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Prevention and Treatment of Frostbite:

Essentials for the Mountain Environment

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Frostbite generally occurs to extremities that are farthest from the heart, including the fingers, toes, nose, ears, cheeks, and chin. It can cause permanent numbness or loss of use of the affected area, and, in the worst cases, the body part must be amputated.

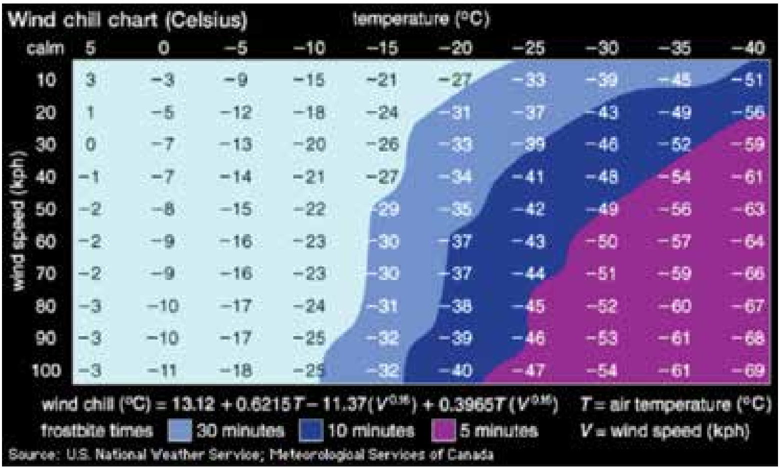
Introduction

Mountaineering and mountain trekking often take us to high, wild places with harsh conditions. One consequence of prolonged exposure to cold temperatures and high winds can be frostbite: the freezing and subsequent death of body tissues. Frostbite generally occurs to extremities that are farthest from the heart, including the fingers, toes, nose, ears, cheeks, and chin. It can cause permanent numbness or loss of use of the affected area, and, in the worst cases, the body part must be amputated. Avoiding temperatures below freezing is impossible for high-altitude and winter climbers, so it's essential to know how to prevent and treat this destructive ailment. To put the risks and implications of frostbite injury into a wider context, cold environments have decided the fate of armies, often causing the deaths of hundreds of thousands of soldiers throughout the recorded history of human conflict. And this reality is nowhere truer than in high altitude conflict zones, where a heavy toll of casualties from frostbite has been extracted through the years.

Causes of frostbite

Environment - The three main risk factors for frostbite are temperature, wind chill, and the length of time of exposure. The wind chill chart (below) is an excellent resource to determine risk for frostbite.

Gear - Tight clothing, ill-fitting boots, rings, watches, and bracelets—anything that restricts circulation—can contribute to the onset of frostbite. Wet clothing and prolonged contact to metal items can also be a factor. Proper-fitting clothing that is layered to prevent overheating and sweating is essential.



Wind chill chart (Celsius)

wind speed (kph) \ temperature (°C): calm	5	0	−5	−10	−15	−20	−25	−30	−35	−40
10	3	−3	−9	−15	−21	−27	−33	−39	−45	−51
20	1	−5	−12	−18	−24	−31	−37	−43	−49	−56
30	0	−7	−13	−20	−26	−33	−39	−46	−52	−59
40	−1	−7	−14	−21	−27	−34	−41	−48	−54	−61
50	−2	−8	−15	−22	−29	−35	−42	−49	−56	−63
60	−2	−9	−16	−23	−30	−37	−43	−50	−57	−64
70	−2	−9	−16	−23	−30	−37	−44	−51	−59	−66
80	−3	−10	−17	−24	−31	−38	−45	−52	−60	−67
90	−3	−10	−17	−25	−32	−39	−46	−53	−61	−68
100	−3	−11	−18	−25	−32	−40	−47	−54	−61	−69

wind chill (°C) = $13.12 + 0.6215T - 11.37(V^{0.16}) + 0.3965T(V^{0.16})$ T = air temperature (°C)

frostbite times: 30 minutes, 10 minutes, 5 minutes V = wind speed (kph)

Source: U.S. National Weather Service; Meteorological Services of Canada

Nutrition. Dehydration, alcohol, smoking, and poor diet can all negatively affect circulation and contribute to frostbite.

