Medical Emergency

Cold Injuries : The Chill Within

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Introduction

Cold injuries have had profound effects upon the fighting force and military operations throughout history[1] including our own military experiences from the highest battlefield in the world, Siachen. Cold injuries are as preventable as heat injuries and require the medical services to work closely with the tactical commanders to implement effective prevention strategies[2]. The initial treatment offered by the Regimental Medical Officer (RMO) is crucial to the final outcome. This article attempts to review the various types of cold injuries and identify prevention and treatment strategies. Cold injuries are divided into freezing and nonfreezing injuries (occur with ambient temperature above freezing). They include hypothermia, frostnip, chilblains, immersion foot and frostbite. Exposure to cold can induce Raynaud's disease, Raynaud's phenomenon and allergic reactions to cold. Other conditions encountered during cold weather operations are acute mountain sickness, psychiatric and psychosocial disorders, snow blindness, and constipation (due to decreased fluid intake).

Thermodynamics [3]

Skin and subcutaneous tissues are maintained at a constant temperature (about 98.6°F) by the circulating blood. Blood gets its heat mainly from the energy given off by cellular metabolism. The optimum temperature for most enzymatic reactions is 98.6°F. In hypothermia, most organs, especially the heart and brain, become sluggish and eventually stop working. The hypothalamus is sensitive to blood temperature changes of as little as 0.5°C and also reacts to nerve impulses received from nerve endings in the skin. Above 105°F many enzymes become denatured while below 98.6°F chemical reactions slow down with various complications which can lead to death.

When body temperature falls on exposure to cold, several protective mechanisms are recruited to generate additional heat. For example, the muscles produce additional heat through shivering. Peripheral vasoconstriction diverts blood flow to organs, such as the heart and brain. Increasing body activity and behavioural responses like putting on more layer of clothing also conserve heat. However, as less warm blood reaches the skin, body parts such as the fingers, toes, ears, and nose cool more rapidly. If body temperature falls much below about 88°F, these protective mechanisms stop working and the body cannot rewarm itself. If body temperature falls below 83°F, death is likely.

As tissue begins to freeze, ice crystals are formed within the cells. Rubbing tissue promotes cell damage from these crystals. As intracellular fluids freeze, extracellular fluid enters the cell and there is an increase in the levels of extracellular salts due to water transfer. Cells may rupture due to endosmosis and/or from tearing by the ice crystals. As the ice melts, there is an influx of salts into the tissue further damaging the cell membranes. Cell destruction results in death and loss of tissue. Tissue cannot freeze if the temperature is above 32°F. It has to be below 28°F because of the salt content in body fluids. Distal areas of the body and areas with a high surface to volume ratio are the most susceptible (e.g. ears, nose, fingers and toes)

Cold injuries usually do not occur, even in extremely cold weather, if the skin, fingers, toes, ears, and nose are well protected or are exposed only briefly. The risk of cold injuries increases when the flow of blood is impeded, when food intake is inadequate, or when insufficient oxygen is available, as occurs at high altitudes.

Hypothermia

Hypothermia is "a decrease in the core body temperature to a level at which normal muscular and cerebral functions are impaired". Any temperature less than 98.6°F can be linked to hypothermia. The core temperature falls due to decreased basal metabolic rate (BMR) and body functions slow down.

Etiology

- Acute exposure to cold wind at high altitude e.g. shelterless situation during blizzard

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- Immersion in cold water after ship wreck
- Less acute, prolonged exposure to cold e.g. in a cold bunker

Aggravating factors

- Improper clothing and equipment
- Wetness
- Fatigue, exhaustion
- Dehydration and poor food intake
- Lack of knowledge of hypothermia
- Alcohol intake - causes vasodilation leading to increased heat loss

Clinical features

Watch for the "-umbles" - stumbles, mumbles, fumbles, and grumbles which show changes in motor coordination and levels of consciousness.

