Frostbite

Frostbite is injury due to freezing of tissue. Initial presentation may be deceptively benign. Skin may appear white or blistered and is numb; rewarming causes substantial pain. Gangrene may develop. Severely damaged tissue may autoamputate. Treatment is rewarming in warm (40 to 42 °C) water and local care. Surgical amputation is occasionally necessary, but a decision, often guided by imaging results, should usually be delayed until definitive demarcation of necrotic tissue.

Frostbite usually occurs in extreme cold, especially at high altitude, and is aggravated by hypothermia. Distal extremities and exposed skin are affected most often.

Ice crystals form within or between tissue cells, essentially freezing the tissue and causing cell death. Adjacent unfrozen areas are at risk because local vasoconstriction and thrombosis can cause endothelial and ischemic damage. With reperfusion during rewarming, inflammatory cytokines (eg, thromboxanes, prostaglandins) are released, exacerbating tissue injury.

Symptoms and Signs
The affected area is cold, hard, white, and numb. When warmed, the area becomes blotchy red, swollen, and painful. Blisters form within 4 to 6 h, but the full extent of injury may not be apparent for several days. Blisters filled with clear serum indicate superficial damage; blood-filled, proximal blisters indicate deep damage and likely tissue loss. Superficial damage heals without residual tissue loss. Freezing of deep tissue causes dry gangrene with a hard black carapace over healthy tissue. Wet gangrene, which is gray, edematous, and soft, is less common. Wet gangrene is characterized by infection, but dry gangrene is less likely to become infected. Depth of tissue loss depends on duration and depth of freezing. Severely damaged tissue may autoamputate. Compartment syndrome may develop. All degrees of frostbite may produce long-term neuropathic symptoms: sensitivity to cold, excessive sweating, faulty nail growth, and numbness (symptoms resembling those of complex regional pain syndrome—see Pain: Complex Regional Pain Syndrome—although any relationship is speculative).

Diagnosis
Diagnosis is based on clinical criteria. However, because many of the early characteristics of frostbite (eg, coldness, numbness, white or red color, blisters) are also characteristic of nonfreezing cold injuries, differentiation of frostbite may require repeated observation until more specific characteristics (eg, black carapace, gangrene) develop.

**Treatment**

- Rewarming in warm (40 to 42°C) water
- Supportive measures
- Local wound care
- Sometimes delayed surgery

**Prehospital care:** In the field, frostbitten extremities should be rewarmed rapidly by totally immersing the affected area in water that is tolerably warm to the touch (40 to 42°C, ideally about 40.5°C). Because the area is numb, rewarthing with an uncontrolled dry heat source (eg, fire, heating pad) risks burns. Rubbing may further damage tissue and is avoided. The longer an area remains frozen, the greater the ultimate damage may be. However, thawing the feet is inadvisable if a patient must walk any distance to receive care because thawed tissue is particularly sensitive to the trauma of walking and, if refrozen, will be more severely damaged than if left frozen. If thawing must be delayed, the frozen area is gently cleaned, dried, and protected in sterile compresses. Patients are given analgesics, if available, and the whole body is kept warm.

**Acute care:** Once the patient is in the hospital, core temperature is stabilized and extremities are rapidly rewarmed in large containers of circulating water kept at about 40.5°C; 15 to 30 min is usually adequate. Thawing is often mistakenly ended prematurely because pain may be severe during rewarthing. Parenteral analgesics, including opioids, may be used. Patients are encouraged to move the affected part gently during thawing. Large, clear blisters are left intact or aspirated using sterile technique. Hemorrhagic blisters are left intact to avoid secondary desiccation of deep dermal layers. Broken vesicles are debrided. If there is no perfusion after thawing, thrombolytic (fibrinolytic) therapy is considered.

Anti-inflammatory measures (eg, topical aloe vera q 6 h, ibuprofen 400 mg po q 8 h, ketorolac 30 to 60 mg IV) probably help. Affected areas are left open to warm air, and extremities are elevated to decrease edema. Anticoagulants, IV low mol wt dextran, and intra-arterial vasodilators (eg, reserpine, tolazoline) have no proven clinical benefit. Phenoxycbenzamine (10 to 60 mg po once/day), a long-acting α-blocker, may theoretically decrease vaso spasms and improve blood flow.

Preventing infection is fundamental; streptococcal prophylaxis (eg, with penicillin) is sometimes provided. If wet gangrene is present, broad-spectrum antibiotics are used. Tetanus toxoid is given if vaccination is not up to date. If tissue damage is severe, tissue pressure is monitored.

**Ongoing care:** Adequate nutrition is important to sustain metabolic heat production.

Imaging tests (eg, radionuclide scanning, MRI, microwave thermography, laser-Doppler flowmetry) can help assess circulation, determine tissue viability, and thus guide treatment. MRI and particularly magnetic resonance angiography (MRA) may establish the line of demarcation before clinical demarcation and thus make earlier surgical debridement or amputation possible. However, whether earlier surgery improves long-term outcome is unclear. Usually, surgery is delayed as long as possible because the black carapace is often shed, leaving viable tissue. Patients with severe frostbite are
warned that many weeks of observation may be required before demarcation and the extent of tissue loss become apparent.

Whirlpool baths at 37°C 3 times/day followed by gentle drying, rest, and time are the best long-term management. No totally effective treatment for the long-lasting symptoms of frostbite (eg, numbness, hypersensitivity to cold) is known, although chemical or surgical sympathectomy may be useful for late neuropathic symptoms.

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