THE PRINCIPLES OF PREVENTION OF COLD INJURIES

NOTES ON THE PROBLEM AS ENCOUNTERED, AND THE METHODS USED, IN KOREA

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[This paper has been written without reference to standard works or recent publications, only those published locally being available to the writer at the time. An attempt is made, however, to summarize, discuss and correlate current trends of thought on this subject, and to interpret these in the light of experience gained in Korea.]

DEFINITION

Cold injuries may be defined as local lesions, usually of the extremities, directly or indirectly due to cold which would not occur under similar circumstances in temperate climates; this paper will be largely concerned with cold injuries of the feet.

Such lesions are known by a variety of names, e.g., immersion foot, shelter foot, trench foot, and frostbite; and at times the differential diagnosis between the various types may be quite difficult. A true case of frostbite is not difficult to distinguish from a thorough-going trench foot, which in turn can easily be distinguished from a simple case of hyperidrotic maceration. There are, however, innumerable intermediate grades between these three types of case,
depending on the relative extent to which cold and moisture have played their part in causation.

**Clinical Features and Pathology**

It is outside the scope of the paper to discuss in detail the clinical and pathological processes which occur, but some brief observations are indicated.

In temperate climates, the reddened, tender, but not much swollen foot, usually heels, soles, under-surfaces of toes and interdigital clefts affected, is well known. This is a result of the effects of moisture on the skin, usually excessive sweat retained in the sock continuously in contact with the skin over a period of months, and is due to localized capillary dilatation.

Should the temperature be lower under similar circumstances, e.g., between 0° and 10° C. (32°-50° F.)—“wet-cold” condition—the effect is more severe; the typical trench foot is seen. Usually the patient has been standing in mud for some time, and his foot is wet either from water leaking through or over the tops of his boots, or from accumulated sweat, and the capillary damage is much greater. The affected areas at first become red and cold, and then, in the pre-hyperemic stage, acquire a sickly whitish-yellow colour and swell slightly. After removal from the wet-cold condition, this stage persists for a few hours, after which the hyperemic stage commences; affected areas become dusky red, more swollen, tense and shiny, and may vesiculate. The skin is hot, painful, and exceedingly tender; and, depending on the degree of vascular damage produced by the ischaemia of the prehyperemic stage, the affected tissues may return to normal over a period of days, weeks or months, or necrosis of tissue distal to the point or plane of occlusion may occur.

Immersion foot, due to prolonged immersion of the lower limb, as seen in shipwrecked sailors or paddy-field workers, follows a somewhat similar course, the only difference lying in the time factors, which depend on the temperature of the water. The condition may take more than six weeks to develop in tropical paddy-field workers, or less than twenty-four hours in northern latitudes at sea.

True frostbite, however, requires little or no moisture for its causation; true freezing of affected areas takes place which, if the patient remains in the cold environment, progresses more widely and deeply. On withdrawal from cold, thawing having occurred, the effects of vascular damage are again seen; painful dusky red swelling of the part with vesiculation. In the same way, depending on the degree of vascular damage, the tissues either return to normal or necrose.

It should be added that the plane of demarcation which occurs at first is not the final plane; much of the proximal part of the lesion will be found to be superficial. Re-establishment of circulation from tissue proximal to that affected is fairly rapid, and if necrosis has occurred a final plane of demarcation six weeks from the time of injury is always much more distal than initial appearances implied.

In other words, all the above conditions appear to have a common patho-
genesis; a period of local ischaemia as a result of different combinations of cold and moisture is followed by evidence of various degrees of vascular damage.

The Three-fold Problem

It follows that the prevention of such lesions requires the solution of three problems which are all inter-dependent, viz:

1. Keeping the foot warm.
2. Keeping the foot dry.
3. Maintaining the vascular tone of and blood flow through the foot.

All attempts to solve the problem must take account of all three.

