

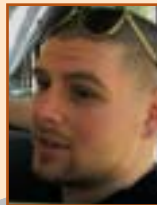
Cold Injuries:

Troy's Right Foot

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Troy's Toes

Troy, 22, presents to the emergency department with an eight-hour history of pain, swelling and pruritus in the toes of his right foot.



He walked several miles through wet snow after his snowmobile broke down. He was warmly dressed, including insulated snowmobile boots, although at one stage, he fell into a creek and both boots filled with water.

On examination, the first two toes of his right foot are red, swollen and sensitive to touch. There are no blisters and there is no evidence of skin breakdown.

Although he was dressed appropriately, the combination of activity (creating a humid environment inside his boots) and cold temperature likely resulted in a cold injury (Figure 1). Initial differential diagnosis of his cold injury includes frostnip, chilblains and



Figure 1. Chilblains of the right first and second toe. Although painful and itchy, this is a minor condition that requires minimal treatment, as described in the text.

Does Troy have frostbite?

Given the presenting history in this case, Troy's most likely diagnosis is chilblains. Chilblains/pernio is considered to be a milder form of cold injury than frostbite. While frostbite occurs when the ambient temperature is below 0 C, chilblains generally occurs in temperatures between 0 C to 15 C.

Chilblains is the result of an abnormal reaction of small blood vessels in the skin to cold exposure, and is more frequent when there are coincident damp or humid conditions. It is characterized by red, itchy lesions most frequently located on the dorsum of the foot.¹ Blisters may form after rewarming. Since there is no true tissue damage, chilblains is not true frostbite and is, thus, considered a non-freezing cold injury.

A similar non-frozen cold injury is "trench foot" or "immersion injury." This results when a body part is immersed in water above 0 C for an extended period of time. Since heat is transferred away from the body approximately 20 times faster in water than in air, knowledge of this condition is necessary even in relatively mild environments (*e.g.*, tropical immersion foot). The blisters formed by this condition are deeper than those of chilblains.

Frostbite is a more severe form of cold injury, where tissue damage occurs as a result of freezing. The process of frostbite begins with "frostnip," another non-freezing cold injury.

Frostnip, a warning sign of impending frostbite, is generally more severe than chilblains, and is characterized by numbness and blanching of the skin without visible tissue injury. Frostbite entails visible tissue injury, and can be divided into four categories (Figures 2-5):¹

Table 1

Treatment protocol for frostbite¹

1. Admit frostbite patient to a specialist unit, if possible.
2. On admission, rapidly rewarm the affected areas in warm water at 40 C to 42 C (104 F to 108 F) for 15 to 30 minutes, or until thawing is complete.
3. On completion of rewarming, treat the affected parts as follows:
 - Debride white blisters and institute topical treatment with aloe vera every six hours.
 - Leave hemorrhagic blisters intact and institute topical aloe vera every six hours.
 - Elevate the affected part(s) with splinting, as indicated.
 - Administer tetanus prophylaxis, as indicated.
 - Analgesia: Narcotic, preferably intravenous, and acetaminophen.
 - Administer ibuprofen, 400 mg to 600 mg, every six hours.
 - Consider benzyl penicillin, 300 mg to 600 mg, every six hours for 48 to 72 hours.
 - Perform daily hydrotherapy for 30 to 45 minutes at 40 C.
4. For documentation, obtain photographic records on admission at 24 hours and serially every two to three days until discharge.
5. Prohibit smoking.

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1. **First degree:** A numb, central-white plaque with surrounding erythema.
2. **Second degree:** Blister formation surrounded by erythema and edema; blisters are filled with clear or milky fluid, which occurs in the first 24 hours.
3. **Third degree:** Hemorrhagic blisters that will result in a hard, black eschar in two weeks.
4. **Fourth degree:** Complete necrosis and tissue loss.

This classification cannot be made before the tissue has been rewarmed. Clinically, a more useful description of frostbite is superficial (first and second degree) or deep (third and fourth degree),¹ similar to the way we classify acute burns.

What is the pathophysiology?

Frostbite occurs in two phases of injury. Phase one is the initial exposure to cold, resulting in extracellular ice crystal formation. These crystals alter membrane integrity, protein function and the intra-extracellular osmotic gradient.² This change in the osmotic gradient causes water to leave the cell, resulting in intracellular dehydration. The increase in electrolyte concentration of the intracellular environment initiates programmed cell death. Intracellular crystal formation also causes mechanical destruction as the crystals expand and, in the presence of a compromised membrane, causes cell lysis.