Mild hypothermia - core temperature 98.6°-96°F

- Shivering - not under voluntary control
- Can't do complex motor functions (ice climbing or skiing), can still walk & talk
- Vasoconstriction of peripheral vessels manifesting as pallor

Moderate hypothermia-core temperature 95°-93°F

- Dazed consciousness and/or irrational behaviour e.g. paradoxical undressing - person starts to take off clothing, unaware he is cold
- Loss of fine motor coordination - particularly in hands - e.g. can't zip up parka,due to restricted peripheral blood flow
- Slurred speech
- Violent shivering
- "I don't care attitude" - flattened effect

Severe hypothermia - core temperature 92°-86°F and below (immediately life threatening)

- Violent shivering occurs in waves, the pauses getting longer until shivering finally ceases - as the heat output from glycogenolysis in the muscles is not sufficient to counteract the continuously dropping core temperature, the body shuts down on shivering to conserve glucose
- Person falls to the ground, can't walk, curls up into a fetal position to conserve heat
- Muscle rigidity develops - because peripheral blood flow is reduced and due to lactic acid and CO_2 buildup in the muscles
- Skin is pale
- Pupils dilate
- Bradycardia
- At 90°F the body tries to move into hibernation, shutting down all peripheral blood flow and reducing breathing rate and heart rate
- At 86° F the body is in a state of "metabolic icebox". The person looks dead but is still alive

At lower temperatures/prolonged exposure, breathing becomes erratic and very shallow. The patient may be semi-conscious. Cardiac arrhythmias develop; any sudden shock may set off ventricular fibrillation.

Treating hypothermia [4]

The basic principles of rewarming a hypothermic victim are to conserve the heat they have and replace the body fuel they are burning up to generate that heat. If a person is shivering, he has the ability to rewarm himself at a rate of 2°C per hour.

Mild-moderate hypothermia

Reduce heat loss with additional layers of dry clothing. Increase physical activity slowly in a sheltered environment.

Add fuel & fluids : It is essential to keep a hypothermic person adequately hydrated and fuelled. Carbohydrates (5 cal/g) are quickly released into blood stream for sudden brief heat surge and are best for quick energy intake especially for mild cases of hypothermia. Proteins (5 cal/g) are slowly released and heat given off over a longer period. Fats (9 cal/g) also release heat slowly, however, it takes more energy to break fats down into glucose - also takes more water to break down fats leading to increased fluid loss. The intake of hot liquids provides calories plus heat source. Sugars and sweet warm drinks are helpful. Chocolates provide both carbohydrates and proteins/fats. However, alcohol is a vasodilator and increases peripheral heat loss. Similarly caffeine increases dehydration due to its diuretic action. Tobacco/nicotine is a vasoconstrictor and can aggravate the injury.

Add heat from fire or other external heat source. Body to body contact is helpful in mild cases of hypothermia. Put the patient in a sleeping bag, in dry clothing with a normothermic person in lightweight dry clothing.

Severe Hypothermia

Reduce heat loss: The idea is to provide a shell of total insulation for the patient. No matter how cold, patients can still internally rewarm themselves much more efficiently than any external rewarming. Make sure the patient is dry, and has a polypropylene layer to minimize sweating on the skin. The person must be protected from any moisture in the environment. Use multiple sleeping bags, wool blankets, wool clothing to

create a minimum of 4" of insulation all the way around the patient, especially between the patient and the ground. Wrap the entire ensemble in plastic to protect from wind and water. (Fig. 1). If someone is truly hypothermic, don't put him naked in a sleeping bag with another person.

Add fuel & fluids : Severe hypothermia causes gastroparesis but the stomach can absorb water and sugars. Give a dilute mixture of warm water with sugar every 15 minutes. Immediate treatment of frostbite using rapid rewarming in tea decoction followed by combined therapy of pentoxifylline, aspirin & vitamin C has been recommended [5].

Urination : Vasoconstriction creates relative intravascular hypervolaemia which leads to diuresis. A full bladder results in body heat being used to keep urine warm rather than vital organs. Urination conserves precious body heat for maintaining the temperature of vital organs.

Add Heat: Heat can be applied to transfer heat to major arteries- at the neck for the carotid, at the axillae for the brachial, at the groin for the femoral, at the palms for the arterial arch. Rewarm slowly (thawing) using hot water bottles, warm rocks, towels, compresses [6]. For a severely hypothermic person, ventilation can increase oxygen and provide internal heat.