Classification of Frostbite

Frostnip is superficial nonfreezing cold injury associated with intense constriction of blood vessels on exposed skin, usually cheeks, ears, or nose. Ice crystals, appearing as frost, form on the skin surface. Frostnip is distinct from and may precede frostbite. With frostnip, ice crystals do not form within the tissue and tissue loss does not occur. Numbness and pallor resolve quickly after warming the skin with appropriate clothing, direct contact, and breathing with cupped hands over the nose, or gaining shelter. No long-term damage occurs. Frostnip signals conditions favorable for frostbite; appropriate action should be undertaken immediately to prevent injury.

Frostbite has historically been divided into four tiers or 'degrees' of injury following the classification scheme for thermal burn injury. These classifications are based on physical findings and advanced in-hospital imaging after rewarming. The classifications can be difficult to assess in the field before rewarming because the still-frozen tissue is hard, pale, and numb. An alternate two-tiered classification more appropriate for field use (after rewarming) is suggested following the four-tier classification below.

First-degree frostbite causes numbness and redness of the affected area. A white or yellow, firm, and slightly raised fluid accumulation develops under the skin in the area of injury. No tissue death occurs at this stage; there may be slight sloughing of the superficial layer of skin. Mild oedema is common.

Second-degree frostbite injury causes a superficial collection of a clear or milky fluid that is present in blisters surrounded by redness and swelling.

Third-degree frostbite causes deeper blood-filled blisters, indicating that the injury has extended into the sub-layer of skin containing blood capillaries and other structures.

Fourth-degree frostbite extends completely through the deepest layers of skin and involves the subcutaneous (fatty) tissues, with tissue death often extending into muscle and bone.

For field classification, after spontaneous or formal rewarming (e.g., in a warm-water bath), many cold injury experts favor the following two-tier classification scheme:

Superficial—no or minimal anticipated tissue loss, corresponding to first and second-degree injury

Deep—anticipated tissue loss, corresponding to 3rd and 4th-degree injury

Severity of frostbite may vary within a single extremity.

Prevention

The adage 'prevention is better than treatment' is especially true for frostbite, which is typically preventable and often not improved by treatment. Underlying medical problems may increase risk of frostbite, so prevention must address both environmental and health-related aspects. Frostbite injury occurs when tissue heat loss exceeds the ability of local tissue perfusion to prevent freezing of soft tissues (blood flow delivers heat). One must both ensure adequate perfusion and minimize heat loss to prevent frostbite. The mountain adventurer should recognize cold-induced 'numbness' as a warning that frostbite injury may be imminent if protective and/or avoidance measures are not taken to decrease tissue cooling. Subsequent loss of sensation does not mean the situation has improved; rather receptors and nerves are not conducting pain/cold signals because they are nearing the freezing point.

Maintaining Peripheral Blood Flow

Preventive measures to ensure local tissue blood flow include:

1) Maintaining adequate core temperature and adequate fluid intake

2) Minimizing effects of known diseases, medications, and substances (e.g. including awareness and symptoms of alcohol and drug use) that might decrease blood flow to tissues in the extremities

3) Covering all skin and the scalp to insulate from the cold

4) Minimizing blood flow restriction, such as occurs with constrictive clothing, footwear, or immobility

5) Ensuring adequate nutrition

6) Using supplemental oxygen in severely hypoxic conditions (e.g. >7500 m).

Exercise

Exercise is a specific method to maintain peripheral blood flow. Exercise enhances the level and frequency of cold-induced peripheral vasodilation. However, using exercise to increase warmth can lead to exhaustion with subsequent profound systemic heat loss should exhaustion occur. Recognizing this caveat, exercise and its associated elevation in core and peripheral temperatures can be protective in preventing frostbite.

Protection from Cold

Measures should be taken to minimize exposure of tissue to cold. These measures include the following:

1) Avoiding environmental conditions that predispose to frostbite, specifically below minus 15°C, even with low wind speeds

2) Protecting skin from moisture, wind, and cold

3) Avoiding perspiration or wet extremities

4) Increasing insulation and skin protection (e.g., by adding clothing layers, changing from gloves to mitts, etc.)

