지역 병원에서 동상 환자에 대한 역학에 관한 연구 및 최근 치료

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Epidemiologic Study of Frostbites and Its Current Managements in Community Hospital

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Purpose: Frostbite is a hazard to people exposed to cold environments. With the progression of modern industrial development and change of leisure behavior encountering cold environments, frequent accidental exposure to frostbite injury during work and human behavior is increasing, and the predisposing factors of frostbite were greatly changed than before. The purpose of this study was to make epidemiological analysis, and to review the treatment outcomes of frostbite.

Methods: From March 2010 to February 2021, this study has included 27 patients with second- to third-degree frostbite injuries in Advanced Burn Reconstruction Center, Bundang Jesaeng Hospital. A retrospective study was made about the distribution of age, gender, predisposing factors, prevalent area, type of managements, and the length of treatment period.

Results: In our institution, acute management of frostbite patients has included rewarming, anticoagulation therapy (acetylsalicylic acid), and agents to improve vascular perfusion (lipo-prostaglandin E1 [Eglandin®]). The 25 frostbite patients with second-degree frostbite (92.6%) were successfully managed by the conservative treatment alone with a mean of 20.3 days healing time. Two patients with third-degree frostbite (7.4%) also showed good outcomes after surgical reconstruction with a mean of 59 days healing time. In our clinical experiences of third-degree frostbite, definitive surgical reconstruction should be recommended to wait for more than 4 ~ 6 weeks for identification of clear demarcation of necrotic tissue caused by frostbite. In this study, 43 frostbite injuries site in 27 frostbite patients occurred. Among them, 15 patients (55.6%) had multiple-site frostbite injury. The most common predisposing cause of frostbite was refrigerant gas accidents (44.4%), followed by outdoor activity in cold environments (40.8%), misapplying ice pack for treatment purposes (7.4%), barefoot walking on the cold ground (3.7%), and loss of consciousness in cold grounds (3.7%). The most prevalent sites of frostbite injuries revealed as the hand (58.1%), followed by the foot (32.6%), face (7.0%), and abdomen (2.3%). And in the winter season from the November to March, the incidence rate of frostbite injuries was high at 74.1%.

Conclusion: This study included 27 frostbite patients with 43 frostbite sites since last decade in a single institution at the community hospital. The frostbite patients with second-degree frostbite (92.6%) were successfully healed by the conservative treatment alone with a mean of 20.3 days healing time. The most common predisposing cause of frostbite was refrigerant gas accidents (44.4%), followed by outdoor activity in cold environments, etc. The most prevalent site of frostbite injuries was the hand (58.1%). And the most prevalent seasonal incidence of frostbite was from November to March (74.1%). (*J Korean Burn Soc* 2021;24:21-29)

Key Words: Frostbite, Cold injury, Refrigerant, Activity, Winter

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INTRODUCTION

A few decades ago, frostbite is an injury that occurred during the war. However, it is now becoming more frequent among the civilian population. In the current modern industrial environment, sanitation, and civilian life-

style, the predisposing epidemiological factors of cold injuries have greatly changed than before.

Frostbite causes tissue to freeze below zero (typically -0.55°C to 2°C for a long period) [1].

With the recent industrial development, the great change of modern lifestyle (e.g., using air conditioner, freezers, refrigerators, and so on) has been done, and frostbite caused by the accidental refrigerant gas is increasing in tendency. Moreover, the frostbite presentation is increasing within the populations, in particular those who are involved in winter sports (e.g., skiing, hiking, and mountain and ice climbing) [2]. Outdoor work is more frequent, and individuals with limited experience/inadequate preparation and protection find themselves at risk of cold thermal injury [3]. Therefore, the predisposing factors causing frostbite have been markedly different than in the last decade. The current study reports 27 cases of patients with second- to third-degree frostbite injuries

in the last decade; retrospectively reviews the predisposing factors, prevalent site, monthly incidence, treatment type; and emphasizes the importance of the protocols of managing frostbite.

MATERIALS AND METHODS

This study included 27 frostbite victims from March 2010 to February 2021 in Bundang Jesaeng Hospital. A retrospective study was made about the distribution of age, gender, predisposing factors, prevalent area, type of managements, and the length and types of treatment of frostbite injury.

