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Director
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Outdoor sporting activities in winter are becoming more popular. There is a significant threat to individuals being hurt or going out unprepared for the rigors of cold weather environment. The injuries of chilblain, trenchfoot, frostbite and hypothermia are a major threat in a cold environment. Prevention, recognition of the injuries along with treatment and management procedures are outlined.

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WINTER SPORTS MEDICINE

With the great increase in outdoor activities, cold injury poses a rising threat for a large segment of the population in winter sports. Although frostbite remains the single greatest cold injury threat, cold also plays a role in other injuries. Because running has become such a popular sport, covering all ages and both sexes, it may be important to start the discussion on the cold injury threat to runners. Runners, because of the high activity, tend to wear limited amounts of clothing with only wind protection. Cold injury prevention is, in fact, the rational use of clothing. Exposed areas of the body, such as the face, ears, and hands, tend to be the highest risk areas. Protection of these parts is relatively simple; however, the sweat produced in running tends to collect in stocking caps, mittens, and gloves where it can freeze. An even greater threat to runners, however, is being injured in the cold. Runners tend to be reclusive type individuals and their training areas are often isolated and remote. A slip and fall injury in the cold, with the minimal protection usually worn for running, then becomes a high threat situation for that individual. There is often little likelihood of being found in a short time and they are therefore subject to frostbite of the hands and feet.

Although performance times in the cold tend to be slower, there have been few scientific studies on why this occurs. One can theorize that the relatively avascular joints cool rapidly when exposed to cold. As the joint fluid viscosity increases, more force is required to bend those joints, particularly the knee. Some loss in nerve conduction across the joints may also play a role in performance decrements. Mechanical factors such as the loss of traction on frozen ground may also play a role and the increase in shock transmitted up the leg from the loss of resiliancy of the foam rubber in the footwear. It suffices to say that performance is decreased and injuries are more frequent and tend to be a bit more long lasting than similiar injuries in a warm climate.

Sports that increase the windchill factor increase the risk of cold injury to exposed flesh.[3] Skiing, biking, and running increase the airflow over the face and, therefore, increase the likelihood of frostbite. Protection of these exposed areas can take many forms. The use of Topical medications to prevent injury has been widely touted, but there have been no solid research studies to verify their advocacy. There is little doubt that these oils, greases and emollients prevent the drying and chapping of skin in the cold/dry air, but whether or not they protect the skin from frostbite is still open for question. Some of these materials definitely change one's perception of cold, but, then may, in fact, not change the freezing rate of skin. We have recently completed a study utilizing some of these compounds with a pig skin model. While the data is incomplete, it appears that of all the compounds tested only the DMSO changed the freezing rate of skin.

The question of whether or not beards prevent cold injury is frequently asked. Beards and mustaches do not protect against cold injury except for the cheeks and this is usually a relatively minor injury. The main advantage for having a beard in cold weather involves avoiding shaving. Shaving removes oils and superficial epitheliai from the skin and renders it more likely to dry and crack in the cold. Wearing a beard helps the face hydrated, leaves oils on the skin and helps prevent the chaffing caused by clothing, a parka hood, etc. rubbing the face.

Historically, people involved in outdoor winter activities were hearty, thoughtful people who had some knowledge of protecting themselves from the cold.[28] With the increase in popularity of outdoor recreation, there has also been an increase in naivity about the threat of cold weather injuries. People tend not to think about the high risk setting, such as, being injured on a run or being run off the road while on a bicycle with no one finding them for an extended period of time. In the winter, only a few minutes of exposure may result in significant risk for cold injury.

CHILBLAIN

A clear definition of the major cold injuries will help establish the threat pattern for different sporting activities. Chilblain is a localized itching and painful erytherma usually confined to the skin in the individual subjected to working long periods in a cold, damp environment. Although this was a common problem in the past, the social structure in the United States tends to reduce this kind of injury. Chilblain does not usually produce permanent damage although long-term exposure in such an environment can produce necrosis of skin, termed pernio. In most cases, the effect of chilblain is short lived and recovery almost always complete. The swelling, itching and tenderness to exposed flesh often recedes within a few hours or overnight. Chilblains usually occurs in climates that are moderately cold with high humidity. It occurs to the dorsum of the hands, toes and can occur to the anterior surface of the leg. Chilblain tissue appears red, swollen and quite tender and is hot to touch. If vasoconstriction alternating with vasodialation occurs chronically, the tissue becomes tense, purple and blister formation may occur. Initial itching may be followed some days later by pain. In its acute form, it is considered nothing more than an aggrevation, but in the chronic form it can be mildly disabling.

