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On-site Management of Frostbite in the Himalayas

Inam Danish Khan[1*]

[1]Clinical Microbiology, Army College of Medical Sciences and Base Hospital, Delhi Cantt 110010 India

Corresponding Author: Inam Danish Khan, MBBS, MD, DNB, Assistant Professor in Clinical Microbiology and Infectious Diseases, Army College of Medical Sciences and Base Hospital, Delhi Cantt 110010 India. Mobile: +91 9836569777, Fax: +91 11 25693490, Email: titan_afmc@yahoo.com

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Abstract

Introduction: Frostbite is a common debilitating condition seen in travelers and residents at high altitudes. Emergent on-site management is warranted in the absence of institutionalized care and compromised evacuation facilities. This prospective, observational study assessed the outcome of on-site emergent management in low-resource, high altitude healthcare setups in the field, applicable in situations of delayed evacuation.

Methods: This is a prospective cohort study. All frostbite patients presenting at 4 Himalayan regions were included. Patients were diagnosed, assessed clinically, and evaluated for causation. On-site emergent management was given in situations of delayed evacuation, and responses were monitored. Further prevention was advised for all patients.

Results: Frostbite presented in 172 healthy, acclimatized patients having knowledge of frostbite. A total of 158 (91.86%) males and 14 (8.14%) females with a mean age of 27.8 ± 7 years sustained frostbite at altitudes between 9000-24000 feet with a mean of 14575 ± 3848 feet. First-, second-, and third-degree frostbite comprised 62.2%, 34.3%, and 3.49% of cases, respectively. Fingertips were most frequently affected, followed by toe tips. Of the frostbite cases treated on-site, 57.94% were first-degree and 34.29% were second-degree.

Conclusion: Frostbite can occur in people who are cold-experienced and knowledgeable. Therapeutic and preventive rewarming can be attempted in limited-resource setups outside the hospital. Frostbite up to second-degree can be treated under high altitude field conditions; however, this is advisable only in situations of delayed evacuation.

Keywords: Frostbite, On-site management, Rewarming, Cold acclimatization, Himalayas

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Introduction

Frostbite is a localized freezing injury known to plague travelers, mountaineers, soldiers, scientists, and the general population who are exposed to cold.[1-6] Prolonged morbidity, long-term sequelae, and reduced performance due to frostbite influence operational targets.[7,8] Emergent on-site management is warranted in the absence of institutionalized care and compromised evacuation facilities prevalent in mountainous terrain.[1,8,9] Current knowledge advocates immediate evacuation to institutional facilities for definitive management; however, evacuation from a high-altitude, remote mountain terrain is often delayed for want of clear weather, a communication infrastructure, or aviation capabilities.

There is a paucity of evidence on emergent on-site management of frostbite. Hospital-based treatment protocols are well defined, though they have limited applicability for management under field conditions with limited opportunities and resources.[1,9] The present prospective, observational study assessed on-site emergent management outcomes in early (first- and second-degree) frostbite occurring in low-resource, high altitude health-care setups, applicable in situations of delayed evacuation. Prior to the study, on-site emergent management based on existing guidelines was attempted in eight frostbite patients who could not be evacuated for 5 days, and considerable improvement was observed. A total of 172 frostbite patients awaiting evacuation were offered on-site management under existing guidelines for hospital settings; promising results were achieved, highlighting the possibility of the on-site management of frostbite under resource-limited, high-altitude field conditions. The results of this study offer suitable extrapolations for all mountain/cold environments encompassing a huge population of travelers, mountaineers, and residents at risk of frostbite.

