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Case Review

A 63-Year-Old Man With Frostbite

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A 63-year-old man with a long history of psychiatric illness, alcohol abuse, chronic obstructive pulmonary disease, and homelessness was found midwinter lying in a snow bank unresponsive at approximately 0530 in the morning. The ambient temperature that night was −8°F. Video cameras recorded the patient in a nearby garage staggering around the local area for several hours. Emergency medical services was called, and he was brought to a local emergency department where his core temperature was recorded to be 26°C. During the initial phase of resuscitation, he received warmed intravenous (IV) fluids and rewarming with a Bair Hugger Rewarming System (3M, St Paul MN). His initial vital signs were significant for bradycardia with a heart rate in the 40s and 50s with concurrent hypotension with systolic blood pressures in the 70s and 80s. There was concern about the actual mechanism of injury, and computed tomographic scans of his head and cervical spine were completed. There were no significant findings. A laboratory evaluation was also completed, and his alcohol level was 110 mg/dL.

He was subsequently brought to the intensive care unit (ICU) with continued rewarming with warmed IV fluids and the use of the Arctic Sun Temperature Management System (Medivance Inc, Louisville, CO). Because of his variable mental status, which was significant for periods of agitation intermixed with somnolence, he was electively intubated without complication. His initial arterial blood gas showed a pH of 7.13, a P_{CO_2} of 42, a P_{aO_2} of 110, and a lactate level of 7.2. He remained hemodynamically unstable despite adequate fluid resuscitation. A quadruple-lumen central line was placed, and norepinephrine infusion was initiated.

During the next several hours, the intensivist noted that all his fingertips blackened. In addition, he had skin and soft tissue changes concerning for severe frostbite on his upper and lower extremities. Black eschars began to form on other exposed regions including his buttocks, elbows, and toes. The local trauma service attending estimated that the total amount of body surface involved was 6% to 10%. He then arranged for transfer to the nearest burn center for ongoing care. Before transfer, the patient received IV antibiotics including vancomycin and piperacillin/tazobactam for concern of soft tissue cellulitis and sepsis.

The local flight service was called to perform an interfacility transfer. When the team arrived on scene, the elderly male was lying on the stretcher in the ICU. He was intubated and sedated on standard midazolam and fentanyl infusions. He was on volume control with a respiratory rate of 22, a tidal volume of 500 mL, and a positive end-expiratory pressure of 5 mm H_2O. His initial vital signs were significant for a pulse of 83 and blood pressure of 92/65 on 8 μg/min norepinephrine. He had received a total of 4 L warmed IV fluid. During the flight to the burn center, his vital signs remained essentially unchanged with systolic blood pressures ranging from 63 to 85 mm Hg despite escalating doses of the vasopressor.

Once he arrived at the receiving institution, his resuscitation and rewarming process continued. At that point, the receiving staff identified his ongoing need for stabilization. His core temperature had improved significantly, but he was still suffering from the vasodilatory effects with the correction of his core temperature. Once his core temperature was normalized, it was identified that the patient was additionally suffering from mixed full and superficial thickness frostbite to his bilateral upper and lower extremities. The interventional radiology staff was consulted for bilateral upper extremity catheter-directed arterial lysis. The patient underwent bilateral catheter-directed tissue plasminogen activator (tPA) lysis to his hands within 24 hours of injury and rewarmed. Both hands were dressed with bulky Xeroform and gauze dressings, Covidien, Dublin Ireland. He was initially anticoagulated with a heparin drip and then subsequently transitioned to enoxaparin twice daily. The tPA infusion was continued, and he underwent an angiogram 24 hours later that unfortunately revealed minimally increased perfusion despite aggressive intervention.

During the next several days, his hemoglobin and hematocrit began to trend downward, necessitating several blood transfusions. Eventually, computed tomographic angiography of the chest, abdomen, and pelvis was completed, which showed a large iliopsoas hematoma, a left psoas hematoma, and a small right psoas hematoma. Simultaneously, it was noted that he was thrombocytopenic at baseline, presumably from his advanced liver disease. This finding was also identified as a factor in the continued bleeding. The enoxaparin was held, and he was transitioned to a daily aspirin for the next 3 months. His vitals and hematocrit stabilized without incident. Approximately 3 weeks after his admission, the injury to his left fifth finger was demarcated enough, and the patient was transferred to the operating room for debridement of his left hand and amputation of his left fifth finger, which was necrotic at this point. Subsequently, a month later, a second debridement was deemed necessary, and the second, third, and fourth digits were also found to be necrotic and were amputated.

