Chapter 18

MILITARY MEDICAL OPERATIONS IN COLD ENVIRONMENTS

WILLIAM H. CANDLER, DO, MTM&H*; and MICHAEL S. FREEDMAN, MD†

*****_Lieutenant Colonel, Medical Corps, US Army; US Army Industry Operations Command, Command Surgeon's Office, Rock Island, Illinois 61299-6000_

†_Lieutenant, Medical Corps, US Navy Reserves, 1448 Burney Lane, Cincinnati, Ohio 45230_

INTRODUCTION

Extreme cold weather poses the ultimate environmental challenge to military operations and adds special challenges to those providing medical support. Historically, harsh winter conditions have had a major impact on the outcome of military campaigns. Napoleon's Grande Armée lost all but 10,000 of its remaining 100,000 soldiers during the retreat from Russia in the winter of 1812. Although a high percentage of these injuries were secondary to frostbite and hypothermia,[1] the cold undoubtedly lessened the chances for survival among the wounded. It was during the Napoleonic Wars, however, that the concept of rapid evacuation by "flying" ambulances, or *volantes,* was developed to expedite removal of the sick and wounded.[2]

During World War I, the US Army had a total of 2,061 hospital admissions for trench foot, with more than 91,000 lost man-days secondary to cold-related injuries.[3] Cold weather injuries were also a serious concern during World War II. On Attu Island, Alaska, in 1943, 1,200 cold injuries (80 of 1,000 soldiers, or 8%) were reported during the Aleutians campaign. Afteraction reports indicated that poor equipment and poor training were major reasons for the high casualty rate.[1] The European theater also had heavy cold weather casualties. General Omar Bradley[4] described the severely crippling effect that trench foot had on the 12th Army Group as they moved toward the Rhine River in late 1944. More than 12,000 riflemen, 19% of the total casualties from this campaign, were evacuated. The decision to favor gasoline and ammunition shipments over winter clothing had been a bad choice, but alert commanders who provided drying tents for soldiers to change socks daily had fewer trench foot injuries, Bradley noted. More than 91,000 cold injuries among US Army personnel serving in all theaters of operation were officially reported by the end of World War II.[3]

Between World War I and World War II, major advances were made in resuscitative care and prevention of shock. Although the adverse effects of cold on the wounded with blood loss was appreciated during World War II, the need for external warmth to treat or prevent hypothermia in wounded patients was not universally recognized.[5] During the Korean War, 6,300 cases of cold injury were reported among US Army soldiers and Marines, 90% of which were frostbite of the feet.[3] More recently, the Falkland War (1982) produced a significant number of casualties among British Royal Marines and sailors. Nonfreezing cold injuries were a significant problem, with 70 patients with severe injuries transferred to a hospital ship. Hypothermia caused the deaths of many Argentine sailors who were forced to abandon ship.[6] In addition, management of human waste was a noted problem during the Falkland War, where the ground froze and latrines overflowed with excreta. Some cases of gastroenteritis were attributed to this lack of sanitation.[6] A more detailed discussion of cold weather operations may be found in Chapter 10, Cold, Casualties, and Conquests: The Effects of Cold on Warfare.

Successful military operations in cold climates require reliable equipment, warm and durable clothing that can be worn in layers, and motivated and extensively trained personnel who can cope efficiently with environmental conditions. Medical personnel must not only master the skills to take care of themselves in a cold climate, they must also be able to effectively treat casualties disabled by trauma or illness without allowing those patients to become hypothermic or frostbitten.

PREVENTIVE MEDICINE IN COLD WEATHER

Medical officers assigned to operational units must understand the organizational structure of the brigade and division to which they are assigned. They must also be fully knowledgeable about the organization's capabilities and mission, and be thoroughly familiar with the capabilities and limitations of the medical assets available. Specific planning for a combat mission will require the medical officer to know the current status of medical supplies, the type of terrain to be encountered, the expected weather conditions, the availability of air and ground support for patient evacuation, and the estimated numbers and kinds of casualties that are expected.

Medical officers must also ensure that they fully utilize their preventive medicine assets to assess field sanitation, including the provision of a safe and adequate quantity of potable water, adequate and properly prepared rations, and adequate latrine structures. Maintaining strict standards for field sanitation is vital to maintaining the health of any deployed force. During cold weather operations, military personnel are inclined to neglect good sanitation practices unless enforced by the command. Latrines should be downwind and 100 m from food service sites and at least 30 m from water points.[7] If the ground is frozen, burn-out latrines or plastic bags ("bag and drag" latrines) may have to be used. Latrines should be in a tent or other shelter and will need to be heated for sustained operations in extreme cold.

Proper water treatment using standard water purification methods is as essential in cold weather as it is in warmer temperatures. Bacteria and parasites may still be present in surface waters. Melted snow should not be considered safe to drink without boiling, using iodine tablets, or other appropriate treatment by trained individuals. Personal hygiene must not be neglected. For sustained operations, enough hot water should be produced to allow personnel to wash the hands after using the latrine; and to wash the feet, face, groin, and armpits daily. For personnel on the move, the disposable hand towelette found in the Meal, Ready-To-Eat (MRE) packets are an alternative to water, but only if they are kept warm. Monitoring foot care is vitally important.