IMMERSION OR TRENCHFOOT

Immersion foot and trenchfoot are physiologically the same injury, that is having cold wet extremities for an extended period of time. Immersion foot usually refers to a shipwrecked type situation where the extremity of the individual is immersed in water while sitting in a liferaft and unable to get dry. Whole body cooling is a significant part of the immersion injury. This is a time/temperature injury. The warmer the temperature the longer the immersion time required to produce the injury. The colder temperatures require shorter durations. Although this injury may be a threat to ocean-going, sailing and perhaps wind surfing, the reporting of this injury in civilian literature is extremely rare. Even military experience in peacetime is rare. Shipwrecked individuals are usually found quickly or lost and the survivors are not exposed long enough to produce this injury. Trenchfoot is quite similar to immersion foot and involves cold wet exposure on land. Being cold and wet along with some immobilization and dependency of limbs, combined with the blunt trauma of walking, produce this injury.

Although some pathology does occur as early as 12 hours of cold wet exposure, The most serious injuries are produced after three days of being cold and wet. This injury goes through prehyperimic, hyperemic, and posthyperemic phases of different durations and severities. There is a difference in tissue susceptibility with skin being quite resistant, and muscle and nerve being extremely susceptible to this cold, wet injury. Diagnosis is by history, by exposure weather conditions and physical appearance of the extremity. Treatment consists of anti-inflammatory medications, elevation of the limb, mild cooling with a fan, and prevention of systemic infections. It should be noted that very little therapeutic value occurs from treatment of this injury. It is generally palative, wait and see, and surgical.

FROSTBITE

Frostbite results from the actual freezing of tissue, that is ice crystal formation within the tissues. There is a much higher likelihood of frostbite injury in sporting events than any other cold injury.

PATHOPHYSIOLOGY

As tissue cools, blood vessels constrict, decreasing blood flow.[16] This constriction may be circumferential in digits but can occur to bare areas of skin such as the face. A combination of cooling and ischemia anesthetizes nerve endings allowing tissue to freeze in a relatively anesthetic way.[22] Many individuals do not perceive themselves getting a frostbite injury and only notice after the fact that their skin is white, hard and insensitive. This injury often progresses painlessly for minutes or hours increasing the amount of frozen tissue and allowing the freezing front to advance proximally up the fingers or toes. Although often anesthetic when produced, rewarming produces extreme pain. An initial rapid hyperemia occurs and within minutes a sudden drop in bloodflow results in ischemia with subsequent cooling of the extremity. The extent and severity of the frostbite injury now defines the amount of tissue that will be lost and the line of demarcation that will form in the next few days. Minor injuries recover with only mild hyperemia, swelling and mininal pain. Deeper injuries involve full skin thickness damage, ischemia, cyanosis, blister formation and eventual mummification of dead tissue. As the injury progresses in severity, the line of demarcation becomes more obvious, occurs quicker, and forms a one or two milimeter line of liquifaction between the viable tissue and the mummifying eschar. This line of demarcation may occur quite early, but may take weeks to clearly differentiate viable from nonviable tissue. Nonintervention in this process is an important part of frostbite therapy.

FROSTBITE TREATMENT

Mild injuries of the face can be warmed with the palm of the hand or the back of a mitten. Although injuries to the face can initially be quite painful on rewarming, major tissue loss is uncommon. If the cartilage of the ear freezes, however, it will mummify and slough. Rubbing is contraindicated as damage to superficial epithelium may result. Injuries to extremities are more severe and pose greater clinical responsibility in management.[24-25-26] Although often initially a painless injury, frostbite to the hands and feet can be extremely painful upon rewarming and poses a significant threat of loss of digits. Rewarming is best accomplished either with body heat or warm water between 105 and 110^{0}F.[1-2] Although rapid rewarming in water produces the greatest pain it also produces the best tissue salvage. Temperatures over 110^0 can produce more injury and because of the initial anesthetic nature of frostbite excessive heat during rewarming can produce devestating results. Physicians will seldom see frozen extremities as some degree of thaw has almost always occured prior to hospitalization. Once rewarming has occured it is ill advised to subsequently place the extremities in a warming bath. Twice daily whirlpooling in water, approximately 95^0 to which Betadine has been added is the treatment of choice. Complete range of motion exercise should be initiated immediately to preclude flexion contractures. If the injury were perceived to be a deep, frostbite injury, the use of interarterial Reserpine[5-29-30-32] appears to give the best long-lasting result. Injection of 1/2 mg interarterially in each affected limb produces immediate vasodilation which may last throughout the entire treatment process. Subsequent injections may be necessary if vasospasm occurs. If the injection is done interarterially, no systemic blood pressure changes or tranquilization occurs. If blisters occur after rewarming, care should be taken not to rupture them during the treatment process. They will slough without any major infection problems some days into the treatment, but should be kept in tact to prevent early infection. Although initial pain may require some analgesia, most patients do not require subsequent pain medication. Pulsitile pain late in treatment is best managed with interarterial Reserpine. Although infections are rare, culture, sensitivity and appropriate antibiotic therapy combined with Reserpine will heal these infections quickly. Surgical intervention should be avoided. Severe injuries should be allowed to demarcate and mummify prior to any surgical intervention. This allows a clear demarcation of viable tissue and provides a good quality granular stump, with fewer retraction problems and fewer phantom limb problems. Little benefit has been shown from other medications although low molecular weight dextran,[8-27] in severe injury, prevents sludging and improves blood distal flow. Heparin and aspirin have not been shown to produce major improvement in tissue salvage.