As an acute treatment, the patients initially received re-warming of the injury site by soaking them in warmed saline attempted as a caution for hypothermia. Moreover, oral anticoagulant and intravenous lipo-prostaglandin E1 (Eglandin®, alrpostadil, $10\ \mu\text{g}/\text{day}$) were given. The pa-

Table 1. Demographic and clinical characteristics of frostbites in March 2010 to February 2021 in Bundang Jesaeng Hospital

Case no.	Gender/age	Onset month	Site of injury	Cause of injury	Degree	Operation	Treatment period (day)
1	M/73	August	Both hand	Freon gas	Second	No	16
2	M/54	October	Hand	Freon gas	Second	No	6
3	M/55	November	Both hand	Freon gas	Second	No	13
4	M/31	December	Hand	Freon gas	Second	No	5
5	F/23	April	Hand	Dry ice	Second	No	4
6	F/39	September	Hand	Dry ice	Second	No	7
7	F/6	March	Both hand	Dry ice	Second	No	10
8	M/18	June	Abdomen	Liquid nitrogen	Second	No	3
9	M/39	March	Both hand	Liquid nitrogen	Second	No	22
10	M/29	January	Both hand	R401 gas	Second	No	35
11	M/26	April	Both hand	R401 gas	Second	No	14
12	M/56	December	Both hand	Halon gas	Second	No	30
13	M/47	March	Both hand	Outdoor work	Second	No	23
14	F/59	January	Both foot	Outdoor work	Third	Yes	37
15	M/53	February	Foot	Outdoor work	Third	Yes	81
16	M/63	February	Foot	Outdoor work	Second	No	16
17	F/14	December	Both foot	Outdoor work	Second	No	11
18	M/54	November	Foot	Outdoor work	Second	No	150
19	F/42	January	Hand and foot	Outdoor work	Second	No	28
20	F/36	November	Hand and foot	Outdoor work	Second	No	10
21	M/48	November	Hand	Outdoor sports	Second	No	10
22	M/57	January	Face	Outdoor sports	Second	No	22
23	M/11	January	Both helix	Outdoor sports	Second	No	7
24	M/65	March	Ankle	Ice pack	Second	No	20
25	F/48	August	Lower leg	Ice pack	Second	No	14
26	M/49	February	Foot and hand	Walking barefoot	Second	No	14
27	M/54	January	Both foot, hand	Losing self-consciousness	Second	No	32

tient who had severe frostbite injuries was admitted and received anticoagulation therapy with aspirin. In addition, analgesic and anti-inflammatory treatment with ibuprofen were given. The frostbite's wound care consisted of cleansing and modern burn dressing method including the topical agent (silver sulfadiazine) and nanosilver dressing (Acticoat®). In the case of large bullae on the second-to third-degree frostbite wounds, the blisters were drained by needle aspiration and preserved. Consequently, the dressing was changed with topical antibiotics ointment after the blisters were dried up.

The conservative frostbite wound dressing was continuously done until the identification of clean demarcation of necrotic tissue, and then tentative management was done through excision of complete necrotic tissue and skin flap or a skin graft. Therefore, definitive treatment is usually delayed after 4~6 weeks until clear demarcation of the necrotic tissue of frostbites. The most far digital necrotic parts were managed by the autoamputation of affected digits.

RESULTS

The current clinical series of frostbite patients (n=27) was composed of 19 (70.4%) males and eight (29.6%) females whose age range was 6~73 years from March 2010 to February 2021 (Table 1).

Fig. 1. The types of predisposing cause of frostbite during March 2010 to February 2021 in Bundang Jesaeng Hospital (Total No. of Patient: 27). The most common predisposing cause was accidental refrigerant gas exposure (44.4%), followed by outdoor activity in cold environment (40.8%), misapplying ice pack for treatment (7.4%), barefoot walking on the cold ground (3.7%) and loss of consciousness in cold ground (3.7%).

As for the most predisposing frostbite causes, 12 (44.4%) patients sustained frostbite while accidental exposure to refrigerant gas (Freon® gas: 4 patients, Dry ice: 3 patients, Liquid nitrogen: 2 patients, R401 gas: 2 patient, Halon gas: 1 patient). Among the frostbite patients caused by the refrigerant, the most prevalent agent was Freon® gas (33.3%). Moreover 11 patients (40.8%) sustained from frostbite while outdoor activity (outdoor work, eight patients; outdoor sports, three patients) followed by two (7.4%) patients misapplying ice pack for treatment purposes, one (3.7%) patient barefoot walking on the cold ground, and one (3.7%) patient a loss of consciousness while sleeping winter outdoors (Fig. 1).