When briefing the commander, the medical officer must be able to describe succinctly the following points, the first of which is the most important:

- the level of readiness of the medical units, including their proficiency to function in a harsh, cold environment;
- the health assessment of the soldiers in the command, including their physical and mental ability to conduct the mission, and the adequacy of preventive medicine measures;
- the current status of medical supplies, including blood supply and the ability to keep casualties warm and stable while awaiting evacuation; and
- the patient evacuation plan using transportation assets expected to be available, including patient-exchange points.

SURVIVAL IN THE COLD

Most newly recruited US military personnel are not accustomed to the rigors necessary to stay healthy and warm in a cold environment. Quality training, motivation, and attention to detail are essential to prevent cold-related injuries.

Keeping Warm

Medical operations in a cold weather environment can be exhausting and mentally draining. However, with proper training and equipment, medical personnel can develop the skills and confidence to perform their mission. All medical personnel must be aware of the signs and symptoms of injuries and illnesses common to a cold weather environment and the necessary measures to prevent them. Cold-related medical problems can be divided into four major areas:

1. cold injuries such as frostbite and trench foot;
2. hypothermia;
3. altitude illnesses, including acute mountain sickness, high-altitude pulmonary edema, and high-altitude cerebral edema; and
4. miscellaneous medical problems, such as snow blindness, carbon monoxide poisoning, and dehydration.

Cold weather can be characterized as two types: cold–wet and cold–dry. Cold–wet conditions occur where temperatures are near freezing, and variations in the day and night temperatures cause alternate freezing and thawing. These conditions are often accompanied by wet snow and rain, which cause the ground to become soft and muddy. With these conditions, service members require clothing that consists of a waterproof or water-repellent, wind-resistant outer layer, and an inner layer with sufficient insulation to provide protection in moderately cold weather, –10°C (14°F), or warmer. Waterproof boots and good foot care are essential to prevent nonfreezing cold injury (eg, trench foot, a term that came into use during World War I but is no longer used in the US military). Cold–dry conditions occur when average temperatures are lower than –10°C, when the ground is usually frozen and the snow is dry. These low temperatures, plus wind, increase the need for protection of the entire body. For these conditions, service members may require clothing that will protect them at a windchill factor of –62°C (–80°F). The inner layers of clothing must provide good insulation; the outer layer must be wind resistant and water repellent, yet allow for ventilation to prevent moisture buildup. The acronym COLD (*c*lean, *o*verheating, *l*oose and *l*ayered, *d*ry) can help service members remember some of the basic principles of cold weather clothing[7]:

C: Keep clothing *c*lean. Clothing keeps one warm by trapping warm air against the body and in the pores of the clothing itself. However, if these pores are filled with dirt, sweat, or other grime, the clothing will not be able to do its job as efficiently.

O: Avoid *o*verheating. Military personnel newly assigned to a cold climate tend to wear too much clothing and overheat. Military personnel should be taught to be comfortably cool and to avoid sweating. Proper ventilation and removal or addition of clothing layers according to temperature and activity level are essential to cold weather survival.

L: Wear *l*oose and *l*ayered clothing. For comfort and to forestall some freezing injuries, clothes should be loose. Tight clothing restricts circulation and prevents the trapping of warm air between the body and clothing. Layering is another important principle for staying warm in the cold. Several thin layers are usually more efficient than one thick layer. Different types of layers are used in the Extended Cold Weather Clothing System (ECWCS), which is currently issued to military personnel assigned to cold climates.[7]

The ECWCS was developed to provide a lighter-weight, less-bulky clothing system that was better suited to the modern cold weather battlefield. This system uses synthetic materials to provide warmth and handle moisture more efficiently than the older standard clothing system. The vapor-transmission layer of the ECWCS is the sweat-transfer layer. This innermost layer soaks up body moisture and draws it away from the body to keep the wearer dry. Significant progress has been made with synthetics such as polypropylene, which draws water away from the body but stays dry. The next layer is an insulating layer. This is the layer that holds the warm layer of air around the body. Polyester pile or wool works well. Cotton should not be used, as it does not retain its insulating factor if it becomes wet. The outside layer is the protective layer, which protects the insulating layer not only from getting dirty but also from getting wet. It consists of a wind-resistant, water-repellent parka and trousers made of GORE-TEX (manufactured by WC Gore and Associates, Newark, Del)

D: Keep *d*ry. The conductive heat loss from wet clothing will rapidly reduce the body's core temperature and lead to hypothermia. The wearing of wet boots and clothing must never be permitted.

Not only proper footwear itself but also the proper *use* of the footwear are critical for all military personnel operating in cold climates. Insulated leather boots, commonly known as mountain boots, are usually adequate for active individuals down to temperatures of –18°C to –23°C (0°F to –10°F), provided that the boots have been properly treated with a waterproofing compound. Military-issue mukluks are lightweight canvas boots with a rubber sole that is lined with wool felt. These boots are excellent for vehicle drivers in a cold–dry environment, but mukluks do not provide the support needed for wearing skis. The vapor barrier (VB) boot, on the other hand, is designed to be worn both on the march and with skis. The VB boot is made of an inner and an outer layer of rubber and is filled with either wool fleece or closed-cell foam insulation. It is designed to be worn with one pair of issue socks, which are thick and insulating. VB boots are worn in a cold–dry environment and will usually protect the feet down to –46°C (–50°F) (Figure 18-1). When using these boots, it is essential to change socks whenever they are wet with sweat. The Ski March Boot System consists of several layers, including vapor transmission socks, insulating socks, vapor barrier socks, the VB boot itself, and several different overboot designs. Other boot systems have been developed and have been used on a limited basis by deploying military units. Boots should be dried whenever possible, but the wearer must be careful not to use open flames or extreme heat, which could cause damage.