POST INJURY SEQUELAE

As the severity of injury increases, post injury sequelae also increase. Cold sensitivity along with peripheral constriction is the most common complaint after frostbite. This may be severe enough to limit outdoor activity and may produce Raynauds, tingling, paresthiasas and hyperhydrosis. Management of these complaints is difficult. Pavlovian conditioning to releive the peripheral constriction has proven to be effective, and in the future,selective peripheral seratonin blockade may be available. Other medical approaches have not been effective and provide only short-term relief of symptomatology. Biofeedback techniques although initially effective, extinguish quickly and do not stand up to significant cold challenge.

UNUSUAL INJURIES

Although penile frostbite has been reported, it is usually easily prevented. It has been reported in runners and cross country skiers with thin racing suits. It is easily prevented by adding layers of insulation in the groin area. It is usually not a severe injury but even superficial injuries can be quite painful. Freezing of the lips, tongue or hands to bare cold metal usually occurs in children but can occur in adults handling supercooled metal objects. The initial pain usually results in stripping of superficial epithelium. If it occurs to the tongue or lips it can be quite painful but usually is not a deep injury. The drinking of supercooled and high alcohol content beverages can result in freezing of the lips, tongue and esophagus. Although rare, it can be a fatal injury. Corneal frostbite injuries are reported in cross country skiers and snow mobilers. The use of goggles will prevent such an injury. These injuries may require corneal transplant and no known treatment other than warming and patching has proven to be effective. Use of carticosteroids is contraindicated in this injury.

HYPOTHERMIA

Hypothermia is whole body cooling, a depressed core temperature. In a sports setting, this occurs usually from an accident or injury which renders the individual incapable of getting back to a warm environment. Exercise hypothermia can occur in marathon runners or skiers shortly after the race where the individual is hypoglycemic, hypovolemic and peripherally dialated for a maximum heat disipation. More commonly, hypothermia occurs in recreational hiking in the mountains where a combination of events, weather changes and physical capabilities place individuals in a high threat setting. Poorly equipped, inexperienced individuals going for a pleasant walk in the hills are often confronted with sudden weather changes. Rain, wind and overexertion combine to get them in trouble. Hypothermia can occur from plunges in water, kayaking, sailing, wind surfing, or from falling through the ice while snow mobiling or ice fishing.[7,18,19] Wet clothing is devestating to the conservation of heat. Individuals should prepare for the worst weather contingency, be trained in rational use of clothing, be alert for changes in weather, and be aware that accidents in remote areas can lead to serious hypothermia experiences. Leaders should be aware that dehydration plays a major role in hypothermia. Individuals should be encouraged to drink in the absence of thirst to prevent peripheral and central dehydration. Peripheral dehydration is a compensatory process that occurs from mild dehydration combined with peripheral vasoconstriction from cold exposure. Cold induced vasodilation is blunted resulting in long-term iscemia of the extremities.

