations most cold injuries will appear en masse (i.e., during periods of heavy action). At the same time large numbers of wounds and injuries occur. The management and evacuation of life-endangering wounds and injuries must take precedent over most cold injuries. Even without wounds and injuries highly individualized treatment is difficult during military operations because of the large number of patients who will present themselves almost simultaneously. In civilian life where frostbite tends to be sporadic treatment may be individualized.

Therapeutic agents and procedures such as sympathetic ganglion blocks, sympathectomy, vasodilators and anticoagulants have been used in the treatment of frostbite. However, it is believed that general therapeutic measures such as avoidance of trauma to the part, prevention of infection and adequate nutrition are sufficient in mild frostbite and will decrease the incidence of complications in severe cases.

Two phases of treatment of frostbite exist. The first phase is the initial or emergency treatment. In military operations this phase deals with the management of the patient in the forward areas of the combat zone but is equally applicable to civilian life. The second phase of treatment deals with the patient after he has reached a hospital.

### 1. Initial or emergency treatment.

The forward areas of the combat zone were advised to remove constricting clothing such as boots, gloves and tight bands from the site of injury. Rewarming was to be accomplished by exposure of the frostbitten part to room temperature (70° to 78°F) if the lesion was in the prehyperemic stage. Rewarming also was to be accomplished by holding the part against another part of the body, such as a frostbitten hand held in the axilla. Massage of the part would aid in rewarming. Brisk rubbing either with the hand or with snow was to be avoided since the tissue might be further traumatized and avenues for infection opened. Exposure of parts which were in the hyperemic phase, as manifested by swelling and vesicles, to temperatures above 80°F resulted in pain.

Recent experimental work (17, 18, 19, 20) on animals frostbitten by a relatively short exposure (3 to 30 minutes) indicates that rewarming in baths with temperatures of 37° to 42°C will reduce the tissue loss after a standard cold injury. In military operations by ground troops rewarming by use of warm baths is not feasible. As previously shown (Table 12), only 2.1 per cent of 1,368 men frostbitten in Korea during the winter of 1950-51 were seen by medical personnel before the appearance of swelling and blisters. The remaining patients were already rewarmed. At frontline medical installations facilities for heating water are not readily available during winter months. Animal experiments have demonstrated rapid rewarming to be effective even the part is actually frozen. The advantage or disadvantage of rapidly rewarming cold injured but not actually frozen parts has not been

General body warmth was restored and maintained by removing wet clothing and wrapping in warm, dry blankets. The restoration and maintenance of general body warmth promoted blood flow to the extremities.

Patients with second, third and particularly fourth degree frostbite of the feet were made litter patients at the earliest practicable moment.

Intact vesicles and bullae offer protection against infection of underlying tissue in the field. They should be protected and not drained, aspirated or debrided. Through the initial period of evacuation or transportation the involved part may be covered with a dry, loose dressing to provide protection and maintain warmth. Pressure and petrolatum dressings to the injured area were to be avoided. Petrolatum dressings when used resulted in maceration and secondary infection of frostbitten tissue.

A tetanus toxoid booster was given at the earliest possible time. Antibiotics were started during the chain of evacuation.

## 2. Hospital treatment.

Bed rest is necessary in the early stages of frostbite in order that trauma be avoided. At the Osaka Army Hospital bed rest was absolute until vesicles and bullae had dried. Bed rest aided in the subsidence of edema. Elevation of the foot of the bed five inches may have increased the rate of disappearance of edema without interfering with the blood flow to the lower extremities.

A ward temperature between 70° and 78°F was found to be the most satisfactory. Higher temperatures increased the degree of pain. It was found desirable to keep frostbite lesions exposed to the air. In those cases where frostbite involved the feet the sheets were folded back 18 inches from the foot of the bed. When a fairly constant ward temperature was used together with bed rest and air exposure of the injured part pain did not become a very serious problem and narcotics were not often required.

At the Osaka Army Hospital, smoking was prohibited because of the known vasoconstrictor properties of nicotine. It was considered inadvisable to allow patients to smoke in the presence of an already damaged vascular bed.

A generally nutritious, high protein, high vitamin diet with additional ascorbic acid (250 mgm. daily) was supplied to aid wound healing.