Just as important as adequate boots is proper foot

Fig. 18-1. The vapor barrier (VB) boot is standard issue for military personnel assigned or deployed to arctic environments. Often nicknamed the "Mickey Mouse" boot, it provides excellent protection from cold under most conditions down to –50°F. Air trapped between two layers of rubber and a thick felt sole pad provide the insulation. A release valve (not shown) is present to relieve pressure when traveling in unpressurized aircraft. VB boots should be inspected at least annually to ensure that the trapped air layer is tightly sealed. Photograph: Courtesy of US Army Northern Warfare Training Center, Fort Greeley, Alaska.

care. A thin, moisture-transmitting sock should be worn next to the foot, with the thick, insulating issue sock worn over that. Socks may need to be changed several times daily to keep feet dry. Sweating can be reduced by using an aluminum hydroxide deodorant on the feet. Using foot powder to absorb excess moisture works well, but with boots designed to breathe (eg, mountain boots), excessive use of foot power can clog the fibrous parts of the boot and reduce their effectiveness. Gaiters, which are leggings worn over boots, may be worn for extra warmth and prevent snow from getting into boots. It is very important that the wearer not restrict circulation in the feet by lacing the cold weather boots too tightly. For sedentary individuals, it is equally important to keep some form of insulation between the ground and the footwear. Personnel working inside a heated tent can still sustain a frostbite injury to their feet if their boots are in direct contact with ice or frozen ground instead of floor boards or other suitable floor covering.

Protecting the hands is critical to cold weather survival and is the most problematic issue with regard to preventing frostbite. Accomplishing a mission in extreme climates often requires a balance between the need for dexterity and preventing cold injury. Insulated gloves are normally adequate for temperatures above –12°C (10°F) if an individual is moderately active. Trigger-finger mittens with wool inserts usually provide good protection between –12°C and –29°C (10°F and –20°F). Arctic mittens are necessary at colder temperatures. At temperatures below –18°C (0°F), contact gloves (thin, snug-fitting gloves made of synthetic fiber) should also be worn, to allow the wearer to remove his mittens for short periods when dexterity is needed to perform tasks. Mittens should always be attached to lanyards, to allow them to be removed without being lost. When not in use, arctic mittens should be carried inside the parka to keep them warm.

Keeping warm involves wearing enough clothing to keep from losing body heat and removing layers as necessary to avoid overheating. Service members must be taught to take immediate action to warm their extremities at the first sign of cold-induced pain or numbness. Changing socks, running in place, or both, will warm feet that are just beginning to get too cold. Likewise, increasing activity, doing "windmill exercises" with the arms, or putting on warm mittens will rewarm hands just beginning to get numb. Chemical heating pads, available commercially, are useful for rewarming feet and hands but should not be used as a substitute for adequate clothing.

Sleeping in an unheated structure in a cold climate requires a fair amount of skill to keep warm. Good insulation between the sleeping bag and the ground is essential to prevent the rapid loss of body heat. Closed-cell foam pads, air mattresses, or small branches from a conifer will provide adequate insulation; take care that plenty of insulation is placed between the feet and the ground to prevent frostbitten feet. Remember that the body heats the sleeping bag; the bag only insulates. On top of the sleeping bag, any waterproof cover will hold the heat in the bag. Sleeping bags should be shaken to ensure maximum loft of the insulating material. The flap should be pulled over the zipper to prevent freezing and heat loss. Service personnel should never sleep in the clothes that were worn all day (cold weather clothing changes are accomplished inside a heated tent or the individual's sleeping bag). Clothes damp with sweat will soon cool the body. Clothes and boots should be placed inside or directly underneath the sleeping bag. A balaclava (a knit cold weather hat) should be worn while sleeping to reduce heat loss from the head. A carbohydrate meal eaten just before bedtime will provide metabolic fuel during the night.

Nutrition and Hydration

Good nutrition and hydration are as essential as warm clothing to functioning well in cold weather. The average person living and working in cold weather needs 25% to 50% more calories than their normal intake, depending on activity level. The average male soldier requires 4,500 calories per day during cold weather field training, and the average female soldier requires 3,500 calories per day under the same conditions.[8] The cold weather ration currently issued to US military personnel provides these needed calories. As often as possible, meals should be served hot, which provides additional warmth as well as improves morale. Tent stoves, cook stoves, or the chemical heater issued with the MRE packets work well under most conditions. In addition to regular meals, frequent high-calorie snacks and hot, non-caffeinated beverages or soups should be provided. High-fat diets are an efficient way to provide needed calories, but carbohydrate sources of calories may be better tolerated by the average service member.[8]

Adequate hydration can be problematic in arctic and subarctic conditions. Service members often do not feel thirsty even though they are operating in an atmosphere as dehydrating as any desert. Depending on activity level, each person will need at least 6 liters of fluid per day. For units operating away from motorized vehicles, obtaining water and preventing it from freezing are difficult chores. Water containers transported on a squad sled known as an *ahkio* (from the Finnish, pronounced ah-kee-oh) soon freeze, as does water in the standard-issue arctic canteen. Many experienced military units operating in cold environments use nonstandard thermos containers or water storage vessels that may be worn inside a parka. Canteens, if used, should be filled two-thirds full and then wrapped in a pack or kept in the sleeping bag. Just before going to sleep, service personnel can fill their canteens with hot water and place them inside the bag. This will not only keep the canteens from freezing, but will also warm the bag.