Causation of Cold Feet

Feet may become cold from indirect causes, either because they are wet or because the blood flow is decreased. Direct causes are, however, a general chilling of the whole body such as occurs at temperatures of 23° F. and below, in which the temperature of the blood falls well below the normal range, and by loss of heat from the foot itself. This is usually by conduction either to the surrounding air or, more important, through the sole of the boot to the ground. Mention should be made here of the “windchill factor.” The rate of loss of heat being proportional to the difference in temperature between the warm object and its environment, it follows that if the air in immediate contact with the object is moving, it has no chance to warm up and so reduce the rate of loss of heat. The effect of this may be calculated, and as an example it may be said that the rate of cooling at a temperature of 24° F. with a 40 m.p.h. wind is the same as that of -11° F. with a 5 m.p.h. wind. Heat is also lost from the skin by the evaporation of sweat, and this loss has to be accepted where it is undesirable that sweat be retained.

Causation of Wet Feet

Feet may become wet because water leaks in through or over the tops of the boot, or because the foot sweats. Whether it be the “insensible perspiration,” leaving the skin as water vapour, or true sweat, fluid invariably accumulates. The amount of sweat produced can be surprisingly large; it is always greater in forward troops, doubtless being of psychosomatic origin, and is to be expected. Foot infections also increase the amount of sweat produced, the chief offender being, of course, chronic tinea pedis.

Causation of Poor Vascular Tone and Blood Flow

The first and most important cause of decreased blood flow in the foot is the peripheral vasoconstriction which occurs automatically as a defence reaction against cold. The skin blanches generally and the blood flow to the extremities decreases in order to reduce the rate of heat loss from the skin surface. Reduction of blood flow to the feet may be still further achieved by inadequate protection of the legs from cold. Dehydration also plays a part in a similar way
by reducing total body fluids, and is more common than might be supposed in
cold weather, when cold water is unpalatable and the amount of hot drinks
available may well be limited. Local factors are prolonged dependency and
immobility of the foot; dependency tends to produce stasis, and failure to use
the muscles of the feet and calves deprives the veins of the assistance thus usually
given to them in returning blood to the heart. Hypoxia of the tissues of the
foot follows from the reduced flow.

METHODS OF TACKLING THE PROBLEM

In a theatre of war in cold climates the threefold problem may only be
approached from three aspects:

1. Modification of the environment.
2. Provision of adequate clothing.
3. Arranging the activities of the individual.

Each of these must be considered from each of the three aspects of the
problem.

ENVIRONMENT

It seems trite and unnecessary to say that as much as possible of the force
should live and work under reasonably warm conditions, but the point has to be
emphasized for planning purposes, so that the requisite numbers of heating
appliances and tents may be provided. Emphasis is placed on tentage, because
cold countries are not as a rule densely populated, and buildings may well be
few. The requirement for heating appliances in Korea has largely been met by
the American tent stove, which is an excellent piece of equipment, burning
petrol, kerosene or diesel, two such stoves being quite adequate to heat a tent
capable of sleeping 18 men comfortably in the conditions experienced.

In addition, several improvised varieties of heater, perfectly safe and burning
petrol or diesel, have been designed and made locally from scrap materials.

Provided that the necessary equipment is available or can be procured or
improvised, the provision of warm working and living conditions presents no
difficulty as far forward as Brigade or even sometimes Battalion Headquarters;
even those whose day-time work is out of doors, e.g., drivers, sappers, pioneers,
linesmen, recovery troops, etc., up to this level can have suitable accommodation,
temporary or permanent, to return to at the end of the day’s or night’s work.
This applies also to artillery and to armoured units when out of contact with
the enemy. The problem is much more difficult, however, for infantry in
contact, occupying positions which are in full view of the enemy, where the
smoke from a stove of any sort may give the position away completely. The
solution in this case is to provide a “warmery” on a company or preferably a
platoon level, a little way back and out of sight of the enemy, to which sub-units
are regularly rotated for a “warm up” lasting a half to one hour at least once
daily. This allows the whole body to warm up, permits peripheral vasodilata-
tion to occur and gives a complete period of rest, relaxation and recuperation.
It allows the removal of boots, changing of socks and insoles, the writing of
letters, and also permits the brain to recover and start functioning again; for one of the side effects of cold is to reduce thought to one track and one track only—how to keep warm.

The foregoing applies to static warfare, such as we have seen in Korea during the winter of 1951-2. During the mobile warfare of 1950-1, much of the foregoing was not possible, but every attempt was made in the Commonwealth Forces to produce something resembling it. Infantry fighting long retiring engagements and never getting a chance to stop and warm up suffered the most, and the incidence of cold injuries was high in such units.