Afterdrop : is a situation in which the core temperature actually decreases during rewarming. This is caused by peripheral vessels in the arms and legs dilating if they are rewarmed. This sends very cold, stagnated blood from the periphery to the core further decreasing core temperature which can lead to death. In addition, this blood is also very acidic which may lead to cardiac arrhythmias and death. Afterdrop can best be avoided by not rewarming the periphery. Rewarm the core only! Do not expose a severely hypothermic victim to extremes of heat.

Cardiopulmonary resuscitation(CPR) & Hypothermia

Patients in severe hypothermia may demonstrate all the accepted clinical signs of death like cold blue skin, fixed and dilated pupils, no discernible pulse or respiration, muscle rigidity, coma & unresponsive to any stimuli.

But they may still be alive in a "metabolic icebox" and can be revived. The old adage 'a hypothermic patient is never cold and dead, only warm and dead' still holds true. During severe hypothermia the heart is hyperexcitable and mechanical stimulation (such as CPR, moving them or afterdrop) may result in fibrillation leading to death. As a result, CPR may be contraindicated for some hypothermia situations:

- Check the carotid pulsations and respiration carefully to detect low heart rate (2-3/minute) and respiration (1/30 seconds). Even though the heart is beating very slowly, it is filling completely and distributing blood fairly effectively. Thus, with its severely decreased demands, the body may be able to satisfy its circulatory needs with only 2-3 beats per minute. Instituting CPR at this point may lead to life-threatening arrhythmias. Ensure that the pulse is absent before beginning CPR and continue it during rewarming.
- The oxygen demand for the body is so diminished with hypothermia that the body may be able to survive for some time using only the oxygen that is already in the body. If ventilation has stopped, artificial ventilation may be started to increase available oxygen. Additionally, blowing warm air into the person's lungs may assist in internal rewarming.

Frostnip

Frostnip is the freezing of top layers of skin tissue. It is generally reversible and manifests with numbness, white, waxy skin-top layer feels hard, rubbery but deeper tissue is still soft. It occurs typically on cheek, earlobes, fingers and toes. Frostnip is managed by gentle rewarming e.g. by blowing warm air on it or placing the area against a warm body part (partner's stomach or armpit). Avoid rubbing as this can damage the tissue by having ice crystals tear the cells.

Rewarm by immersing the affected part into a water bath of 105°-110°F for 25-40 minutes. This is the temperature which feels warm to the skin. Monitor the temperature carefully with a thermometer as higher temperatures are damaging. Remove constricting clothing. Place the appendage in the water and maintain the water temperature by adding additional warm water. Do not add this warm water directly to the injury. Thawing is complete when the part is pliable and colour and sensation has returned. Once the area is rewarmed, there can be significant pain. Discontinue the warm water bath when thawing is complete. Do not use dry heat to rewarm. It cannot be effectively maintained at 105°-110°F and can cause burns, further damaging the tissues.

Once rewarmed, the injured area should be wrapped in sterile gauze and protected from movement and further cold. Emolients may be applied [7]. Refreezing causes extensive tissue damage and may result in tissue loss. If the Medical Officer cannot ensure that the tissue will stay warm, do not rewarm. Free oxygen radicals have been postulated to be an important mediator of injury in frostbite[8]. Once the tissue is frozen major harm has been done. Keeping it frozen will not cause significant

additional damage.

Frostbite

Frostbite is more severe and includes all layers of skin. The skin appears white and has a "wooden" feel all the way through with numbness and possibly anaesthesia. Deep frostbite can include freezing of muscle and/or bone, it is very difficult to rewarm the appendage without some damage occurring.

- First degree frostbite is similar to mild chilblain with hyperemia, mild itching, and edema. No blistering or peeling of skin occurs. (Fig. 2).
- Second degree frostbite is characterized by blistering and desquamation. (Fig. 3).
- Third degree frostbite is associated with necrosis of skin and subcutaneous tissue with ulceration. (Fig. 4).
- Fourth degree frostbite includes destruction of connective tissues and bone, with gangrene (Fig. 5). Secondary infections and nonfreezing injuries are not uncommon, particularly if there is a history of a freeze-thaw-refreeze cycle with the tissue.