Methods

This prospective cohort study was conducted in 4 different geographical regions of the Himalayas, Karakoram, Kashmir, Garhwal, and Nepal, from 2007-2016. The necessary advance approvals from the Nehru Institute of Mountaineering

expedition team and voluntary, blanket, written informed consent from the participants for training, treatment, and evacuation were obtained prior to beginning the study. All frostbite patients were included, while patients of non-freezing cold injuries were excluded. Age, gender, occupation (mountaineer/porter/student/native resident), and knowledge of frostbite and cold weather preparedness (availability and adequate usage of cold weather clothing) were noted by the researcher on-site during the course of treatment. Pre-existing risk of frostbite was assessed based on a prior history of frostbite and the consumption of tobacco or alcohol. Histories were collected from the participants to determine the altitude, duration, and probable causes of the cold injury. Frostbite was diagnosed and clinically assessed by assessing painful superficial numbness, erythema, raised plaque, and mild edema for first-degree; clear blisters, erythema, and oedema for second-degree; hemorrhagic blisters for third-degree; and necrotic involvement of deeper tissue for fourth-degree frostbite.[10-12] Dehydration was assessed subjectively based on a history of increased thirst at the time of injury, dry mucous membranes, and tachycardia.

Evacuation was often postponed until a suitable window of opportunity arose, determined by conditions of weather, communication, or evacuation capability. On-site management was initiated on presentation and continued until evacuation/healing. Elevation of the affected area and avoidance of high/low temperature exposure and movement such as rubbing and massaging were ensured. Intact blisters were preserved, while ruptured blisters were debrided and bandaged. Oral doses of diclofenac sodium 50 mg and amoxicillin-clavulanate 1000 mg were given twice a day.[5,10,12,13] Tetanus toxoid was not given as all patients had been pre-immunized.

Supervised therapeutic rewarming was initiated on-site after ensuring protection from refreezing or excessive movement and continued until evacuation/healing. Active moist rewarming was done 5-6 times a day with chlorhexidine water bath immersion at 40-43°C (104-110°F) for 15-45 minutes while maintaining a therapeutic temperature by recirculating the water.[10-13] Passive rewarming was done using sleeping bags, blankets, and by increasing ambient temperature to augment active rewarming.[12] Exposure to dry heat such as a flame or stove was avoided. A bucket, mug, saucepan, or messtin was used in the absence of a designated rewarming contain. Aloe vera 10% cream was applied over frostbitten areas, including blisters.[12] Oxygen and surgical debridement were not offered. The decision to evacuate was made based on the degree of injury, altitude/location of presentation, availability of supervised care, and previous history of cold injury. Primary responses to on-site treatment were monitored by relief of symptoms, healing of injuries, and return of function. The secondary outcome was the avoidance of evacuation in early frostbite patients. Descriptive statistics with percentages were calculated. Further prevention was advised to all patients.

Results

All patients (N = 172) were healthy, altitude-acclimatized, had knowledge of frostbite, and were prepared for cold weather. Participants' ages ranged between 16-37 years with a mean of 27.8 ± 7 years. Participants comprised 158 (91.86%, 95% CI: 87.77%-95.95%) males and 14 (8.14%, 95% CI: 4.05%-12.23%) females. Most of them (150, 87.21%, 95% CI: 82.22%-92.2%) were amateur mountaineers; others were seasoned mountaineers or porters (Table 1). All but 28 (16.28%, 95% CI: 10.76%-21.8%) had prior cold weather experience. One hundred (58.14%, 95% CI: 50.77%-65.51%) patients gave a previous history of cold injury (not necessarily frostbite), 51 (29.65%, 95% CI: 22.82%-36.48%) consumed tobacco products, and 12 (6.98%, 95% CI: 3.17%-10.79%) consumed alcohol while on the mountains. None of them were taking any medications at the time of injury.

The patients sustained frostbite at altitudes of 9000-24000 feet with a mean of 14575 ± 3848 feet (Figure 1). Mean duration of injury at the time of presentation was 2.25 ± 1.85 days. Cases of first-, second-, and third-degree frostbite were diagnosed in 107 (62.2%, 95% CI: 54.95%-69.45%), 59 (34.3%, 95% CI: 27.21%-41.39%), and 6 (3.49%, 95% CI: 0.75%-6.23%) participants, respectively (Table 2). Fourth-degree frostbite was not encountered. No associated comorbidities or complications were present. Most commonly affected sites were the fingertips (131, 76.16%, 95% CI: 69.79%-82.53%) and toe-tips (37, 21.51%, 95% CI: 15.37%-27.65%) (Table 2). Apart from fatigue and likely dehydration present in all patients at the time of injury, the contributory cold exposure is depicted in Table 3.