A tetanus toxoid booster was given to all individuals. To prevent secondary infection the cases of second, third and fourth degree frostbite received a minimum of 300,000 units of penicillin daily.

Vesicles and bullae were left intact at the Osaka Army Hospital. They often dried into hard eschars. However, superficial debridement of broken vesicles or necrotic tissue in the presence of frank or threatened suppuration was performed. This was done frequently, particularly at the periphery of the lesion and including toe nails where suppurative material most commonly collected. In the presence of excessive necrotic and suppurative material the wound was wiped clean with a hydrogen peroxide-aqueous zephiran chloride solution and soaked for 30 minutes in a solution of normal saline. When vesicles had dried into eschars, these eschars were lifted away when possible.

Physiotherapy was instituted at the bedside and continued in the hospital. Passive manipulation was avoided in the presence of threatened gangrene. Attention was directed towards the positioning of the feet and movement of the toes and fingers and other major joints. Patients were prone to develop an inversion of the foot and an ankylosis of the interdigital joints. The patients were placed on a more active program of physiotherapy when an ambulatory status was reached.

Emergency amputations are seldom indicated in frostbite except in cases showing extensive putrefactive gangrene associated with lymphadenopathy and signs of general sepsis. It was found desirable to allow a definite line of demarcation to appear in order to preserve the greatest possible amount of tissue and attain maximum function. An apparent line of demarcation appeared early but debridement revealed that the proximal part of the apparently necrotic tissue was superficial with normal tissue below. This is illustrated in Figures 30 and 31. Tissue distal to a definite line of demarcation was dry, black and shriveled, or mummified.

Numerous agents and procedures which have been recommended in the treatment of early frostbite were used at the Osaka Army Hospital. These included heparin intravenously every 4 to 6 hours sufficient to maintain the clotting time above 20 minutes for 8 days; intravenous procaine (0.1 per cent solution in 1000 cc. 5 per cent dextrose in water, twice daily) for 3 to 10 days; oral priscoline, 250 mgm. every 6 hours for 30 days; and sympathetic ganglion blocks for 5 consecutive days. In addition many patients received only general supportive care.

It was impossible to make frequent and accurate observations on these patients because of the shortage of medical personnel. Furthermore, many patients entered the hospital many days after being frostbitten. Because of the difficulty in determining the eventual outcome in a patient with early frostbite, the results of comparing a few non-treated cases with a few treated cases may be inconclusive.

Nevertheless, certain impressions were gained by comparing the course of several hundred patients entering 18 hours to 5 days after frostbite and treated with various agents or procedures with the course of similar patients treated by general supportive care only.

The presence and severity of pain in early, non-complicated frostbite was not markedly altered by any agent or procedure. Frostbite is actually a relatively painless injury except where the patient has been ambulatory for weeks with frostbite of the feet. It was believed that intravenous procaine decreased the severity of pain in these late, traumatized cases but it failed to produce a noticeable effect on patients placed at bed rest within a few days of injury.

No agent or procedure was clearly demonstrated to prevent gangrene. However, in a few 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. Seven of 14 cases of fourth degree frostbite extending proximal to the web of the toes who received only general supportive measures developed soft, wet infected gangrene. Similar results occurred among patients receiving vasodilators and sympathetic ganglion blocks. Of 4 cases of severe fourth degree frostbite extending proximal to the web of the toes who received heparin, all dried and mummified.



Fig. 30 - Case J. M. Showing apparently necrotic tissue through the distal one-third of the left foot.



Fig. 31 - Showing left foot after removal of superficially necrotic tissue. Only great toe visible.



Fig. 30 - Case J. M. Showing apparently necrotic tissue through the distal one-third of the left foot.