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Unfortunately, because of his underlying comorbidities, the patient required an extended hospital stay of greater than 2 months. During this time, he was subsequently diagnosed with Haemophilus influenzae type b pneumonia as well as complications around his chronic liver disease secondary to alcohol abuse, including anemia and thrombocytopenia. Additionally, he was treated for significant cellulitis around a percutaneous endoscopic gastrostomy tube that was placed during his hospitalization. Ultimately, after 65 days in the hospital, he was transferred to a skilled nursing facility.

Discussion

Frostbite and hypothermia are a combination of both local and systemic effects that occur as a result of cold exposure to a low absolute temperature for a prolonged duration. In the civilian realm, urban exposures leading to frostbite and hypothermia may typically result in impaired judgment to seek shelter from extreme temperatures. Many cases of cold exposure without the concurrent diagnosis of a trauma-related injury occur as a result of alcohol or sedative consumption or in the setting of mental illness, both of which can obscure appropriate decision making around the effects of temperature-related injury.[4]

Normally, the human body has inherent mechanisms to initially mitigate these severe deleterious effects in order to preserve core body temperature with temporarily shunting blood flow away from the peripheral regions. However, if the exposure remains prolonged, the net result is that cold injuries can occur. The management of central core hypothermia is beyond the scope of this brief overview; however, it is important to note that in order to address these peripheral injuries, further cold exposure must be arrested, and hypothermia and other systemic illness injury (ie, trauma) must be treated concurrently. In this case study, the patient was brought to the ICU for aggressive rewarming. As noted, it was not until a few hours into the rewarming that the peripheral frostbite was identified and tertiary care center level treatment was sought.

Classification of Injury

Peripheral cold injury is described in a similar fashion to burn injuries in the fact that it is not a singular diagnosis; rather, it is a spectrum of disease. As noted previously, in order to classify the degree of injury, the core temperature of the patient must be normalized, and other injuries and illnesses must be treated accordingly. There are 2 classification schemes used to describe the severity of peripheral cold injury. Both will be outlined later. Many people experience numbness and superficial feelings of cold with prolonged exposures to cold ambient temperatures and have no sequelae after rewarming. These patients are excluded from the classification schemes to be outlined. Rather, true frostbite injuries from cold temperatures are identified upon rewarming. There is significant pain, swelling, or evidence of gross ischemia in the tissues. Subsequent classification is based on the severity and depth of the injury into the tissues.[1-3]

Frostnip is worth describing here in detail, and there is much discussion regarding whether it should be considered a type of superficial frostbite or its own entity. The Wilderness Medical Society describes it as "a superficial nonfreezing cold injury associated with intense vasoconstriction on exposed skin."[2,3] It typically occurs in areas such as cheeks or distal portions of the nose. By its own definition, ice crystals do not form within the tissues, and after elimination of the cold conditions, they resolve spontaneously without any long-term adverse effects.

The older description of the severity of injuries classifies degrees of injury as follows[1-3]:

1. First-degree frostbite occurs with continued exposure and is characterized by hyperemia, blue mottling, swelling, and superficial desquamation of skin (which can occur up to 5 days later). No tissue infarction has occurred at this point.
2. Second-degree frostbite is an actual partial-thickness injury and results in the previously described findings for first-degree frostbite with vesiculation (blister formation) associated with edema and erythema.
3. Third-degree injuries involve the entire dermis and some subcutaneous tissues. Upon rewarming, hemorrhagic blisters and ulcerations can form and are associated with findings consistent with first- and second-degree injury.
4. Fourth-degree injuries involve the entire dermis and subcutaneous tissues including underlying bone. On examination, the affected tissue is cold, woody, and stiff.

The Wilderness Medical Society has updated the classification scheme to match it to those describing tissue burns. Superficial frostbite includes first- and second-degree injuries, whereas third- and fourth-degree injuries are classified as deep frostbite. Superficial injuries typically do not involve any tissue loss, whereas the latter, deep injury, typically does.[2] See Table 1. Lastly, it is important to note that there can be areas of variable levels of injury in an affected area.

Treatment of Frostbite

As noted earlier, the 2 initial management strategies required to care for the patient is first to remove the patient from the austere environment that is causing the cold injury and second to identify any other concurrent diagnoses.[3] Once the patient is normothermic and stabilized, treatment of frostbite can occur. In cases in which the patient is mildly hypothermic, care of the area of frostbite can occur simultaneously.[2] Limbs or tissues that have intracellular crystallization secondary to frozen tissues should only be thawed if the risk of refreezing has been removed. Numerous studies have shown the deleterious effects of the prostaglandin and thromboxane release associated with a freeze-thaw cycle.[1-3] Additionally, passive rewarming or dry heating is not currently acceptable.[2,3]

In some cases in which patients are not able to reach definitive care, passive rewarming may occur in the setting with blankets and body heat. The use of dry heat including heaters, blow dryers, or an equivalent can lead to superficial burns with underlying continued frozen tissues.[2,3] There is little sensation remaining at the skin level. Lastly, with rewarming, it can be exquisitely painful.

