Cold Injury

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KEYWORDS

• Frostbite • Cold injury • Intra-arterial thrombolytic therapy • Amputation • Angiogram

HISTORICAL IMPACT OF COLD

Man is a warm-blooded organism best suited to a tropical environment with temperatures around 81°F (27°C).[1] Our sense of adventure and entitlement has led us to live in climates not ideally suited to our existence. Although we have some ability to adapt to colder climes, most of our survival is due to behavioral changes in response to the weather conditions. When we impair our ability to prepare adequately for freezing temperatures, we place ourselves at risk for cold injuries.

Throughout history man has paid a price for living in cold climates. The oldest documented case of frostbite was recognized in a mummy found in the Chilean mountains, and dates back 5000 years.[2] Hippocrates recognized that tissues with frostbite blistered after warming,[3] Celsus provided the first description of tissue necrosis with frostbite,[4] and Baron Dominique Larrey, Napoleon's military surgeon, gave the first description of the devastation of freeze-thaw-freeze injury in French troops retreating from Moscow.[5] Subsequent study has clarified the physiology and laid the groundwork for our current treatment of frostbite.

It is clear that military and world history has been changed several times by cold weather. Xenophon lost half of his 10,000-man Spartan army in the Carduchian Mountains of Armenia in 400 BC.[6,7] The armies of Charles XII of Sweden, the Napoleon, and Hitler all fell victim to the Russian winter.[8–10] The German army sustained 250,000 cases of frostbite in the attack on Moscow and resulted in 20,000 amputations in the winter of 1941 to 1942.[6,7] Combined troops lost to cold injuries in World War I were more than 280,000.[7] Although military personnel still risk cold injury in harsh weather conditions, frostbite today is a disease predominantly of civilian populations, particularly among the indigent, intoxicated, and the mentally ill.

EPIDEMIOLOGY/PREDISPOSITION

Many factors increase the risk of cold injury. The majority of civilian frostbite injuries are associated with mental impairment related to mental illness (10%–100%),[11,12] alcohol consumption (35%–53%),[11,13–15] or drug use (4%).[14,16] Alcohol and sedative drugs decrease the awareness of cold and impair the judgment necessary to seek shelter.[17] Alcohol also inhibits shivering and causes cutaneous vasodilatation,[18] precipitating frostbite at warmer temperatures (−8°F [−22°C] vs −20°F [−30°C]).[15] Many schizophrenic patients exhibit acrocyanosis,[19] and their ability to assess tissue cooling or comprehend cold injury is often impaired. Any behavior that prolongs the cold exposure will worsen the prognosis.[20] There are several known risk factors associated with the development of frostbite (**Box 1**). Identification of the causative factors is important for prevention of recurrent cold injuries. A growing participation in winter sports and outdoor activities,[9,21,22]

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Box 1
Risk factors for frostbite

- The intoxicated (alcohol, other drugs)
- The incompetent (mental illness or dementia)
- The infirm (elderly, especially with falls)
- The insensate (diabetes, neuropathy, paraplegia)
- The inexperienced (new to cold climates)
- The inducted (wartime increases risk)
- The indigent (homeless)

combined with persons who become stranded while traveling, now account for up to one-third of cold injuries.[11,14] The extremities are the most susceptible sites; hands and feet account for 90% of reported injuries.[20] Preparation for emergencies is the key for survival and to avoid injuries. In Minnesota, local media remind residents yearly to prepare a car emergency kit as winter approaches.

Although under identical conditions, infants and the elderly are more susceptible to local cold injuries,[23] they are not prone to the behaviors that promote cold exposure. Adult men, aged 30 to 49 years, are the most commonly affected.[14,24] Because muscle and fat have insulation properties, body mass may be more important than age or body surface area.[25] Malnutrition and exertion decrease the fuel available for heat generation.[25] Many medical problems may contribute to the extent of the cold injuries, but are rarely the sole cause in our experience.

The authors have reviewed the predisposing factors in 133 patients with severe frostbite admitted to the regional burn center over a 17-year period. Approximately 80% were men and their mean age was 40 years. The authors found 50% of these patients had documented alcoholism or an elevated blood alcohol level, 24% were positive for drugs of abuse, 59% were smokers, 29% had major mental health diagnoses, and 20% were homeless. Almost 30% had greater than a 24-hour delay to definitive treatment, either due to poor decisions following the injury or because of weather related issues. Hands were frequently affected (48%), with 26% of patients having only hand frostbite.[26]

In the absence of wind, skin can freeze at 28°F (−2°C). Freeze injury to exposed skin occurs in 1 hour with a temperature of 0°F (−18°C) and a 10 mph wind, but in 30 minutes with a 20 mph wind. The wind speed accelerates the heat loss by convection, defined as the wind chill temperature.[27] As the wind chill reaches approximately −40°F (−40°C), tissue freezing occurs in minutes. Although tissue freezes more quickly at lower temperatures, the degree of irreversible damage is related to the length of time the tissue remains frozen, not the final temperature of the injured tissue.[27]

SPECTRUM OF INJURY

Frostbite is the most common local cold injury, although not all cold exposure results in tissue freezing.[28] There is a continuum that ranges from minimal skin chilling to frank tissue crystallization from exposure to subfreezing temperatures.[29,30] There are two key factors that categorize these injuries, the rate of cooling and the ultimate presence or absence of ice crystals in the tissues (**Box 1**). A patient may have a combination of these injuries in different body parts following a cold exposure.

Frostnip represents a mild cold injury and is completely reversible. This injury is characterized by skin pallor and numbness,[9,31] and the rapid temperature drop causes local pain.[29] It is seen typically on the face and hands. There is no ice crystal formation and no tissue damage. The warmed tissue becomes hyperemic without blistering, and decreased sensation or tingling may persist for weeks.[29,31]

Chilblain (pernio) results from repeated exposure to near freezing temperatures and is a more severe form of cold injury, but has no ice crystal formation.[29,31] A chronic vasculitis develops and is usually located on the face, anterior lower leg, the hands, and feet.[29,31] The skin has a violaceous color with plaques or nodules, and patients exhibit pain and pruritus with cold exposure.[29] The calcium channel blocker nifedipine significantly reduces the pain and time to healing of this condition, although many cases are self-limited.[29,32]

Frostbite occurs when tissues freeze slowly and form ice crystals. The temperatures necessary to produce this injury are typically less than 28°F (−2°C). The injuries are circumferential, progress distal to proximal, and are potentially reversible.

Flash freeze injury causes extremely rapid cooling and formation of intracellular ice crystals. The mechanism is contact with cold metals or volatile liquids. These injuries have a rapid onset, occur along a body surface plane and are almost never circumferential.

PATHOPHYSIOLOGY

The body's thermostat for temperature regulation is the hypothalamus with sensors located in the skin and core.[33] This system allows us to maintain