The body's natural response to the cold is to try to stop this by the "hunting reaction," a periodic perfusion/occlusion cycle in the affected extremities. Persistence of the physiologic insult, however, will eventually lead to a thrombotic phase where tissue perfusion ceases and necrosis ensues.^{1,2}

Phase two is characterized by progressive dermal ischemia. This phase is comparable to what occurs in thermal burn injuries, in that prostaglandin F2a and thromboxane A2 signal the arrest of dermal blood flow.¹ Other chemotoxins, such as metabolites of arachidonic acid and histamine, have been implicated in this inflammatory process.² Phase two continues until approximately one to three months after the injury, by which time the dead tissue will have mummified and will eventually be removed by surgery or autoamputation.¹

How should it be treated?

The treatment for chilblains is to elevate the area affected and apply moisturizing cream to maintain the skin's

First-degree frostbite:
White plaque with erythema



Figure 2. First-degree frostbite.

Second-degree frostbite:
Blisters with erythema and edema;
clear/milky fluid in 24 hours



Figure 3. Second-degree frostbite.

Third-degree frostbite:
Hemorrhagic blisters (will progress to a black eschar)



Figure 4. Third-degree frostbite.

Fourth-degree frostbite:
Complete necrosis and tissue loss



Figure 5. Fourth-degree frostbite.

Figures 2-5: An approximation of the degrees of frostbite.

integrity, since there is no true tissue damage. Recovery should be complete within a few days, although, affected areas may be predisposed to recurrence with a lesser cold insult.

Management of frostbite is more specific and occurs in three phases:

1. *Pre-thaw field care phase*

The affected area should be protected from mechanical force. Any force can cause fracture or chipping of the frozen tissue.³ *Do not* rub the area. Ideally, the person should be taken to a care facility where total rewarming can occur. Active rewarming should not be initiated and then stopped, as thawing followed by refreezing leads to a poorer prognosis.

2. *Rewarming*

The patient should be placed in a warm bath between 40 C to 42 C, for 15 to 30 minutes, until a pink colour is attained. The range of temperature is critical since cooler temperatures cause a slow rewarming, which has been shown to lead to increased tissue damage, whereas a warmer temperature may result in burns. The patient should be encouraged to move, but not to

actively massage the affected areas. A mild antibacterial agent can be added to the bath for prophylaxis. Narcotic analgesia is likely to be needed during this process.

3. *Post-rewarming*

The post-rewarming phase is observed in Table 1. Rewarming appears to reverse the ice crystal formation,

but furthers the inflammation process.¹ The protocol attempts to limit this process while giving supportive care (pain modulation) and also to consider prophylaxis for infection. Ibuprofen is preferred to acetylsalicylic acid, which eliminates positive healing prostaglandins.

The management of blisters remains an area of debate. In second-degree frostbite (with white or clear blisters), the current consensus is to debride the blister so that chemotaxins are removed and the inflammatory process is, therefore, diminished. Hemorrhagic blisters (third degree) are left unaltered, so the structural integrity of the deep tissue injury is maintained (Figures 6 and 7). After the treatment, aloe vera application is indicated for its anti-thromboxane effect.⁴

Another important issue in the treatment of frostbite patients is to consider the etiology of the frostbite. Although in this case, Troy's cold exposure followed vehicular failure, there are several risk factors that may predispose patients to frostbite. Frostbite is associated with alcohol use (46%), homelessness and psychiatric illness (17%).¹ Dehydration, malnutrition and poor circulation (*e.g.*, diabetes, anemia) can also contribute to the development of cold injury. These should be investigated and included in the treatment plan, as necessary.

What do you advise for prevention?

All persons who are going out into the cold should be prepared. They should check the weather forecast and should be aware when to seek shelter from the cold. They should dress appropriately with layered clothing so they are insulated, but must also be able to remove their clothing if they begin to sweat from exertion. An attempt should be made to stay dry and it would be ideal to bring along an extra set of dry clothes. Alcohol and tobacco should be avoided and caloric intake should be increased. Further,



Figure 7. The decision to debride or not to debride may be difficult. If in doubt, it is probably better to avoid debridement to maintain the integrity of the deep tissue.

Figure 6. Frostbite blisters. Since the large toe may be hemorrhagic, debridement would not protect the underlying deep tissue and is not indicated. The other four, however, appear to be "white" blisters, so the current protocol would suggest debridement. Treatment after the initial decision regarding debridement would be identical.

weathered skin is more resistant to the cold,⁴ so less vigorous cleansing of exposed areas may offer some protection.

Even with planning and appropriate dressing, unexpected prolonged exposure to the cold (as in this case) may result in cold injury. It is important for people to recognize the initial signs and symptoms of cold injuries so that they can avoid the end result of permanent tissue damage.

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