Evacuation under protection was done for 45.45% patients (second- and third-degree frostbite), and efforts to reduce continued exposure to cold were made during the evacuation. All third-degree frostbite patients were evacuated (Table 4). Many patients had to be treated on-site because of delayed evacuation. Therapeutic rewarming was well tolerated by all patients, albeit blistering, swelling, and pain occurred or increased after rewarming in 29 (16.86%) patients. All medications were well tolerated by all patients without any significant side effects. In 62 out of 107 (57.94%, 95% CI: 48.59%-67.29%) first-degree frostbite cases and 22 out of 59

Table 1. Distribution of Patients (N=172) in Place and Occupation

	Himalayan Region				Total
	Karakoram	Kashmir	Garhwal	Nepal	No. (%)
Seasoned mountaineer	1	Nil	Nil	10	11 (6.4)
Porter	4	3	2	1	10 (5.8)
Amateur mountaineer	61	33	56	Nil	150 (87.2)
Mountain resident	Nil	1	Nil	Nil	1 (0.6)
Total	66	37	58	11	172
Cumulative percentage	38.37%	21.51%	33.72%	6.39%	
95% CI	31.1–45.64	15.37–27.65	26.65–40.79	2.73–10.05	

Table 2. Presentation of Frostbite

	First-Degree			Second-Degree			Third-Degree		
	No.	%	95% CI	No.	%	95% CI	No.	%	95% CI
Fingertips	88	51.16	43.69–58.63	37	21.52	15.38–27.66	6	3.49	0.75–6.23
Toe tips	18	10.47	5.89–15.05	19	11.05	6.36–15.74	Nil	Nil	-
Nose	Nil	Nil	-	2	1.16	-0.44–2.76	Nil	Nil	-
Ear	Nil	Nil	-	1	0.58	-0.55–1.71	Nil	Nil	-
Cheek	1	0.58	-0.55–1.71	Nil	Nil	-	Nil	Nil	-

Table 3. Contributory Cold Exposure in Frostbite Patients

Site	Causes	No.	% age	95% CI
Upper limbs	Walking/working wearing gloves	91	52.91	45.45 – 60.37
	Walking/working without gloves	20	11.63	6.84 – 16.42
	Contact with wet gloves	13	7.56	3.61 – 11.51
	Contact with metal	3	1.74	-0.21 – 3.69
	Contact with cold fuel	3	1.74	-0.21 – 3.69
Lower limbs	Prolonged standing wearing cold weather shoes	2	1.16	-0.44 – 2.76
	Walking/working wearing cold weather shoes	35	20.35	14.33 – 26.37
	Sleeping with feet exposed	1	0.58	-0.55 – 1.71
All	Unknown	4	2.33	0.08 – 4.58