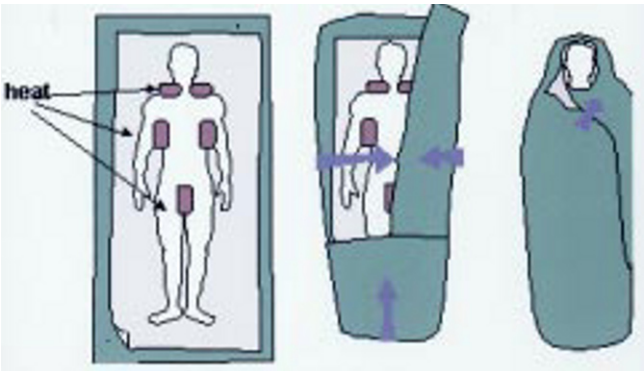

Fig. 1 : Hypothermia wrap

Fig. 2 : First degree frostbite

Fig. 3 : Second degree frostbite

Fig. 4 : Third degree frostbite

Fig. 5 : Fourth degree frostbite

Treatment of frostbite

Treatment of frostbite begins in the field with first aid or buddy aid. Protect the individual from further harm, keep warm, remove any restricting clothing, and begin rewarming. If the lower extremity is involved, the patient must be evacuated as soon as feasible. If he cannot be transported immediately, wait until evacuation to begin rewarming the injured area. The freeze-thaw-refreeze cycle causes more damage than waiting for definitive treatment.

Regimental Aid Post(RAP)

At the RAP, rewarm the injured area in a carefully controlled water bath at 104°F (not to exceed 108°F). Rewarming may be quite painful and requires analgesics and sedatives. Hydration must be maintained with intravenous fluids if required [9]. Once thawing is complete the injured part must be kept clean and dry and protected from further trauma. All patients with cold injuries of the lower extremity are best evacuated. A tetanus toxoid booster should be given. Prophylactic antibiotics are not indicated. Patients with more than first degree frostbite should be evacuated as soon as possible to a definitive treatment facility, since the extent of injury may not be readily apparent and convalescence is usually prolonged.

Active debridement or minor surgery

Active debridement or minor surgery on frostbitten tissue should never be done in the field [10].It may take days to weeks for the demarcation line between viable and nonviable tissue to form. Bone scans have been used for early appreciation of bone involvement but are usually not available in our setting [11,12]. Similarly, hyperbaric oxygen therapy is capable of improving nutritive skin blood flow in frostbitten areas more than 2 weeks after the injury [13].

Signs noted in early rewarming that affect prognosis

- Good prognostic signs: Large, clear blebs developing early and extending to the tips of the digits; rapid return of sensation; return to normal temperature in the injured area; rapid capillary filling time after pressure blanching; pink or mildly erythematous skin colour that blanches.
- Poor prognostic signs: Hard, white, cold, and insensitive tissue; cold and cyanotic tissue without blebs or blisters; complete absence of edema; dark hemorrhagic blebs, early mummification; constitutional signs of tissue necrosis: fever, tachycardia, and prostration; superimposed trauma; cyanotic or dark red skin that does not blanch on pressure.

Chilblains

Chilblains (erythema pernio) is a superficial tissue injury that occurs after prolonged or intermittent exposure to temperatures above freezing and high humidity with high winds. Initial pallor characterizes chilblains followed by erythema and pruritus of the affected area. Women and young children are the most susceptible and chilblains commonly involve cheek and ears, fingers and toes. The cold exposure causes damage to peripheral capillary beds, this damage is permanent and the redness and itching will return with re-exposure to cold. The condition is uncomfortable but not serious. Preventing exposure to cold is the best treatment. The drug nifedipine, taken by mouth, sometimes relieves symptoms.

Trench foot-immersion foot

Trench foot is a process similar to chilblains. It is caused by prolonged immersion of the feet in cool, wet conditions. This can occur at temperatures as high as 60°F if the feet are constantly wet e.g. sea sports.

Since wet feet lose heat 25 times faster than dry, the body uses vasoconstriction to shut down peripheral circulation in the foot to prevent heat loss. Skin tissue begins to die because of lack of oxygen and nutrients and due to buildup of toxic products. The skin is initially reddened with numbness, tingling pain, and itching, then becomes pale and mottled and finally dark purple, grey or blue. The affected tissue generally dies and sloughs off. In severe cases trench foot can involve the toes, heels, or the entire foot. If circulation is impaired for over 6 hours there will be permanent damage to tissue. If circulation is impaired for over 24 hours the victim may lose the entire foot. Trench foot causes permanent damage to the circulatory system making the person more prone to cold related injuries in that area. A similar phenomenon can occur when hands are kept wet for long periods of time. The damage to the circulatory system manifests as Raynaud's phenomenon.