Shelter and Heaters

The Arctic 10-Man Tent is currently the standard tent used by most US military forces deploying to extremely cold regions. This tent can be managed by a squad, has a liner, and can be warmed effectively by a variety of stoves. It can be carried by an ahkio. The tent has ventilation openings and accommodates a stove pipe. To avoid a fire hazard, safety must be the utmost concern when using a stove inside the tent. The sides of the tent must not be staked down to allow rapid egress in the event a stove flares up. Good ventilation is essential to prevent carbon monoxide poisoning or loss of oxygen. Stoves should never be operating when all tent occupants are asleep.

Another shelter system currently used is the Modular Command Post System. This special tent is designed to use a heating system that will allow temperature-sensitive equipment to operate. This system can also be used to provide medical care.

The stove most commonly used by US military units in cold climates is the M1950 Yukon Stove. This simple but effective stove will burn wood or liquid fuel dripped onto a burner. Diesel fuel, kerosene, or gasoline may be used, but gasoline has proven to be the most efficient fuel. Gasoline is also the most dangerous fuel, especially when it is not handled properly. The US Army Research, Development, and Engineering Center, Natick, Massachusetts, has developed the Family of Space Heaters (FOSH) (Figure 18-2). These stoves are designed to operate without external electric power, use all types of liquid or solid fuel, and work at temperatures as low as –51°C (–60°F). Because they control the flow of fuel through a regulated vaporization step, these heaters are designed to be safer than the M1950 Yukon Stove. A thermoelectric fan powered by the heat of the stove helps improve efficiency by circulating warm air.[9]

Mobility

Traveling over snow and ice can be challenging for military personnel who have never participated in outdoor winter activities. Medical personnel will have to master basic snowshoe and skiing skills to conduct their mission in snow country. Lightweight, tracked vehicles designed for off-road movement in snow greatly enhance both military operations and the ability to evacuate casualties.

Fig. 18-2. The Family of Space Heaters (FOSH) was developed to provide safer, more efficient heaters for field use. Each stove is capable of using multiple fuels including diesel, JP8, JP5, kerosene, wood, and coal. (**a**) The Space Heater, Convective (SHC) is a 35-kBTU, 67-lb heater that provides forced hot air to heat tents. It can be operated inside or outside the shelter. The SHC has a thermoelectric heater that uses waste heat to generate enough electricity to power the blowers, pumps, ignition system, safety system, and controls. (**b**) The Space Heater, Arctic (SHA) is a 28-kBTU heater designed to heat the Arctic 10-Man Tent and other tents with 100 to 200 ft^2 of floor space. Weighing 35 lb, it was designed to be mobile and easy to assemble. (**c**) The Space Heater, Small (SHS) is a 12-kBTU heater designed to heat the Soldier Crew Tent (5-man tent) and other tents with 80 to 100 ft^2 of floor space. It weighs 19 lb, including an integral fuel tank. (**d**) The Space Heater, Medium (SHM, or H-45) is designed for general purpose and TEMPER (*t*ents, *e*xtendable, *m*odular, *per*sonnel) tents. It replaces the older M-41 heater, which had operational and safety problems. The H-45 weighs 70 lb. The SHA and SHM heaters utilize an attached thermoelectric fan (shown atop the SHA, b) that circulates heat down to the tent floor, improving heat distribution and providing fuel savings. Photograph: Mr Joe Mackoul, Project Engineer, US Army Soldier Systems Center, Natick, Mass.

Fig. 18-3. The standard issue snowshoe is lightweight, versatile, and easy to learn to use. This soldier is wearing vapor barrier (VB) boots (see Fig. 18-1) and the Extended Cold Weather Clothing System (ECWCS), with winter overwhites for camouflage. Photograph: Courtesy of US Army Northern Warfare Training Center, Fort Greeley, Alaska.

Snowshoes

Personnel can master the necessary skills to walk in snowshoes in a short period of time (Figure 18-3). Snowshoes require very little maintenance and allow movement in densely wooded terrain. They are particularly useful for individuals working in confined areas, such as around bivouac sites and supply dumps. However, they are not an efficient means to travel long distances because they are slow and require a great expenditure of energy.

Although the types of snowshoes vary, the concept remains the same. The magnesium snowshoe commonly issued to US military personnel is light and durable. The nylon binding used with this snowshoe is adaptable to all types of issued footwear. The magnesium snowshoe also has “teeth” on the bottom, which aid in traction. An additional feature in a survival situation is that magnesium shavings from the snowshoe frame make an excellent fire starter.