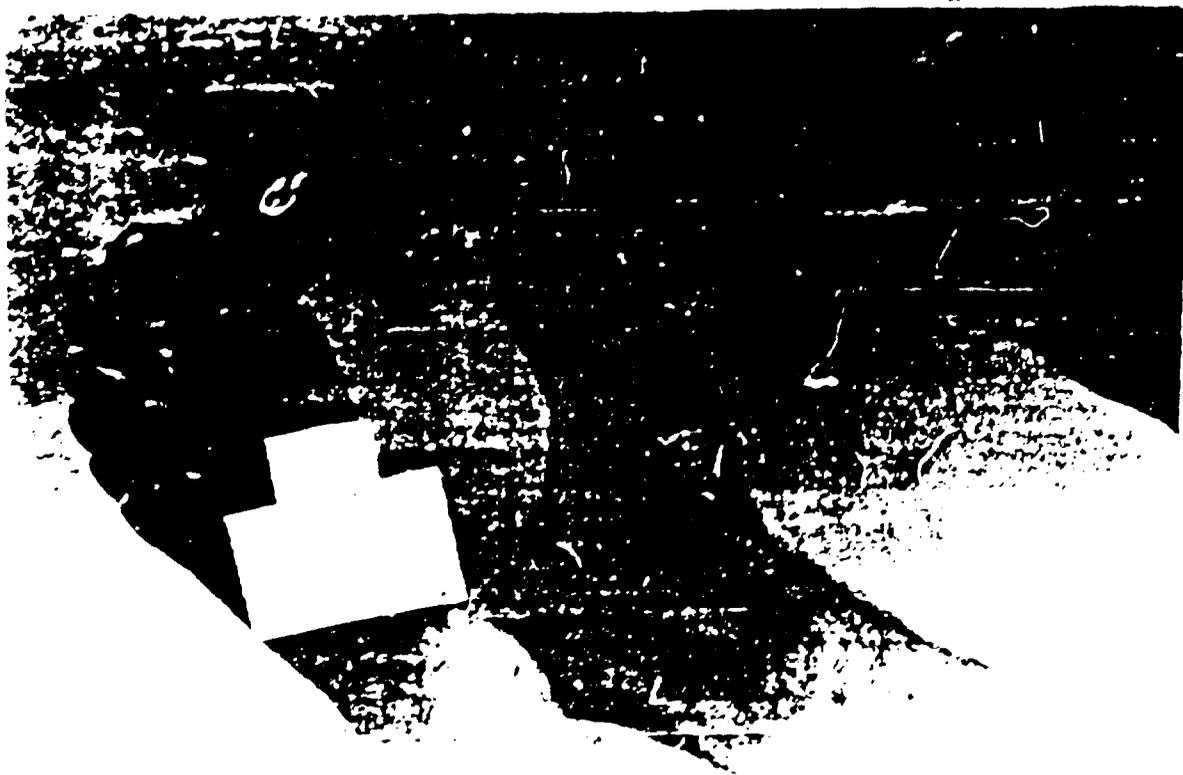


Fig. 31 - Showing left foot after removal of superficially necrotic tissue. Only great toe was left.

## IX. DISCUSSION

Almost all cold injuries occurring in Korea during the winter of 1950-51 were ground-type frostbite. In one unit 98.8 per cent cases occurred when the minimum temperature on the day of injury was less than 30°F. The duration of exposure was 12 hours or less in more than 80 per cent of 812 cases of frostbite.

Sub-freezing temperature is a prerequisite of ground-type frostbite. However, sub-freezing temperature by itself did not result in large numbers of cold injuries. Large numbers of cold injuries occurred in Korea only when low temperatures were combined with immobilization of the individual soldier. Immobilization of the individual seldom occurred when the enemy was not engaged in combat.

It is doubtful if practical clothing for ground troops can be designed which will protect all men immobilized at low temperatures. Heat loss and fall in temperature of the extremities is inevitable under these conditions without a source of external heat. Therefore, ground-type frostbite is not considered to be entirely preventable. Frostbite casualties must be accepted as a calculated risk of a winter operation. While ground-type frostbite cannot be entirely prevented, the incidence might be reduced below that which occurred in Europe in World War II and in Korea during the winter of 1950-51. This might be accomplished by: 1) improved combat training at low environmental temperatures; 2) by continued research in environmental protection; 3) by command recognition of the factors involved in the production of ground-type frostbite; and 4) by continued and intensified stress of individual hygiene as outlined in Army publications (21).

Individual variations in susceptibility to cold injuries should be investigated with the intention of eliminating highly susceptible individuals from front-line duties during winter operations. Suggestions of increased susceptibility now available include racial differences, previous cold injury, peripheral vascular disease, and a high cold hemagglutinin titer (22).