**Clothing**

Reference may be made here to certain well-known general principles in the maintenance of thermal equilibrium of the body and the design of winter clothing. Maintenance of thermal equilibrium demands that the rate of generation of heat by the body shall equal the rate of loss. Production of heat can only be increased by giving a high calorie diet and by muscular exercise. The rate of heat loss can, however, be controlled to a considerable degree by provision of adequate clothing. Heat loss from skin surface occurs by radiation to a small extent, but chiefly by conduction to the air and by the evaporation of sweat. The well-known solution is to surround the body with layers of air, trapped but circulating, which serves the several purposes of good insulation, maintaining a constant temperature of the air next the skin, and allowing gradual evaporation of sweat at a steady rate, so that the rate of heat loss remains more or less constant. This system also has sufficient "elasticity" to accommodate an increase in heat production, e.g., by violent muscular exercise, and still keep the temperature of air next the skin about the same. Consequently British winter clothing consists of the string (Brinje) open-work vest next the skin, covered by a loose flannel shirt and a heavy loose knitted woollen pullover. In the winter of 1950-1 a battledress jacket was worn over the pullover, and the final layer was a windproof smock. The present issue for 1951-2 is a windproof jacket closing with a zip fastener in front, over which may be worn the middle parka with a wool pile lining and windproof outer cover. Similarly the legs are covered with long loose drawers, pyjama type, heavy "trousers inner fleece," with windproof trousers as the outer layer. (In 1950-1 the equivalent was battledress trousers with windproof over-trousers.)

Whatever the type of clothing, the outer layer is a close-woven material, windproof to reduce the wind-chill factor and to enclose the layers of air. It may be partially impervious to water but must not be impervious to water vapour, and consequently not waterproof, otherwise water vapour from the so-called insensible perspiration will condense on the inside and freeze, as will liquid sweat produced during muscular exercise.

The main difficulty in designing such clothing always lies in the disposal of sweat, and the method described above allows ventilation, variable at will by the individual by opening the neck of his garments and changing the position of his zip fastener.
A somewhat different approach to the problem has been made in the American Vapour Barrier suit. This is of polyvinyl chloride, a plastic in a foam structure, about three-quarters of an inch thick, worn next the skin as the only garment and separated from it by numerous small hummocks on the inside of the suit. Sweat is retained and consequently little heat is lost by its evaporation; the insulation provided by the waterproof and consequently windproof plastic is adequate to ensure that the sweat does not freeze. This method shows considerable promise for the future provided that continuous exposure of the skin to 100 per cent. humidity does not give rise to trouble.

Whatever method is used, however, the important effect is to maintain thermal equilibrium and prevent or reduce the peripheral vasoconstriction of the extremities.

The problem of clothing the feet, however, is not quite so straightforward. Similar principles to those of conventional winter clothing can be applied in dry-cold conditions (i.e., temperatures persistently below freezing point at all times of the day, when the ground is either always frozen or always covered with dry snow) by the use of the mukluk. This calf-length boot has a rubber sole and a close-woven canvas upper; it is worn with a thick felt insole separated from the sole by seven layers of fine plastic (saran) mesh. Two pairs of heavy wool socks and one of duffle socks (same material as duffle coats) are worn. The most important layer is the saran mesh, which maintains an insulating layer of warm air between the sole and the ground and permits evaporation of sweat.

Foot-gear in regular use in Korea, however, has to be designed for wet-cold, since however cold the nights, there is on most days a midday thaw, and the late autumn and early spring are par excellence wet-cold conditions. The problem is to keep mud and water out of the boot as well as keeping the foot warm. One attempt at a solution is a rubber overboot, worn over an ordinary light leather marching boot (U.S. description "high shoe"), e.g., the U.K. type ammunition boot or the U.S. type "combat boot." The disadvantages are, however, clear. Although there is no leakage of water into the boot, and there is a layer of enclosed air between the rubber boot and the marching boot, nevertheless sweat accumulates and pools in the sole of the marching boot if the two types of boot are worn together constantly. Further, even two pairs of socks worn with the marching boot give inadequate insulation. The position is improved if the overboots are removed regularly whenever the soldier is in a warm place, or when marching over dry areas, so that sweat can evaporate from the feet, but the disadvantages of carrying two pairs of boots are apparent. This type of footwear was used with some success in the winter of 1950-1 by one Commonwealth battalion, but cases of cold injury did occur.