Table 1
Classification of Frostbite Injury[2]

Classification of Frostbite	Depth of Frostbite	Potential Tissue Loss	Signs	Symptoms
First degree	Superficial	No	Hyperemia, swelling, desquamation	Numbness, pain with rewarming
Second degree	Superficial	No	Clear or milky blisters upon rewarming	Numbness, pain with rewarming
Third degree	Deep	Yes	Hemorrhagic blisters, eventual ulceration	Numbness, pain with rewarming
Fourth degree	Deep	Yes	Full thickness, cold, woody	Numbness, pain with rewarming

Ibuprofen, acetaminophen, or even narcotic analgesia should be used liberally during the initial rewarming phase.[2,3] The remainder of this overview examines treatments that can occur within the setting of a hospital or equivalent level of care.

If the patient is in a setting that is appropriate for rewarming and the reestablishment of perfusion, rapid active rewarming with the use of warm water is the mainstay of therapy. Using water that is between 104°F and 108°F (or 40°C-42°C) for 15 to 30 minutes is the initial indicated therapy.[2,3] Once the affected area is thawed, electrolyte monitoring including monitoring for rhabdomyolysis must occur. Additionally, during this phase, a consultation with staff credentialed in general, burn, or orthopedic surgery is recommended to remain aware of potential needs including fasciotomy caused by tissue swelling, debridement, or amputation.[3,4]

Once the tissue is thawed, the patient will be monitored for continued pain, swelling, and infection, and basic wound care will be performed. Typically, wound care has consisted of allowing the extremity to air-dry, some application of topical aloe vera (because of its powerful antithromboxane effects), and debriding blisters that are clear or milky in nature.[3] Research has shown that interventions associated with hemorrhagic vesicles have resulted in worse outcomes than leaving them intact because of the fact that these vesicles are thought to signify a deeper level of tissue injury.[3] There are recommendations to use anti-inflammatories for pain control and to limit the inflammatory cascade associated with severe frostbite.[5] Systemic antibiotics are not typically indicated unless a concurrent infection develops although tetanus prophylaxis should be completed immediately. Along with aggressive fluid resuscitation, there are some other therapies that have variable levels of acceptance.

The use of tPA has gained acceptance for use to combat the effects of microvascular thrombosis. It is indicated for use within the first 24 hours from the start of the injury and should be used in those patients who have evidence of vascular compromise. If indicated, angiography is used to assess initially and then every 8 to 12 hours ongoing to determine tPA is a success.[6-9] Catheter-directed lysis is typically indicated for those patients who have vascular compromise proximal to the proximal interphalangeal joints of the digits. There are potential complications including systemic and catheter-site bleeding, compartment syndrome, and failure to salvage tissue. However, in a single-center review by Bruen et al,[10] they showed a reduction in digital amputation rates from 41% in those patients who did not receive tPA to 10% in those patients receiving tPA within 24 hours of injury. In centers with experience managing patients with frostbite injuries, equivalent results have occurred.[2]

Lastly, there are several other therapies that remain controversial. Using systemic heparin exclusively (without concurrent catheter-directed lysis) has shown little benefit to the patient population discussed. Additionally, the use of hyperbaric oxygen between days 5 and 10 has only been used in selected cases and has had variable levels of success.[11] In Europe, the use of iloprost is gaining traction in the setting of vasodilation for the treatment of frostbite. Although not currently available for intra-arterial or intravenous use in the United States, its use around the world in this population is gaining traction.[2]

The management of peripheral cold injuries in the inpatient setting remains challenging. Initial management revolves around the stabilization of the patient and identifying concurrent injuries or illness. Once the patient is stabilized, attention can be turned to the classification and treatment of peripheral frostbite. As the affected areas are thawed, indicated therapies can be initiated, and given the patient setting, aggressive therapies can be completed in order to salvage the greatest percentage of tissues. With the advent of catheter- directed lysis and the use of vasodilatory medications, the treatment of frostbite continues to evolve with significant reduction in morbidity and mortality. Summaries of treatment for frostbite is summarized in Table 2.

Table 2
An Overview of the Inpatient Treatment of Peripheral Cold Injuries and Frostbite[2]

Treat concurrent hypothermia, trauma, or other diagnoses
Rapidly rewarm in water heated and maintained between 40°C and 42°C (104°F-108°F) for approximately 15 to 30 minutes)
Ibuprofen (12 mg/kg per day divided twice daily)
Opiate pain medication as needed
Tetanus prophylaxis
Air-dry
Debridement: selectively drain or aspirate clear blisters and leave hemorrhagic blisters intact
Topical aloe vera
Dry, bulky dressings
Systemic hydration
Thrombolytic therapy
Evaluation by a surgeon with clinical expertise in frostbite management for continued care

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