It is difficult to predict the number of cold injuries which will occur during any particular winter operation. The incidence will depend on the type of combat, the existing environmental conditions and the protective equipment available.

In the past, weather data from areas of ground troop action have been sparse and inadequate. Forecasts of weather would be useful in estimating the cold injury casualties which might be expected from an anticipated engagement with an enemy. Better weather data is necessary to determine the exact relationship between environment and cold injuries.

The medical facilities and personnel supporting ground troop action must be prepared to admit and treat large numbers of cold injuries during the same period that large numbers of battle casualties must be treated. General measures of treatment are thought to be sufficient in mild cases of frostbite and should reduce the incidence of complications in severe cases. No specific therapeutic agents or procedures have been conclusively shown to reduce the tissue loss in cold injuries, to shorten the duration of healing, or to prevent sequelae. Additional information is needed.

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It is difficult to evaluate therapeutic measures in humans and the factors of temperature, duration of exposure, etc. vary from patient to patient. Measures designed to prevent gangrene must be instituted within a few hours of injury or rewarming. In the military operations in Korea in 1950-51 it was rare that men were seen while still in the frozen state and it was uncommon for them to be seen within a few hours of rewarming. The severity of injury and the prognosis frequently could not be determined until several hours or days after rewarming. Prognostic features of value in the first few days were: 1) parts which became cold and remained cold were lost; and 2) parts which were vesiculated usually were not lost, but non-vesiculate areas distal to vesicles and bullae generally were lost.

## I. SUMMARY AND CONCLUSIONS

Cold injuries occur in great numbers during winter military operations and materially reduce the effective fighting strength of an Army. These cold injuries include trench foot and frostbite. Based on existing weather conditions and the duration of exposure, most cold injuries in Korea during the winter of 1950-51 were frostbite occurring in ground troops--so-called ground-type frostbite.

Approximately 17 per cent of 2,257 cases evacuated from Korea to Japan failed to display signs and symptoms typical of frostbite. These patients showed hyperhidrosis of the feet with erythema and maceration of the plantar aspects. This condition may be very mild trench foot although hyperhidrosis is not characteristic of early trench foot. It was the result, in part, of physical irritation from trauma and chemical irritation from prolonged contact with perspiration in impermeable footwear.

In 1,889 cases diagnosed as frostbite, 86 per cent of the lesions involved the feet alone, 11 per cent the hands and feet, 2.5 per cent the hands alone and 0.5 per cent other sites including ears, face and knees. Frostbite extending above the ankle or wrist was rare. Six and one-tenth per cent of these 1,889 frostbite patients lost parts, usually digits.

Sub-freezing temperature is a prerequisite of ground-type frostbite. However, frostbite was uncommon when there was no contact with the enemy even when the temperature was near 0°F. Engagement of the enemy in combat resulted in immobilization of the individual soldier and the production of large numbers of cold injuries when the temperature was low. The duration of exposure was 12 hours or less in more than 80 per cent of 812 cases of frostbite.

Several other factors influenced the development of frostbite in some soldiers. The incidence of frostbite was higher in Negro than in White soldiers. Fifteen per cent of frostbite cases gave a past history of a cold injury, either during or before the winter of 1950-51. Wet feet probably increased the incidence of frostbite although 39.8 per cent of 937 cases of frostbite gave a history of the feet being dry at the time of injury. The proportion of cold injury in privates and privates-first-class was slightly higher than the proportion in a rifle company.

Age, time in combat, and smoking could not be conclusively demonstrated to play a role in the development of frostbite.

The clinical manifestations of frostbite varied depending on the severity of the injury and on the early management. General therapeutic measures were

requate in mild cases and reduced the incidence of complications in severe cases. No specific therapeutic agent or procedure was conclusively shown to reduce tissue loss, prevent sequelae, or shorten hospitalization.

Eighteen per cent of 4,216 patients admitted to the Osaka Army Hospital with a diagnosis of a cold injury were subsequently evacuated to hospitals in the Zone of Interior. Patients with frostbite not returned to the Zone of Interior required 45 days of hospitalization and rehabilitation before being returned to duty. Only patients with mild frostbite or minimal sequelae were returned to the combat zone while cold weather still existed.

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