The U.S. Army shoepac is another attempted solution. The sole and lower part of the upper are made of thick rubber; the upper part is of leather closely stretched to the rubber, the tongue being attached at both sides all the way up, and the whole lacing up in front. It is a calf-length boot, completely waterproof, and is worn with a half-inch felt insole and three pairs of heavy woollen
socks. The advantages are that no water enters the boot except over the top, and that when first put on with dry socks and insoles it is warm and comfortable, and being flexible, it allows toe movement and consequent increased blood flow in the foot. The disadvantage is that disposal of the sweat is impossible; experience has shown that with this type of boot socks and insoles become appreciably wet in half a day and require changing twice daily.

In temperatures below 10° F. this sweat will freeze on the inside of the boot, and if there is no opportunity to change insoles and socks within twelve hours, the foot is in contact with a wet woollen material little above freezing point—the ideal condition for producing trench foot. Under wet-cold conditions above 32° F. the foot, being warmer, sweats even more; a similar state of affairs exists at a higher temperature, and a condition intermediate between a trench foot and a hyperidrosis occurs. It is such a specific entity that it has been given the local title of "shoepac foot." Troops wearing this boot suffered heavy casualties from cold during the winter of 1950-1, during periods of heavy fighting and continuous movement where they had little or no opportunity to change their socks and insoles.

Two types of leather boot have been designed as compromises. The Boot F.P. (Finnish Pattern) is in many ways an excellent boot. It is made of thicker leather than the ammunition boot, has a leather sole half an inch thick, heavily studded, and is worn with a quarter-inch thick felt insole mounted on a thin cork base and two pairs of socks. This boot was worn exclusively by one Brigade Group in Korea in the winter of 1950-1; it is true that a number had deteriorated during storage, the leather cracked and the stitching rotted, but those which were in good condition were waterproof enough but not completely impervious to water vapour. The insole became appreciably damp after twelve to eighteen hours and the socks were similarly affected. An issue of two pairs of insoles was made with each boot, which allowed one pair of insoles to be constantly drying. Appreciable numbers of cold injuries did in fact occur, on one occasion in one battalion in which there was a 100 per cent. stand-to on two successive nights and a 70 per cent. stand-to on the third, no opportunity being given to the men to change their socks or insoles. The disadvantage of this type of boot is that it does not in fact give sufficient insulation from the environment, but it is certainly adequate in rear areas and even in forward areas if the socks and insoles can be changed daily.

The new U.K. boot in use in Korea (Boot C.W.W.—"cold-wet weather") is a leather boot modified from the design of the ammunition boot. The uppers are of similar type of leather, waterproof enough but not impervious to water vapour, with a leather rolled "hem" round the ankle to fit snugly. The sole is a little more than half an inch thick; the lower layer is thick cleated composition rubber and there is a layer of plastic between the two layers of leather. The various layers of the sole with which the upper makes a watertight junction are held together by screws. The toe is blocked to allow free movement of the toes. The insole is a simple arrangement of seven layers of fine plastic mesh (saran) just less than a quarter of an inch thick. One pair of worsted socks and
one pair of heavy woollen socks are worn. Apart from certain minor defects in
the manufacture of the sole, this boot has proved excellent. Perspiration from
the foot does tend to collect on the sole of the boot, but this little pool is separated
from the sole of the sock by the layers of air enclosed in the meshes of the saran
insole and consequently, though the sole of the boot may be wet and even frozen,
the sock and foot are dry. On theoretical grounds there are obvious advantages;
the combination of a good leather marching boot with a waterproof sole from
which the foot is separated by a layer of trapped air in the meshes of the saran
insole satisfies most of the requirements. The number of cases of cold injury
in troops wearing this boot has been negligible in comparison with other types
of footwear, and it has been generally found to be warm, comfortable and
practical. There is no doubt that it is superior to any other cold weather foot­
gear in current use in Korea.