5) Ensuring beneficial behavioural responses to changing environmental conditions (e.g., not being under the influence of illicit drugs, alcohol, or extreme hypoxemia)

6) Regularly checking oneself and the group for extremity numbness or pain, and warming the digits and/or extremities as soon as possible if there is concern that frostbite may be developing

7) Recognizing frostnip or superficial frostbite before it becomes more serious

8) Minimizing duration of cold exposure. Emollients do not protect against—and might even increase—risk of frostbite. The time that a digit or extremity can remain numb before developing frostbite is unknown; thus, digits or extremities with abnormal sensation should be warmed as soon as possible. An extremity at risk for frostbite (e.g. numb, poor dexterity, pale colour) should be warmed with adjacent body heat from the patient or a companion, using the axilla or abdomen.

Field Treatment and Secondary Prevention

If a body part is frozen in the field, the frozen tissue should be protected from further damage. Remove jewellery or other constrictive extraneous material from the body part. Do not rub or apply ice or snow to the affected area.

Refreezing Injury

A decision must be made whether to thaw the tissue. If environmental conditions are such that thawed tissue could refreeze, it is safer to keep the affected part frozen until a thawed state can be maintained. One must absolutely avoid refreezing if field-thawing occurs.

Spontaneous or Passive Thawing

Most frostbite thaws spontaneously and should be allowed to do so if rapid rewarming (described below) cannot be readily achieved. Do not purposefully keep tissue below freezing temperatures because this will increase the duration that the tissue is frozen and might result in more proximal freezing and greater morbidity. If environmental and situational conditions allow for spontaneous or slow thawing, tissue should be allowed to thaw.

Strategies for two scenarios are presented:

Scenario 1: The frozen part has the potential for refreezing and is not actively thawed

Scenario 2: The frozen part is thawed and kept warm without refreezing until evacuation is completed

Therapeutic Options for both Scenarios

Hydration

Vascular stasis can result from frostbite injury. Appropriate hydration is important for frostbite recovery. Oral fluids may be given if the patient is alert, capable of purposeful swallowing, and is not vomiting. If the patient is nauseated or vomiting or has an altered mental status, intravenous normal saline, if available, should be given to maintain normal urine output. Intravenous fluids should optimally be warmed (minimally to 37°C but preferably to 40-42°C) before infusion and be infused in small (e.g. 250 ml), rapid quantities because slow infusion will results in fluid cooling and even freezing as it passes through the tubing. Fluid administration should be optimized to prevent clinical dehydration.

Ibuprofen

A non-steroidal anti-inflammatory drug such as ibuprofen should be started in the field to inhibit harmful prostaglandins and to treat pain from the cold injury. Dosing recommendations can be found in the Wilderness Medical Society Practice Guidelines for the Prevention and Treatment of Frostbite listed at the end of this article.

Specific Recommendations—Scenario 1 (no active thawing)

Dressings

Bulky, clean, and dry gauze or sterile cotton dressings should be applied to the frozen part and between the toes and fingers.

Ambulation and protection

If possible, a frozen extremity should not be used for walking, climbing, or other manoeuvres until definitive care is reached. If using the frozen extremity for mobility is considered, a risk-benefit analysis must consider the potential for further trauma and possible poorer outcome. Although reasonable to walk on a foot with frostbitten toes for evacuation purposes, it is inadvisable to walk on an entirely frostbitten foot because of the potential for resulting morbidity. If using a frozen extremity for locomotion or evacuation is unavoidable, the extremity should be padded, splinted, and kept as immobile as possible to minimize additional trauma.

Specific Recommendations—Scenario 2 (thawing and continued warming)

Rapid field rewarming of frostbite

Field rewarming by warm water bath immersion can and should be performed if the proper resources are available and definitive care is more than two hours away. Other heat sources (e.g., fire, space heater, oven, heated rocks, etc.) should be avoided because of the risk of thermal burn injury. Rapid rewarming by water bath has been shown to result in better outcomes than slow rewarming.