MANAGEMENT OF HYPOTHERMIA

Field management: The most important single factor in the treatment of hypothermia is to recognize that individuals, even comatose, asystolic individuals, may be resusitated successfully.[11] Treatment is different for conscious and unconscious individuals. The conscious hypothermics should have their wet clothing removed and should be insulated with added garments, sleeping bags, blankets, or whatever is available. They should be encouraged to drink warm, sweet liquids in large volumes to improve circulating volume and to provide an energy source for exercise. Once hydrated and insulated they should be encouraged to exercise to increase muscle activity and heat production. If possible, they should be put in a warm building or provided a warm shower. Although hypothermic individuals may appear as drunks, i.e., stumbling or uncontrolled shivering, these individuals generally respond to peripheral rewarming procedures without harm. Comatose hypothermics in a field setting offer a much greater challenge. These individuals should be handled carefully, insulated and transported as quickly as possible to definitive medical facilities. Positive pressure respiration is advisable during evacuation, but CPR remains controversial. Verification of ventricular fibrilation is extremly difficult in a field setting and chest compression almost surely produces asytole. CPR also compromises the rescue effort signficantly. Field rewarming procedures are generally not effective and also lengthen the time required to get to definitive medical care. Heated humidified oxygen, if available, can be used but provides little heat input and should not be perceived to be a major rewarming technique. Intravenous fluids are life saving but extremely difficult to start in a field setting.

HYPOTHERMIC HOSPITAL MANAGEMENT

General Principles:

The general treatment of hypothermia is a five step process.[33] It can be summarized as follows: rapid core rewarming, prevention of arrhythmias, replacement of circulating volume with I.V. fluids, respiratory support and pH and electrolyte management. Although mild hypothermics can be managed rather simply with warming blankets and bedrest, severe hypothermics require significant intervention to bring them back to normothermia. The review of the physiology of cooling can be found elsewhere.[9] Specifics of clinical management will be covered here.[13,14,15,23]

REWARMING:

Patients with a core temperature above 32^{o} C and conscious can be managed with external methods of rewarming only. They are usually lucid, able to describe their experience, and able to carry on a reasonable conversation. Warm blankets are usually sufficient to return them to normal core temperature. Patients below 32^{o} are either conscious or unconscious. Those below 32^{o} that are conscious generally are significantly incoordinate, incoherent, and unable to recite simple phrases. They require a little more aggressive rewarming and heated, humidified oxygen or water torso immersion is advisable. Patients below 32^{o} who are unconscious require specific rewarming techniques. Patients who are unconscious between 26 and 32^{o} should be considered for internal methods of rewarming.[6,12,20,21] A description of the advantages and disadvantages will follow, however, peritoneal dialysis[10,17,31] and torso immersion are generally most acceptable. Patients below 25^{o} should generally be considered for femoral-femoral bypass rewarming. Although many patients have been rewarmed with other techniques, bypass appears to give the greatest chance of survival. The coldest successful resuscitation appears to be near 15^{o}C. Emergency room staff should be trained to recognize hypothermic patients and to know the options for rewarming.

REWARMING TECHNIQUES

Warm blankets are sufficient for conscious individuals, but provide very little total heating input and only prevent further heat loss. Heated humidified oxygen produces small total heat input and should not be considered a major rewarming technique. Dry land hypothermics who are volume depleted because of long term cold diuresis and long term cooling can generally manage the precipitation of water in the lungs from heat transfer with this process. Normovolemic hypothermics however, such as scuba divers, will not tolerate airway rewarming techniques. Rewarming rates are slow with this procedure and it should be considered an adjunct to other rewarming methods. Hypothermia rewarming blankets which contain circulating fluid are often available now in hospital surgical suites. These blankets are convenient and do provide a significant amount of heat input in a controlled setting. The patient's torso should be wrapped with these blankets, but the limbs should be left out in the room air. Warm water immersion has been used extensively for rewarming hypothermics and provides a significant heat input but does pose some specific problems. Total body immersion produces peripheral vasodilation in the limbs. During the hypothermic experience, large volumes of blood are sequestered in the limbs which become colder than the core and also become severely acidotic from shivering. Third space fluid contains a significant amount of potassium from the loss of the sodium pump in the muscle cells. Immersing these limbs causes peripheral vasodilation with return of this colder blood to the core along with hyperkalemic, acidotic blood. The sudden loss of pressure, acidosis and hyperkalemia produce major cardiac arrhythmias and may cause cardiac standstill or fibrillation. For that reason, it is wise to immerse only the torso. The arms, legs and the head are kept out of the rewarming bath. Warm peritoneal dialysis is growing in acceptance and provides a significant heat input to the core because of the large surface area for heat exchange. It can be done easily and readily in an emergency room. The technique also provides some control over pH and electrolytes and may remove drugs and alcohol from the hypothermic individual. Extracorporeal circulation utilizing cardiac bypass specifically, femoral-femoral bypass, has been used on extremely cold patients but requires surgical intervention and support from the hospital staff elsewhere. It provides a method of rapid return of heat and circulation to the severely hypothermic patient. One major drawback involves trying to raise the central venous pressure to rapidly. Endothelial cells below 30^{0}C are unable to hold fluid in the vascular space. Attempting to raise the CVP early will cause extensive leakage into third space with devestating results. Circulation should be maintained at low venous pressures above 30^{0}C. Clear indications of the ability of the vascular system to hold fluid should be seen before slowly raising central venous pressure.

