

CASE REPORT

Frostbite—A Case Series From Arctic Greenland

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Greenland is not only the largest island in the world, it is also the least densely populated country on the globe. The majority of Greenland's landmass lies within the Arctic Circle. Weather conditions in Arctic areas can be extreme, thus exposing locals and visitors to a high risk of acquiring frostbite injuries. More than two thirds of Greenland is covered by a permanent ice sheet, and temperatures can drop to below -70°C . In addition, frequent storms, occupational exposure, and alcohol all contribute to an increased risk for frostbite injury. Frostbite may cause major morbidity, including tissue loss and limb amputation. Hence, proper diagnosis and treatment of frostbite injuries is of utmost importance. We present 6 cases of frostbite injuries in Greenland, ranging from mild to severe frostbite in both locals and foreign visitors. The cases illustrate some of the known risk factors for frostbite injuries. The etiology, pathophysiology, clinical presentation, and recommended management of frostbite are summarized. Novel treatments for frostbite and frostbite sequelae are discussed in the context of the Greenlandic healthcare system. Furthermore, cultural aspects and reasons for a seemingly low incidence of frostbite injuries in Greenland are explored.

Keywords: injuries, sequelae, extreme

Introduction

The circumpolar areas are characterized by extreme weather conditions. Freezing temperatures, strong winds, snow, ice, and long polar nights with perpetual darkness are all mainstays of Arctic winters. Greenland constitutes a significant fraction of the landmass in the Arctic, with the majority of its 2,166,086 km² located above the Arctic Circle (Figure 1). Around 85% of Greenland is covered by a permanent ice sheet, which measures around 3 km at its thickest. Due to the Arctic climate, temperatures can drop to -70°C (-94°F) in the coldest places.

Greenland is a land of extremes. The largest island on the globe, it is also the least densely populated country in the world. Spanning 2600 km from north to south, the country is vast. The Greenlandic population of around 57,000 inhabitants is dispersed in settlements along the coastline; the 18 cities and 120 villages constitute small clusters of human habitation amidst the masses of rock and ice. No roads exist between cities in Greenland, the

main transportation routes are by airplane, helicopter, boat, snowmobile, and dogsled. The majority of the Greenlandic Inuit employ themselves with fishing and hunting, which often requires multiple-day dogsled expeditions, lengthy hunting trips, and long boat excursions during all seasons of the year. In addition to prolonged exposure to icy winds and freezing temperatures in the wintertime, the journeys often venture deep into the Greenlandic icescape, and thus further away from medical care.

The healthcare system consists of 1 referral hospital, Queen Ingrid's Hospital in the capital city Nuuk; 4 regional hospitals in the largest cities Sisimiut, Ilulissat, Qaqortoq, and Asiaat (Figure 1); 13 physician-staffed health clinics; and 48 rural health clinics staffed by a nurse or a healthcare worker. The regional hospitals serve as referral hospitals for the smaller health clinics. Physicians from the regional hospitals undertake medical visits to the regions' rural settlements 2 to 4 times a year. In addition, a telemedical system is in service all over Greenland, allowing the rural-based nurse or healthcare worker to send electrocardiograms, clinical photographs, otoscopic images, stethoscopic sound files, and live video transmission to the regional hospital. In cases of medical emergency or trauma, the regional physician on call is contacted and can initiate evacuation by

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Figure 1. Map of Greenland. More than two thirds of Greenland's landmass is covered by a permanent ice sheet. Around 17,000 of Greenland's 57,000 inhabitants live in the capital city Nuuk. The other major cities are Sisimiut (5500 inhabitants), Ilulissat (4500 inhabitants), Qaqortoq (3500 inhabitants), Aasiaat (3000 inhabitants), and Qaanaaq (600 inhabitants), which is the most northern city in Greenland.

snowmobile, boat, helicopter, or airplane, depending on the level of critical illness of the patient. The geography, climate, and infrastructure can make the provision of healthcare in Greenland a logistical challenge, as patients from rural settlements who experience severe trauma or acute life-threatening illness might not be easily evacuated due to Arctic storms, heavy snowfall, low-visibility conditions, or limited availability of evacuation transportation vehicles.

Frostbite is a cold injury often encountered in circumpolar areas.¹ It occurs when body tissue is exposed to temperatures below 0°C (32°F) for long enough for ice crystals to form. The pathophysiology of frostbite has

been extensively reviewed elsewhere^{2,3} and includes vasoconstriction, ischemia, ice crystal formation, and cell disintegration. Rewarming leads to reperfusion, causing an inflammatory surge, vascular leak, thrombosis, and embolization. Refreezing of thawed tissue triggers further inflammatory reactivity, resulting in significant tissue damage.³

Clinically, frostbite injuries present with loss of sensation and a pale, waxy, bluish skin discoloration. Blisters and edema may be present in the affected areas.³ Symptoms include numbness and paresthesia, followed upon rewarming by significant pain, to the extent that parenteral analgesia can be necessary. Frostbite injuries can be classified into 4 stages based on clinical findings. First-degree frostbite presents with numbness and erythema; a white, firm, elevated plaque in the frostbitten tissue; mild edema; no gross tissue infarction; and no blisters or necrosis. Second-degree frostbite presents with erythema, edema, and bullae containing clear or milky fluid. Tissue destruction is confined to the dermal layer. First- and second-degree frostbite represent superficial frostbite injuries, in which there is no or minimal anticipated tissue loss.² Third-degree frostbite is defined by tissue destruction extending to subcutaneous levels and presents with deep hemorrhagic blisters, skin necrosis, and a blue-gray discoloration. Fourth-degree frostbite affects deeper layers of tissue, including muscle and bone, and presents with little edema and deep red or cyanotic skin, which later becomes dry, black, and mummified.³ Third- and fourth-degree frostbite comprise deep frostbite injuries, in which significant tissue loss should be anticipated. In addition to possible tissue loss, other long-term sequelae include chronic pain, increased vulnerability to future cold injuries, neuropathy, cold hypersensitivity, and diminished sensation and numbness.³⁻⁶ Chronic pain may be difficult to control. A novel case study reported reduced cold sensitivity and improved somatosensory nerve function after treatment with botulinum toxin in a soldier with bilateral second-degree frostbite in both hands.⁷

Risk factors for the development of frostbite include temperature, wind chill, immersion, fatigue, malnutrition, smoking, alcohol and substance abuse, and medical conditions including peripheral vascular disease, diabetes, neuropathies, dementia, and mental illness.^{4,8} Digits, nose, cheeks, and ears are often affected. Frostbite largely affects healthy individuals aged 30 to 49 y,⁹ ranging from military personnel operating in cold regions, industrial workers, and the homeless population, to people engaging in recreational activities such as skiing, hiking, mountaineering, and ice climbing.⁴

Current guidelines for the management of frostbite injuries have recently been summarized by an expert panel;² however, evidence is often low quality

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