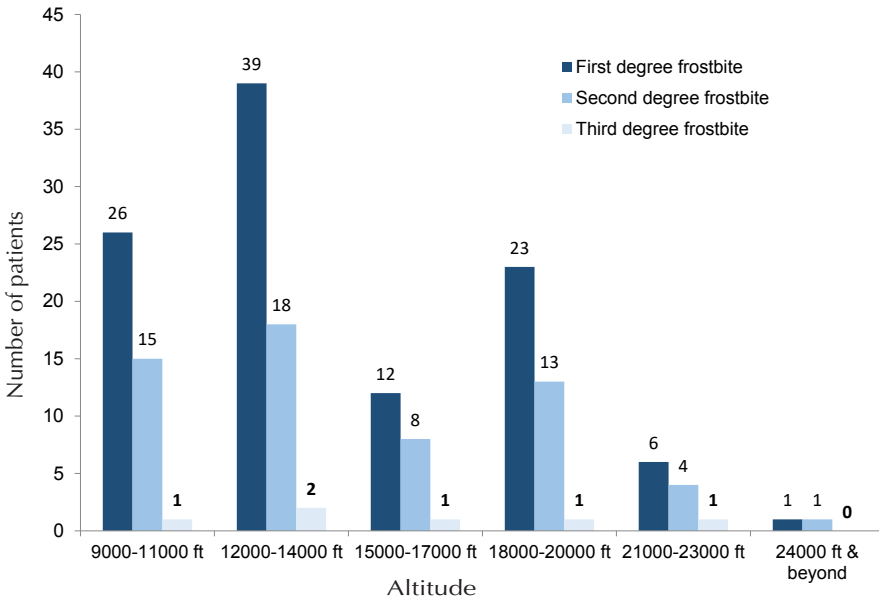

Figure 1. Presentation of Frostbite at Various Altitude.

(37.29%, 95% CI: 24.95%-49.63%) second-degree frostbite cases, the patients were treated on-site and returned to their normal routine at a high altitude while being kept under observation (Table 4). Active therapeutic rewarming was effective. Passive rewarming had limitations as the study was conducted on-site in low ambient temperatures.

Preventive measures such as preventive rewarming; contact precautions against strong soap, metals, and fuel; high-performance, expanded polytetrafluoroethylene clothing in layers; 100 ml non-alcoholic, non-caffeinated warm fluid per kg body weight per day; exercise, and education were implemented.[12,14]

Discussion

On-site treatment of frostbite in this study reflects the potential possibility of optimal treatment, avoidance of the requirement of evacuation, and early reversal to routine activities at high altitude. Therapeutic and preventive rewarming along with nonsteroidal anti-inflammatory drugs (NSAIDs) and Aloe vera can definitely be attempted under controlled and protected conditions in limited-resource, high altitude camps outside the hospital setup. People with first- and second-degree frostbite presenting early for medical help can be treated under high altitude field conditions with therapeutic rewarming forming the mainstay of treatment, although

Table 4. Treatment and Evacuation of Frostbite Patients

	Treated On-site			Evacuated		
	No.	% Age	95% CI	No.	% age	95% CI
Degree						
First-degree (107)	62	57.94%	48.59–67.29	45	42.06%	32.71–51.41
Second-degree (59)	22	37.29%	24.95–49.63	37	62.71%	50.37–75.05
Third-degree (6)	0	n/a	n/a	6	100%	100–100
Altitude of Presentation						
9000-11000 ft (42)	29	69.05%	55.07–83.03	13	30.95%	16.97–44.93
12000-14000 ft (59)	36	61.02%	48.58–73.46	23	38.98%	26.54–51.42
15000-17000 ft (21)	2	9.52%	-3.03–22.07	19	90.48%	77.93–103.03
18000-20000 ft (37)	17	45.95%	29.89–62.01	20	54.05%	37.99–70.11
21000-23000 ft (11)	0	n/a	-	11	100%	100–100
24000 ft and beyond (2)	0	n/a	-	2	100%	100–100

it is advisable only in situations of delayed evacuation. The outcome of this study was positive, though it cannot be quantified in view of ethical limitations, because no control-arm patients were included. Therapeutic rewarming on-site, as attempted in these patients, is in accordance with the latest guidelines and thus furthers the concept of physiological cold injury reversal.[12,15] Aloe vera, a potent anti-prostacyclin, inactivates bradykinins in vitro and reduces tissue loss.[12]