A new and totally different principle in footwear design has been developed
by the U.S. Army—the vapour barrier boot—similar in principle to, and
intended to be worn with, the vapour barrier suit. The aim is purely to ensure
that the foot is warm; sweat is retained, thereby reducing loss of heat by
evaporation. The boot is made of rubber and lined with rubber; the insulating
material lies between the two waterproof layers and only one pair of socks is
worn. The principle is that the insulating material never gets wet or freezes
and consequently the foot remains warm. Sweat collects within the boot, does
not escape and on account of the warmth of the foot does not freeze. The
atmosphere surrounding the foot remains constantly at 100 per cent. humidity,
and under these conditions a water equilibrium on the skin surface is attained,
fluid being simultaneously excreted and re-absorbed. In practice this boot
has in U.S. troops already shown itself superior to the shoepac, as judged by the
incidence of cold injuries; the long-term effect of 100 per cent. humidity on
the foot at body temperature remains to be seen.

ACTIVITIES OF THE INDIVIDUAL

Military operations are undoubtedly the biggest single factor influencing
the incidence of cold injuries. Heavy fighting, much movement of units and
high intensity of work have invariably produced a marked rise in the incidence.
This is true even if the lesions sustained after wounding are excluded, and has
been proved on many occasions by the U.S. Army during the two winters in
Korea. A clue to the reason is given by the experience of a U.K. battalion,
already mentioned, in the winter of 1950-1 wearing the Boot F.P. The battalion
sustained forty-eight hours on 100 per cent. stand-to followed by twenty-four
hours on 70 per cent. stand-to and had no opportunity to get warm, to remove
their boots or to change their socks or insoles. This battalion had a week or so
previously lost the equivalent of a company in battle, including the Second-in-
Command; the Commanding Officer had been evacuated sick, and they were
in a very tense state. Operational discipline was strict and to this everything
else was subordinated. Their role prior to the battle had been in reserve, or
carrying out blocking operations, usually in hilly country in places where a
resourceful man had the time, materials and opportunity to construct himself a shelter; the position they held after the battle was flat with little cover and there was little tentage and no buildings. Night temperatures were not much below 12° F., but there was a considerable amount of sleet at times. They dug little more than slit trenches and in these they remained. The situation did not improve until a "warmery" was set up by the supporting field ambulance—a heated tent in which each man spent, in rotation, one hour, removed his boots, massaged and dried his feet, changed his socks and dried his insoles. After this the battalion constructed its own "warmeries" and the flow of cases of cold injury was reduced to a trickle.

Other U.K. battalions similarly dressed but more fortunately placed with respect to buildings and availability of material had been able to construct "warmeries," and their incidence of cases was very much less. At this time also a brigade order laid down that every man's feet would be inspected daily by an officer, and the situation came under control.

This incident confirms the view that lack of foot care is the most important factor involved. It is clear from what has been said before that the problems reduce to those of disposing of the sweat and maintaining the circulation of the feet.

Obviously the basic step is to reduce the amount of sweat produced. Hyperhidrosis is all too common and its treatment difficult. The only treatment of any avail is the use of formaldehyde as a 3 per cent. solution in a footbath twice a day, or as a 20 per cent. paint on the soles, not more often than fortnightly. The latter requires careful supervision and the foot must be dry before it is painted. This the medical officer can do, and it is no great hardship to inspect all the feet of a unit at a periodic F.F.I. and bring under treatment the infected and hyperidrotic.

However, the feet have to be maintained in good condition, and since cold injuries can develop rapidly, commonly over a period of twenty-four hours, it is necessary for daily attention to be given to ensure daily removal of surplus sweat and restoration of the circulation. This was for the winter of 1951-2 in the Commonwealth Division taught as a daily drill under the supervision of an officer as follows:

Each man, once a day, preferably in the late afternoon or evening, is brought into a warm place and removes his boots and socks. The inspecting officer asks him if he has any foot trouble, checks his boots, socks and insoles and examines his feet. Any deterioration in the condition of the feet is noticed and the man referred to the M.O. The man then washes his feet in warm water, dries them carefully, powders them and puts on a clean dry pair (or two pairs) of socks. Insoles are also changed.