A total of 43 frostbite sites in 27 frostbite patients were identified, of which 15 (55.6%) patients had multiple-site frostbite injury. The prevalent sites of frostbite injuries were the hand, foot, face, and abdomen in 25 (58.1%), 14 (32.6%), three (7.0%), and one (2.3%) case, respectively (Fig. 2).

Seven patients (25.9%) sustained a frostbite injury in January, which was the highest prevalence. Moreover, frostbites injury were sustained in March (four patients, 14.8%), November (four patients, 14.8%), February (three patients, 11.2%), April (two patients, 7.4%), August (two patients, 7.4%), December (two patients, 7.4%), June (one patient, 3.7%), September (one patient, 3.7%), and October

Fig. 2. Distribution of prevalent site of frostbite during March 2010 to February 2021 in Bundang Jesaeng Hospital (Total No of frostbite sites: 43). The most common prevalent site of frostbite injuries was hand in 25 cases (58.1%), followed by foot in 14 cases (32.6%), face in 3 cases (7.0%) and abdomen in 1 case (2.3%).

Fig. 3. Distribution of onset month of frostbite during March 2010 to February 2021 in Bundang Jesaeng Hospital (Total No of Patient: 27). 7 patients (25.9%) who sustained a frostbite injury in January, which was the highest prevalence, and 4 patients (14.8%) in March, 4 patients (14.8%) in November, 3 patients (11.2%) in February, 2 patients (7.4%) in April, 2 patients (7.4%) in August, 2 patients (7.4%) in December, 1 patient (3.7%) in June, 1 patient (3.7%) in September, 1 patient (3.7%) in October.

Fig. 4. Case 1. A 49 year-old-male patient had a second degree frostbite on the his left foot showing blue-grayish discoloration on entire 1,2,3,4 distal toes and sole area on 7 Jan 2021.

(one patient, 3.7%; Fig. 3).

Twenty-five patients (92.6%) had second-degree frostbite, all of whom were completely cured with only conservative treatment during a mean period of 20.3 days (range, 3~150 days). Moreover, two patients (7.4%) with third-degree frostbite underwent partial distal digit amputation, local flap, and split-thickness skin graft (STSG; one case) and STSG due to skin necrosis (one case). In the surgical treatment cases, the mean period of wound healing was a mean 59 days (range, 37~81 days).

1. Illustrated Cases:

Case 1. A 49-year-old male patient visited the emergency department due to a second-degree frostbite injury to the left foot on 7 January 2021. The patient had no medical history was under the influence of alcohol, and

have been exposed for about 3 h at temperatures below -15°C . Clinical assessments revealed that all distal phalanx of the left foot and sole area showed blue-grayish discoloration, swelling, and distal numbness (Fig. 4). On post-frostbite day 1, hemorrhagic blisters began to form on the wound (Fig. 5). After the hemorrhagic blisters were drained by needle aspiration, the wound care consisted of saline cleansing and nanosilver wound dressing (Acticoat®) every other day. On post-frostbite day 19, the large hemorrhagic blisters dried up and changed to black thick scabs, and the dressing was changed with topical antibiotic ointments (Fig. 6). From this time on, the distal numbness symptoms on the digit gradually improved. On post-frostbite day 32, uneventful healing of the frostbite site was observed (Fig. 7).

Case 2. A 73-year-old male patient had second-degree

Fig. 5. On post-frostbite day 2, the large hemorrhagic blisters and moderate swelling developed on the frostbite sites on left foot. After the hemorrhagic blisters was drained by needle aspiration, the wound was cleansed with saline, and nano-silver dressing (ACTICOAT®) was done on 9 Jan 2021.

Fig. 6. On post-frostbite days 19, gross photographs showing the black colored large clustered hemorrhagic thick eschars, which were dry up state.