CARDIAC ARRHYTHMIAS

The major cause of problems in rewarming hypothermics is cardiac arrythmias standstill, or ventricular fibrillation. Dramatic cardiac rhythm disturbance may be present but it should be recognized that many of these arrhythmias are physiologically normal for that patient at that temperature. It should also be recognized that cardiac arrhythmias do not respond well to chemical intervention. Most, however, will disappear during rewarming. We must also remember that the fibrillatory threshold is decreased and that it may be triggered by manipulating the patient causing peripheral stimuli and that fibrillation will not be treated until some degree of rewarming has occurred. Dose-response curves for the standard antiarrhthmic drugs have not been done for hypothermics, and if given to subjects while cold, will provide toxic effects on rewarming. There are a variety of things causing the arrhythmias including pH, O2 concentration, the direct effect of cold, and volume depletion, so attempts at cardioversion are not usually successfully in the fibrillating heart below 30°C. Cardiac arrest below 30°C requires continuous half rate CPR, some method of core rewarming and management of the physiological needs. Once above 30°C cardioversion can be attempted, but one should not give up too soon. The arrhythmic drugs have not been effective although Bretylium[4] at slightly larger than normothermic dosage appears to be effective in hypothermia. It should be again noted that CPR with the hypothermic heart can produce ventricular fibrillation or standstill. EKG proof of asystole or fibrillation must be obtained before CPR is initiated. Also, when rewarming starts, some cardiovascular support must be attempted.

I.V. FLUID REPLACEMENT

Intravenous fluids in the hyperthermic are lifesaving. Decreasing blood viscosity increases cardiac output, prevents sludging and improves general circulation. Fluids should be potassium and lactate free. Crystaloid solutions with glucose are probably the safest and easiest tc use. Dilution alone decreases the concentration of potassium, changes the pH and improves peripheral bloodflow. Rapid correction of pH should be avoided and the patient should be kept mildly acidotic throughout the entire rewarming process. Two ampules of bicarbonate may be necessary early, but the use of continuous bicarb should be avoided. Extremely elevated serum potassiums can be managed with glucose and insulin but the use of insulin should be carefully monitored. Rapid shifts in blood glucose may occur during rewarming and should be monitored carefully to coincide with insulin use. Early hyperkalemia can be managed with insulin but late in rewarming pancreatic rebound production of insulin may drive potassium dangerously low. Electrolyte figures, particularly potassium, should be reported as real numbers not greater than numbers. Potassiums in the 30 milliequivalent range have been recorded with subsequent successful resuscitation.

RESPIRATORY SUPPORT

In general, some initial small volume positive pressure respiration is indicated in the comatose hypothermic, however, the volume should be kept small to prevent overstimulation of the heart. Many hyothermics will start exasperating respiration if initiated by small volume respiratory support. Respiration will improve during rewarming and will have a major impact on pH management throughout the process. Some oxygen is indicated early but overzealous respiratory support is generally not necessary. The correction of PO2 and PCO2 for temperature is probably not necessary in decision making for resuscitation. Early oxygen support is necessary to lower the fibrillatory threshold--50% is the wisest choice. Acute pulmonary edema may require the utilization of positive end expiratory pressure, but should not be considered in a normal resuscitation. Intubation may be necessary and bronchorrhea may require significant airway management to prevent obstruction. Hyperventilation should be avoided to prevent respiratory alkalosis and ventricular fibrillation.

AFTERCARE

The most common problem following a hypothermic experience is pneumonia. Good cleansing respiratory therapy is advised with sequential chest x-rays. Although the pancreas is the only organ to show lesions in hypothermia, internally rewarmed patients do not develop pancreatitus. Pulmonary edema, acute tubulanecrosis, disseminated intravascular coagulation and gastric ulcers have been reported. Patients have trouble controlling blood pressure and temperature regulation after their hypothermic experience, but these parameters will return to normal over a period of weeks.

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