Skiing

Skis, once mastered, are much faster and more efficient than snowshoes in open terrain. Military personnel unfamiliar with their use, however, may require several weeks of training to be proficient with them. The backcountry or mountaineering ski commonly issued to arctic units is a cross between Nordic (cross-country) and alpine-type (downhill) skis. They have a metal edge and cable bindings that allow free movement of the heel. This binding is designed to fit the VB boot (Figure 18-4). The mountaineering ski functions adequately under a variety of conditions and can be used in steep terrain by a skilled individual.

a

b

Fig. 18-4. (**a**) The military ski is a metal-edged mountaineering ski suitable for downhill and cross-country skiing. The soldier in this photograph is making a telemark turn. (**b**) The detachable fabric “skins” seen on these military skis provide traction for steep uphill climbs. Photographs: Courtesy of US Army Northern Warfare Training Center, Fort Greeley, Alaska.

Fig. 18-5. These US Marines are extending their range by skijoring behind a Small Unit Support Vehicle (SUSV): the tracked vehicle is towing them. Skijoring requires balance, but the technique is easily mastered. Unit members attach themselves by wrapping one turn of the towrope around the ski poles, which are held under the arm. For safety, skiers are not directly attached to the towrope.

Nordic skiing uses a "kick and glide" action. The skis have a bow, called a camber, in the center portion. When fully weighted on one ski, this center portion flattens to allow the ski to grip the snow, thus allowing the kick. The tips and the tails of the skis provide the glide. Skis must be waxed, using the appropriate wax for the temperature and snow conditions. For ascending steep inclines, a fabric "skin" can be attached to the entire length of the ski bottom to provide grip.

Unit mobility over long distances can be enhanced by towing ski-mounted service members from a vehicle. This technique, called *skijoring*, works well with seasoned troops, but care must be taken to prevent frostbite caused by the windchill (Figure 18-5).

Ground Vehicles

Requirements for ground vehicles will vary depending on the type of operation and the terrain. Wheeled vehicles are frequently limited to paved roads. Chains are frequently required, even on vehicles with four-wheel drive. Tracked vehicles are often of limited utility because of their heavy weight. The standard vehicle used by most US military units deployable to arctic and subarctic regions is the Small Unit Support Vehicle (SUSV). This lightweight, tracked vehicle can negotiate most types of terrain, pull skijoring units and supplies, or evacuate patients. Snowmobiles are quite versatile in snow country but are not standard equipment for most units. They can move rapidly and pull ahkios.

MANAGEMENT OF CASUALTIES IN THE EXTREME COLD

Managing seriously injured casualties in an extremely cold environment (≤ –20°F wind chill equivalent) is difficult, especially if there has been significant blood loss or the casualty cannot be rapidly evacuated to a warm place. The basic tenets of emergency trauma care as taught in the American College of Surgeons' Advanced Trauma Life Support[10] course remain the same, but the medical care provider may need to balance the casualty's need for medical stabilization against the risk of hypothermia or frostbite from exposure. A review of a mass casualty situation during an arctic winter illustrates this point well (Exhibit 18-1).

The detrimental effect of hypothermia on trauma victims has been noted in several studies. In a study of adult trauma patients, Jurkovich and colleagues[11] found that trauma victims with similar Injury Severity Scores had significantly higher mortality rates when their core temperature decreased compared with those whose core temperatures were normal. In this study, no trauma victim with a core temperature below 32°C survived. In a study of 94 trauma victims, Luna and colleagues[12] reached similar conclusions. Both studies indicated that an increased risk for hypothermia existed when large volumes of blood or crystalloid fluids were infused.

Locating Casualties

Casualties dressed in camouflage whites can be difficult to find in the snow. Ice fog and lack of daylight during the winter months in the extreme Northern Hemisphere (or extreme Southern) can further challenge search efforts. Successful rescue requires finding and evacuating wounded personnel rapidly. Those conducting the search should ascertain the last known position of missing service members and look for signs of equipment and tracks. Search efforts must be rapidly organized, with defined search grids for all parties involved. Good communication is vital. If a rapid systematic search fails to locate the individual, then infrared detection devices, if available, should be used—from either the ground or the air. These devices

EXHIBIT 18-1

TRAUMA AT FIFTY BELOW ZERO

In January 1989 a military C-130 aircraft crashed as it approached the runway at Fort Wainwright, Alaska. The temperature was –47°C (–51°F) with calm winds and ice fog. Visibility was approximately 200 m. Of the 18 passengers and crew, 7 were dead at the scene from multiple trauma, which included head, abdominal, and chest injuries. An eighth soldier, who sustained a subdural hematoma, died 3 days after the crash.

Rescuers required approximately 120 minutes to extract a ninth casualty, whose injuries consisted of a comminuted lower leg fracture and blunt chest trauma, from the wreckage. Attempts to keep the ninth casualty warm with blankets and a portable space heater proved unsuccessful. Fluid administration was attempted during the extraction process but proved impossible because the intravenous fluid would rapidly freeze and the plastic tubing would shatter. When he arrived at the hospital, the casualty's core temperature was 28°C (82°F). He was rewarmed with infusions of warmed intravenous fluids in addition to peritoneal lavage, and intubated and ventilated with warm air. Despite these efforts, he went into ventricular fibrillation, progressed to asystole, then died 75 minutes after resuscitation began.