The occurrence of frostbite in healthy, knowledgeable travelers with prior cold weather experience is attributable to natural factors like unforeseen cold exposure as well as individual limitations in judgment, attitude, and behavior. Frostbite at high altitude occurs early due to the synergistic effects of cold, hypoxia, and dehydration often presenting as comorbidity with hypoxic disorders.[12] Hypoxia-induced cerebral impairment, noted around 4570 m/15000 ft, may affect a traveler's ability to assess frostbite risk.[5,9,12,16] In their study of 1500 patients with high altitude frostbite in the Karakoram region of the Himalayas, however, Hashmi et al found a significant association between altitude and frostbite incidence and severity. The extent and severity of frostbite also depended on temperature, duration of exposure, and individual susceptibility.[8,12] Chronic smokers, alcoholics, residents of tropical climates, and those who have previously had frostbite are more prone to frostbite, while cold-experienced or cold-acclimatized individuals may have reduced susceptibility.[17] Cold-induced distal vasoconstriction leads to frostbite developing in the toes and feet, fingers and hands, ears, face, and groin region.[12,18] As seen in this study, first-degree frostbite involving the fingers/hands and toes is the most common.[12,19] The relative inactivity of fingers while walking, frequent exposure due to personal and professional work, and inadvertent touching of cold surfaces may be contributory. Toe tips may be affected because of prolonged standing, extended outdoor work, and during sleep.

Emerging therapies with a recombinant tissue plasminogen activator, prostacyclin, nerve blocks, and oxygenation are applicable in third- and fourth-degree frostbite, but they are yet to be tested in the field on a large scale.[1,10,11] In the current study, therapeutic rewarming was tried only in first- and second-degree frostbite cases. The use of vasodilators, Chinese herbs, infrared exposure, and antimicrobial prophylaxis have been claimed to be beneficial.[12,20,21]

The successful treatment of frostbite is dependent on situational complexity. The presentation of frostbite and associated ailments to medical authorities may be delayed because of the unavailability of medical personnel; inaccessibility due to weather, terrain, or communication; a false sense of bravado; fear of deinduction from the team or mission; and poor judgment about the injury due to numbness.[9,16,22,23] High altitude-induced lassitude and indifference lead to outdoor inactivity and negligence. By the time a patient presents, the discovery of severe frostbite is expected in high-intensity, long-duration missions, such as traveler explorations, summit ascents, organized training, ferry loading by porters, and in the exuberance of mountaineers.

The present study was conducted in low-resource setups where in-patient facilities, laboratory and imaging services, advanced treatment and patient monitoring infrastructures were non-existent. Communication and evacuation facilities were severely compromised by inclement weather conditions. Patient management was done in mountain tents.[9,16,24] The subjective parameters, the absence of controls, and the absence of detailed guidelines may limit conclusions from this study, implying the need for further work in suitable field conditions or appropriate simulations incorporating elements of cold acclimatization, risk assessment of cold injuries, and appropriate modeling.[8,9,17,25,26] Multi-centric research on frostbite can help quantify the contributions of various etiologic factors; ascertain the initiation, course, and prognosis of frostbite; formulate observational diagnostic parameters; and identify feasible, effective interventions regarding evacuation and treatment. An interdisciplinary approach incorporating translational medicine and operations management capabilities is required to develop better guidelines for mountain and cold environments.

Conclusion

Frostbite can occur in people with cold-experienced and knowledgeable travelers. While it is already known that therapeutic rewarming is effective in hospital environments, the present study adds that therapeutic and preventive rewarming can be attempted in controlled and protected conditions in limited-resource setups outside the hospital. With this advancement in the existing knowledge, frostbites can be treated under high-altitude field conditions with certain limitations, although it is advisable only in situations of

delayed evacuation. Astute management, acclimatization, and travel risk assessment strategies can aid in planning traveler explorations, summit ascents, and mountain activities.

Conflicts of Interest Disclosures

No conflicts of interest.

Ethical Approval

The written informed consents and necessary advance approvals of the institutional committee were obtained prior to the start of the Himalayan expeditions/mountaineering training programs.

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Research Highlights

What Is Already Known?

It is already known that therapeutic rewarming is effective in hospital environments.

What This Study Adds?

The present study adds that therapeutic and preventive rewarming can be attempted in controlled and protected conditions in limited-resource setups outside the hospital. With this advancement in the existing knowledge, frostbite can be treated under high-altitude field conditions with certain limitations.

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