Field rewarming should only be undertaken if the frozen part can be kept thawed and warm until the victim arrives at definitive care. Water should be heated to 37°C to 39°C using a thermometer to maintain this range. If a thermometer is not available, a safe water temperature can be determined by placing a caregiver's uninjured hand in the water for at least 30 seconds to confirm that the water temperature is tolerable and will not cause burn injury. Circulation of water around the frozen tissue will help maintain correct temperature. Because the water may cool quickly after the rewarming process is started, the water should be continuously and carefully warmed to the target temperature. If the frozen part is being rewarmed in a pot, care must be taken that the frozen part does not press against the bottom or sides, to prevent damage to the skin. Rewarming is complete when the involved part takes on a red or purple appearance and becomes soft and pliable to the touch. This is usually accomplished in approximately 30 minutes but is variable depending on the extent and depth of injury. The affected tissues should then be allowed to air dry or be gently dried with blotting technique (not rubbing) to minimize further damage. Under appropriate circumstances, this method of field rewarming is the first definitive step in frostbite treatment.

Pain control

During rewarming, pain medication (e.g. non-steroidal anti-inflammatory drugs or an opiate analgesic) should be given to control symptoms as dictated by individual patient situation.

Spontaneous or passive thawing

According to the foregoing guidelines, rapid rewarming is strongly recommended. If field rewarming is not possible, spontaneous or slow thawing should be allowed. Slow rewarming is accomplished by moving to a warmer location (e.g., tent or hut) and warming with adjacent body heat from the patient or a caregiver.

Debridement of blisters

Debridement of blisters should not be routinely performed in the field. If a clear, fluid-filled blister is tense and at high risk for rupture during evacuation, blister aspiration and application of a dry gauze dressing should be performed in the field to minimize infection risk. Hemorrhagic (blood and serous fluid-filled) blisters should not be aspirated or debrided in the field.

Topical aloe vera

Topical aloe vera should be applied to thawed tissue before applying dressings.

Dressings

Bulky, dry gauze dressings should be applied to the thawed parts for protection and wound care. Substantial oedema should be anticipated, so circumferential dressings should be wrapped loosely to allow for swelling without placing pressure on the underlying tissue.

Ambulation and protection

After the rewarming process, swelling should be anticipated. If passive thawing has occurred, boots (or inner boots) may need to be worn continuously to compress swelling. Boots that were removed for active rewarming may not be able to be re-donned if tissue swelling has occurred during the warming process. Extensive clinical experience supports the concept that a recently thawed extremity should (ideally) not be used for walking, climbing, or other manoeuvres, and should be protected to prevent further trauma.

Elevation of extremity

If possible, the thawed extremity should be elevated above the level of the heart, which might decrease formation of dependent oedema.

Oxygen

Recovery of thawed tissue partly depends on the level of tissue oxygenation in the postfreezing period. Oxygen may be delivered by face mask or nasal cannula if the patient is hypoxic (oxygen saturation less than 88%) or the patient is at high altitude above 4000 m.

For a summary of the suggested approach to the field treatment of frostbite, see Table 1 in the Wilderness Medical Society Practice Guidelines for the Prevention and Treatment of Frostbite: 2019 Update (listed as a reference below).

Hospitalization

Patients with superficial frostbite can usually be managed as outpatients or with brief inpatient hospital stays followed by take-home wound care instructions. Initially, deep frostbite should be managed in a hospital setting. Complete demarcation of tissue necrosis (i.e. tissue death) may take one to three months.

References

Wilderness Medical Society Practice Guidelines for the Prevention and Treatment of Frostbite:

2019 Update. McIntosh SE, Freer L, Grissom CK, Auerbach PS, Rodway GW, Cochran A,

Giesbrecht GG, McDevitt M, Imray CH, Johnson EL, Pandey P, Dow J, Hackett PH. *Wilderness*

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Summary

Continuing his series for the *THJ* on high altitude diseases and their causes/preventions/cures, Dr George Rodway has written as simply as possible on Frostbite and steps to prevent/cure it.

About the Author

George W. Rodway, PhD, represents a combination of scientific researcher, mountaineer and science writer. An Associate Clinical Professor at the University of California, Davis, his academic work focuses on the cardiopulmonary response to hypoxia and it has on occasion, presented him with the opportunity to climb mountains with scientific intent. He serves international organizations as well such as the International Society for Mountain Medicine and the Medical Commission of the Union Internationale des Associations d'Alipinisme (UIAA).