A tenth casualty, found injured in a snowbank, had a skull fracture with intracerebral hemorrhages, abdominal injuries, and deep facial lacerations that bled profusely but only after the casualty was rewarmed in the emergency room. This individual, who arrived at the hospital 1 hour after the crash, was wearing arctic gear except mittens. He suffered deep frostbite to both hands, but recovered. Most of the other victims suffered mild hypothermia and frostbite in addition to their injuries from the crash.

Source: Johnson DE, Gamble WB. Trauma in the arctic: An incident report. *J Trauma.* 1991;31:1340–1346.

have proven to be highly effective for locating people.[13]

Assessing the Patient

As with any trauma victim, a rapid initial assessment must be completed on a casualty, even in extreme cold weather. The assessment should be done with minimal, if any, removal of clothing. Ensure that an airway is established and maintained with cervical spine control and that the patient is breathing adequately. Cardiopulmonary resuscitation should be rendered as necessary in the best manner possible. Severe bleeding should be stopped with a pressure bandage, or a constricting band if necessary, in the event of a traumatic amputation or severed artery. Severe extremity wounds may have little or no bleeding, however, secondary to vasoconstriction from the cold environment. Estimating blood loss by pulse, skin color, or capillary refill will not be useful after prolonged exposure to subfreezing temperatures.

If a spinal injury is a possibility, care must be taken to immobilize and lift the victim carefully. Obvious fractures should be immobilized to prevent further damage, but splinting should normally be delayed in favor of expediting evacuation, especially if the patient is to be placed on a sled or litter. Intravenous fluid replacement in the field at extremely cold temperatures is not feasible. Veins constrict, making the establishment of a patent intravenous line difficult. The exposure and delay could lead to hypothermia, and the intravenous line will quickly freeze if left exposed to the outside air. Once immediate life-threatening problems are stabilized, the casualty's best chance for survival is rapid evacuation to a warm treatment site.

Management at a Battlefield Medical Treatment Facility

Once a casualty has been transported to a battalion aid station or other battlefield medical treatment facility, a more thorough assessment can be made. Intravenous fluids will need to be warmed (to 39°C) to prevent hypothermia.[10] Normal saline may be more practical to carry and use in forward areas than Ringer's lactate. Usually the preferred replacement fluid for victims with traumatic blood loss, Ringer's lactate may precipitate after freezing; normal saline does not. In a battalion aid station, crystalloid solutions can be heated in a water bath using a stove or, preferably, an electric heater if a generator is available. In combat area support hospitals, microwave ovens can be used to warm crystalloid fluids except glucose-containing solutions, blood, and plasma. If a patient arrives with significant hypothermia, intravenous fluids should be warmed to 39°C (43°C).[14]

In an extremely cold environment, keeping a casualty warm is an integral part of emergency management. Tents may be difficult to warm, especially when temperatures are extremely low and the wind is blowing, so casualties must be kept inside prewarmed arctic sleeping bags (Figure 18-6). Several effective heat sources for individual patients are available, but not all are commonly used by military units subject to deployment in cold regions. Chemically activated heating pads will last several hours when placed inside a sleeping bag. A surprisingly safe charcoal heater known as the Norsk Personnel Heater (Figure 18-7), a Norwegian innovation, uses a battery-operated fan to provide an individual heat source.[15] This device also comes with a humidifier. Both of these heat sources will keep an individual warm when used appropriately but are not efficient for rewarming a seriously hypothermic casualty.

Intravenous solutions, once warmed, must be kept warm. In a shelter or tent, insulation placed on the bag of infusate and the tubing may be adequate if the temperature is not too cold. Otherwise the apparatus will have to be placed inside the sleeping bag with the casualty, with a pressure cuff to maintain flow. Portable devices capable of delivering warm, humidified air to casualties in the field are available. These greatly increase the amount of heat that can be delivered. A thermometer, if used, should be placed in the airway tubing to monitor the temperature. To prevent injury to the casualty's bronchi, the temperature should be between 42°C and 46°C.

Fig. 18-6. Care of a trauma victim is extremely challenging in a cold environment. The need for exposure for wound care and intravenous access must be balanced with the risk of hypothermia.

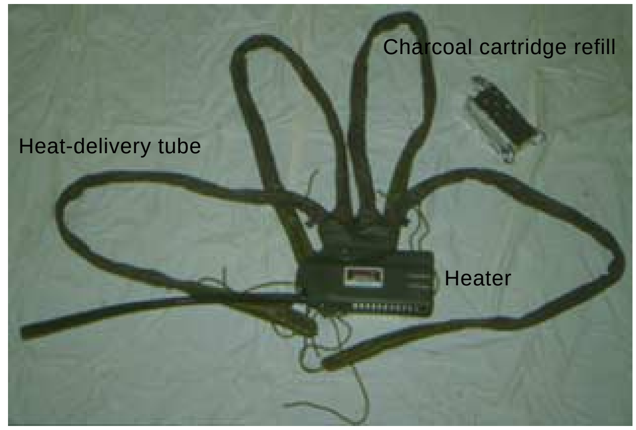

Fig. 18-7. The Norsk Personnel Heater, for individual use, is currently part of the US Army medical inventory for warming casualties. The heater, which measures approximately 9 x 5 x 2 in., provides 40 to 250 W of heat for 6 to 20 hours on one charcoal cartridge. The flexible tubes are placed around the casualty's body to circulate heat. A unique, specially designed catalytic converter converts carbon monoxide to carbon dioxide.