Treatment and prevention of Trench foot

Treatment consists of gentle drying, elevation, and exposure of the extremity in an environmental temperature of 64°-72°F, while keeping the rest of the body warm. Since the tissue is not frozen as in severe frostbite, it is more susceptible to damage by walking on it. Bed rest, cleanliness, and pain relief with NSAIDs are essential. The prognosis depends upon the extent of the original tissue and nerve damage. Minimal and mild cases can resolve in hours to days or weeks and most eventually return to full duty. However, moderate to severe cases can take months to heal and most of these patients do not return to full duty. Expect to MEDEVAC these patients to the rear for convalescence.

Prevention is the best approach in dealing with trench foot. Keep feet dry by wearing appropriate footwear. Check feet regularly to see if they are wet. If feet get wet (through sweating or immersion), stop and dry the feet and wear dry socks. This applies especially to people who sweat more than usual. Change socks at least once a day and avoid sleeping with wet socks. Tight socks can further impair peripheral circulation. Periodic air drying, elevation, and massage will also help.

Foot powder with aluminium hydroxide can help. High altitude mountaineers put antiperspirant on their feet for a week before the trip. The active ingredient, aluminium hydroxide will keep the feet from sweating for up to a month and there are no confirmed contraindications for using antiperspirant. [Some studies have shown links between aluminium in the body and Alzheimer's].

Eye Injuries

Freezing of cornea: Caused by forcing the eyes open during strong winds without goggles. Treatment is very controlled, rapid rewarming e.g. placing a warm hand or compress over the closed eye. After rewarming the eyes must be completely covered with patches for 24-48 hours.

Eyelashes freezing together: Put hand over eye until ice melts, then open the eye.

Snowblindness (sunburn of the eyes): Prevention by wearing good sunglasses with side shields or goggles. Eye protection from sun is just as necessary on cloudy or overcast days as it is in full sunlight when on snow. Snow blindness can occur during a snow storm if the cloud is thin. The eyes feel dry, irritated and gritty and moving or blinking becomes extremely painful. Photophobia occurs, eyelids may swell, with erythema and epiphora. Treatment involves cold compresses and dark environment while avoiding rubbing the eyes.

Basic principles for the prevention of cold injury

Keeping warm in a cold environment requires several layers of clothing-preferably wool or synthetics such as polypropylene, because these materials insulate even when wet. Since the body loses a large amount of heat from the head, warm headgear is essential. Adequate food and fluid intake provides fuel to be burned, and warm fluids directly provide heat and prevent dehydration. Alcoholic beverages should be avoided, because alcohol causes cutaneous vasodilatation, which makes the body temporarily feel warm but actually causes greater heat loss. Similarly nicotine in cigarette smoke has a vasoconstrictor action and aggravates cellular hypoxia. An outline for the implementation of these measures at the unit level is given below:

Training

The education of all personnel on how to practise personal prevention measures should include the following subjects:

- proper foot care
- frequent changing of clothing
- the exercise of extremities in pinned-down positions
- proper dress and work in a cold environment
- recognition of symptoms of cold injury
- buddy aid treatment
- maintaining adequate hydration and nutritional status

Proper cold weather clothing

Proper cold weather clothing based on area of operation.

Command support

Command support is very important in enforcing prevention guidelines whenever possible. These areas should include the distribution and enforced wearing of cold weather clothing, proper personal hygiene, especially foot care, proper rotation cycles into sheltered areas, and the distribution of sufficient rations and fluids for cold weather operations, particularly hot liquids.

Early diagnosis and treatment

Emphasis is placed on early diagnosis and treatment of cold injuries by medical personnel.

Acclimatization

Acclimatization to cold weather environment should be performed whenever possible. This usually takes 1-4 weeks.

Avoid accidents

Don't touch cold metal with bare skin or spill gasoline on skin or clothes

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