It is quite certain that a daily drill of this nature will prevent the vast majority of cold injuries, provided that the clothing and footwear are adequate. It is equally certain that failure to do so will produce cold injuries, as was demonstrated in one U.K. battalion in the winter of 1951-2.
It is impossible for the medical officer to carry out or supervise the drill in detail; it cannot be entrusted to the individual soldier or even N.C.O., who has many other things to think about, and it must therefore be the responsibility of the officers of the unit to ensure that it is in fact carried out. Not only is the drill necessary to ensure care of the feet, but also to be certain that the man is in fact wearing the right footwear. The four cases sustained in the battalion quoted above all occurred in one platoon in which the drill had not been carried out; and although the C.W.W. boot was in regular issue in that Battalion, one man wore a U.S. shoepac without insole and another a C.W.W. boot with felt insoles which was too tight for him. The other two wore C.W.W. boots, but none had changed their socks for two to three weeks.

It may well be argued that the drill cannot always be carried out in periods of heavy fighting or considerable movement, but this is not so. It may be necessary to forgo the washing, but there are very few occasions or situations in which a man cannot take ten minutes off once in the course of twenty-four hours and, one foot at a time, take off his boots, powder and massage his feet and put on a clean pair of socks. Much has been written of the "buddy" system, and there is no doubt that working in pairs men can without any difficulty assist each other in the care of the feet. It is particularly important to take such action after a day of marching or climbing, during which time the feet have sweated more than usual, before either being carried elsewhere in a vehicle or mounting guard, manning an F.D.L. or holding a position just taken. There is, as we have seen, no better way of inducing a cold injury than to stand or sit still with moist feet, and the drill should be carried out routinely in every case.

If a C.O. decides that the tactical situation does not permit removal of boots, then he must accept the inevitable casualties which follow, just as in advancing over a minefield or a mustard gas contaminated area.

In addition to the daily drill, there are certain things men can be taught to do to maintain the circulation in their feet, and these lie chiefly in continuously exercising them when standing still. Ankle rolling and toe wriggling within the boots are the most important exercises and men soon learn their value in keeping the feet warm once they have grasped the idea. Exercise in general is valuable in increasing the output of heat of the whole body.

Activities of the man include also his consumption of food, and there is no doubt that a high calorie diet is essential to ensure that the body generates sufficient heat to prevent peripheral vasoconstriction. A minimum of 5,000 calories is the accepted figure and the appetite in cold weather justifies this. It seems probable also that the requirement for vitamin C is increased, and while no definite figure has yet been decided it appears to be not less than 50 mg. daily and possibly as much as 100 mg.

**Summary and Conclusions**

It is not the writer's place to discuss the details of administration necessary to ensure that proper precautions against cold injuries are taken. The allocation
of responsibility for the various measures is, however, important. The administrative staff at the planning stage must consider the problems of shelter, heating appliances, adequate food and clothing. In particular enough socks and laundry facilities must be provided. It is manifestly impossible for a man to wash his own socks in extreme cold. The number of pairs of socks per man depends on the speed of laundry turn-round. With a twenty-four-hour turn-round the minimum number is five pairs per man in order to ensure a clean pair daily for issue. Sock washing should not be made a unit responsibility, although most quartermasters can and do run their own laundries.

The General Staff should be responsible for training all ranks in personal precautions.

The responsibility of the Medical Services is to ensure that all feet are in good condition by treatment and by rejection of the unfit. But, whatever equipment or training is provided, cold injuries will still occur unless the man himself ensures that he does not accumulate sweat in his boot and that he keeps his circulation going. The responsibility for ensuring that this is done must lie with the unit.

In the Commonwealth Division this was so; in the majority of cases where cold injuries did occur (and there were few in comparison with other members of the U.N.) the men had in some way escaped the daily foot inspection drill. It came to be felt that to have a case of cold injury was a slur on the unit, and there is no doubt that the fostering of this attitude played a very great part in the prevention of such casualties. The policy for any future campaign in a cold climate should be that, no matter what equipment is provided, it is the responsibility of the unit to ensure that every man's feet do in fact receive daily attention. Under these circumstances cold injuries should never present any problem, and cold weather becomes merely another health hazard overcome by competent unit administration and discipline.

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