Establishing a medical station (US Navy) or battalion aid station (US Army) requires proper planning. Avoid avalanche zones; make sure the aid station is in a good defensive position, such as a forested area, and that it is near a good water supply. Ensure that good track discipline (ie, minimize the trail size by keeping infantry and vehicle tracks in line and in shadows or near trees) is used when traveling to the aid station to lessen the chance of enemy detection. Among units deployed to the arctic, the 10-man mountain tent is used as a battalion aid station more than any other shelter. When running an aid station out of this or other similar shelters, some form of improvised flooring such as plywood should be used, if possible, to keep feet warmer. On tundra, the ground will become wet and soggy without a floor as the tent becomes warmer. In extreme cold, the temperature at ground level will likely remain below freezing, especially near the door and edge of the tent. Therefore, it is very important to keep medications elevated to prevent damage from freezing. Table 18-1 lists the stability after freezing of commonly used medications in a deployment setting.

In highly mobile settings, it may be expedient to establish an aid station in an ambulance or other vehicle such as an SUSV, particularly if the predicted number of casualties is light. An SUSV may provide a warmer and cleaner environment with a

TABLE 18-1

STABILITY OF MEDICATIONS AFTER FREEZING

Medication	Stability After Freezing ≤ 0°C
Normal saline	Can be used upon rewarming
Ringer's lactate	Unstable
Lidocaine 1% injection	Can be used if clear
Sodium bicarbonate injection	Unstable
Naloxone hydrochloride	Unstable
Diphenhydramine injection	Can be used upon rewarming
Tetanus toxoid	Unstable
Meperidine hydrochloride	May be used if clear
Calcium chloride 10% solution	Unstable
Penicillin GK injection	Stable in powder form
Procaine penicillin G injection	Stable; potency is retained
Furosemide injection	Stable; potency is retained
5% dextrose in water, 5% dextrose in normal saline	Unstable
Morphine sulfate: injection solution or tablets	Potency is retained; insoluble particles may form
Prochloroperazine: injection, solution, tablets, capsules	Unstable
Promethazine injection, tablets, suppositories	Unstable
Antacids	Potency is probably not affected, but emulsions may separate
Epinephrine injection	Unstable
Diazepam injection	May be unstable; thaw in warm water bath; use if no precipitate is visible

Source: Auerbach PS, Geehr EC, eds. *Management of Wilderness and Environmental Emergencies.* 2nd ed. St Louis, Mo: Mosby; 1989: 356–357.

ready source of electrical power, but use as an aid station will encumber a vehicle.

Military Medical Evacuation

The method of military medical evacuation can take many forms; however, the chain of participants remains relatively constant. The infantryman is often overlooked as a member of the treatment team, but all service members are trained in "self-aid" and "buddy-aid." The hospital corpsman or medic attached to each company is the next link in the chain. They provide first aid and emergency procedures; continual observation; and care to ensure that the casualty's airway is open, bleeding has ceased, and circulatory shock and further injury are prevented. Corpsmen and medics also ensure that medical supplies are used effectively and make requests for air or ground ambulance, as appropriate. The unit medical station or the battalion aid station is the first link in the chain of evacuation where a casualty can expect to see a physician or physician assistant.

To provide the best chance for a casualty to survive evacuation to the next-higher echelon of care, all service members should be taught the following guidelines:

- Apply essential first aid to treat life-threatening conditions and stabilize the patient.
- Obtain the fastest means of evacuation available. Use aviation support whenever possible.
- Warm the casualty if necessary and keep him warm. Protect from the elements.
- Check on the casualty's condition frequently, but avoid unnecessary handling and exposure. In extreme cold, the casualty's breathing rate, mental status, and subjective reporting of pain and feeling may be the best indicators of his condition.
- If evacuation must be by ground, select the easiest route, by using scouts if necessary. If the route is long and arduous, set up relay points and warming stations using minimal medical personnel. Normal litter teams must be augmented in arduous terrain.
- Do not separate the casualty from his gear.

Fig. 18-8. The akhio is a fiberglass sled designed to carry up to 200 lb of equipment. Infantry squads usually use them to carry their 10-man tent, stove, fuel, water, and other equipment. The akhio can also be used to evacuate a casualty. The sled weighs 38 lb and measures 88 x 24 x 8 in. Three rails on the bottom help the sled track in a straight line. Maneuvering the fully loaded akhio requires the coordinated efforts of up to four individuals, especially on turns. A knotted rope, seen in this photograph, is placed beneath the akhio as a brake for downhill runs. Photograph: Courtesy of US Army Northern Warfare Training Center, Fort Greeley, Alaska.

In snow, putting the casualty on the standard ahkio and towing it is usually the easiest method of manual evacuation (Figure 18-8). The ahkio can be pulled by snowmobile or loaded into a SUSV or helicopter. The ahkio is large enough to accommodate one casualty and most, if not all, of his survival gear. To evacuate a casualty using an ahkio, pad the bottom with one or more sleeping mats. The patient may be placed in a standard issue sleeping bag or an evacuation bag, which is a larger bag that provides room for extra medical items. In extreme cold or for a lengthy evacuation, a Norsk Personnel Heater or chemical heat pad should be used to provide additional warmth. A poncho or other suitable vapor barrier should be placed on the outside of the sleeping bag to prevent heat loss. The canvas cover should then be placed over the casualty except for the face. Ths casualty should be lashed securely but not too tightly. The casualty's head should be slightly elevated and placed to the rear of the ahkio, unless the evacuation route is downhill; then the head should be placed to the front. Evacuation by stretcher can be arduous if the casualty must be carried a great distance over rough terrain. It takes up to eight individuals (squad size) rotating turns to complete an evacuation this way.

Medical evacuation by air is the ideal method to transport a critically injured casualty to the definitive care needed to preserve life. The extreme cold found in the Arctic, Antarctic, and at high altitude can place limitations on aircraft, however, and especially on their navigation systems. Visibility is often poor secondary to snow and ice fog. Aircraft may also be limited by the difficulty of finding a landing zone, the height of an obstacle, the size and topography of the landing zone, and the wind direction and velocity. Personnel on the ground must ensure that the landing zone is free of obstacles, that the snow is firmly packed down in the landing zone, and that the landing zone is appropriately marked.

When a rotary aircraft lands, care must be taken to avoid frostbite from the windchill produced by the rotating blades. As with all requests for air evacuation, establishing good communication is vital.

SUMMARY

Medical operations in cold environments require constant vigilance by medical personnel and the chain of command to prevent disease and nonbattle injury and to limit morbidity and mortality of combat casualties. Good planning, careful oversight, and thorough training are essential. Management of casualties in an extremely cold environment greatly challenges the resources and ingenuity of the medical team. Rapid assessment, stabilization, and evacuation will, in most situations, be the key to survival for casualties with significant injuries. All healthcare providers, from the soldier in the field providing basic first aid to the physician at a field hospital, must take aggressive measures to prevent hypothermia from occurring.

REFERENCES

1. Whayne TF, DeBakey ME. *Cold Injury, Ground Type, in World War II.* In: Coates JB Jr, McFetridge EM, eds. *Medical Department, US Army.* Washington, DC: US Department of the Army, Medical Department, Office of The Surgeon General; 1958.

2. Gillett MC. *The Army Medical Department 1775–1818.* Washington, DC: US Army Center of Military History; 1981: 167.

3. Hanson HE, Goldman RF. Cold injury in man: A review of its etiology and discussion of its prediction. *Mil Med.* 1969;134:1307–1316.

4. Bradley ON. *A Soldier's Story.* New York, NY: Henry Holt; 1951: 444–445.

5. Beecher HK. *Resuscitation and Anesthesia for Wounded Men.* Springfield, Ill: Charles C Thomas; 1949: 104–105.

6. Marsh AR. A short but distant war—The Falklands campaign. *J R Soc Med.* 1983;76:972–982.

7. US Army Medical Research and Development Command. *Sustaining Health and Performance in the Cold: Environmental Medicine Guidance for Cold-Weather Operations.* Natick, Mass: US Army Research Institute of Environmental Medicine; 1992. USARIEM Technical Note 92-2.

8. US Army Medical Research and Development Command. *Nutritional Guidance for Military Field Operations in Temperate and Extreme Environments.* Natick, Mass: US Army Research Institute of Environmental Medicine; 1993. USARIEM Technical Note 93-8.

9. Mackoul J. US Army Soldier and Biological Chemical Command, Natick, Mass. Personal communication (telephone), March 2000.

10. Committee on Trauma, American College of Surgeons. Injuries due to burns and cold. In: *Advanced Trauma Life Support Program for Doctors.* 6th ed. Chicago, Ill: American College of Surgeons; 1997: 273–288.

11. Jurkovich GJ, Greiser WB, Luterman A, Curreri PW. Hypothermia in trauma victims: An ominous predictor of survival. *J Trauma*. 1987;27:1019–1022.

12. Luna GK, Maier RV, Pavlin EG, Anardi D, Copass MK, Oreskovich MR. Incidence of hypothermia in seriously injured patients. *J Trauma.* 1987;27:1014–1018.

13. Cooper CC, Lavalla PH, Stoffel RC. Search and rescue. In: Auerbach PS, ed. *Wilderness Medicine: Management of Wilderness and Environmental Emergencies.* St Louis, Mo: Mosby; 1995: 506–534.

14. Committee on Trauma, American College of Surgeons. Initial assessment and management. In: *Advanced Trauma Life Support Program for Doctors.* 6th ed. Chicago, Ill: American College of Surgeons; 1997: 21–46.

15. Äijälä HAE. Clothing and external heating systems. In: Vuori HA, ed. *Sotilasvaatetus ja sen kehittäminen.* Julkaisija, Finland: Pääesikunnan Materiaalihallinto-Osasto Oulun Aluetyöterveyslaitos; 1995: 116–119 [in Finnish but each chapter has an abstract in English].