Fig. 7. On post-frostbite 4.5 weeks, on 9 Feb 2021. Well healed frostbites on his left foot with complete loss of left 3rd toe nail were observed.

frostbite injury on the right 1, 2, and 3 fingers caused by accidental Freon® gas exposure on 19 August 2017. From the initial management, the conservative dressing was done. Three weeks after frostbite, healing of the frostbite site was noted (Fig. 8).

Case 3. A 53-year-old male patient had a third-degree frostbite injury on his right great toe caused by vigorous outdoor activity. Six weeks after frostbite, full-thickness skin necrosis of the distal phalanx of the right first toe with chronic exposure of distal phalangeal bone was

Fig. 8. Case 2. A 73 year-old male patient sustained from the second degree frostbite caused by accidental Freon® gas exposure. (Left) On post-frostbite day 2, moderate large bullae on his right 1, 2, 3 fingers were shown. (Right) From the initial management, conservative dressing was done. Three weeks after frostbite, healing of the frostbite site of his right hand was noted.

Fig. 9. Case 3. (Upper left) A 53-year-old male patient had third degree frostbite injury on his right great toe caused by vigorous outdoor activity. Six weeks after frostbite, full thickness skin necrosis of the distal phalanx of right first toe with chronic exposure of the distal phalangeal bone. (Upper right) Partial osteotomy of the exposed distal phalangeal bone was done. (Lower left) A local advancement flap and STSG were done. (Lower right) After postoperative week 4, well healed frostbite site of his right first toe was noted.

noted. In week 6 post-frostbite, osteolytic finding at the distal phalanx of the right first toe was observed on X-ray examination. Partial osteotomy of the exposed distal phalangeal bone of the right first toe was done. The skin defect was resurfaced with a local flap and S.T.S.G. After postoperative week 4, the well-healed frostbite site was shown (Fig. 9).

DISCUSSION

Frostbite occurs when exposure to extremely low temperatures causes the freezing of the skin or other tissues. It brings a significant cause of long-term morbidity of the

affected sites (e.g., finger, toes, face, and extremities) because of long treatment periods.

Epidemiological studies have been usually done at military hospitals. However, civilian hospitals may more frequently encounter and treat frostbite patients with the current industrial development and change of modern lifestyle.

In 1993, Valnicek et al. conducted a retrospective analysis of 125 patients based on a 12-year multicenter experience and reported that the predisposing factors included alcohol use (46%), psychiatric problems (17%), trauma due to a vehicle (19%), vehicle failure (15%), and drug abuse (4%) [4]. In the current clinical series of patients

from March 2010 to February 2021, the predisposing factors include refrigerant accident (44.4%), followed by outdoor activities (40.7%), misapplying icepack for treatment purposes (7.4%), barefoot walking on the cold ground (3.7%), and loss of consciousness in cold grounds (3.7%). Among the frostbite patients caused by the refrigerant, the most prevalent agent was Freon® gas (33.3%). This quite difference of predisposing factors compared to the last decade is due to the change of modern lifestyle and human behavior. In particular, it is noteworthy that refrigerant-induced frostbite has emerged as the most common cause.

Regarding the predisposing factors for frostbite, Woo et al. reported a retrospective analysis of 17 cases based on a 3-year single institution experience and found that of the two patients who sustained a frostbite injury while walking barefoot, one had auditory hallucinations due to schizophrenia, but there were no patients who sustained a frostbite injury caused by exposure to refrigerant [5].

In 2015, Choi et al. reported that the most frequent predisposing factor was outdoor activities (94%), and the frequent prevalent frostbite sites were the foot, followed by the hand and face. The frequency of the multiplicity of the frostbitten area caused by outdoor activity was 55.8% [6]. This study included 43 frostbite sites in 27 frostbite patients, of which 15 patients (55.6%) had multiple-site frostbite injury. The prevalent sites of frostbite injuries were the hand (58.1%), followed by the foot (32.6%), face (7.0%), and abdomen (2.3%). Therefore, the prevalent area and incidence of the multiplicity of frostbite sites in this study showed similar results compared to the data of Choi et al.

7 patients (25.9%) sustained a frostbite injury in January, which was the highest prevalent month. And in the winter season from the November to March, the incidence rate of frostbite injuries was high at 74.1%.

The mainstream acute frostbite treatment had been rewarming, local wound care, watchful waiting, and then progression to either recovery or amputation [7]. The possible mechanisms by which hyperbaric oxygen therapy is likely to benefit frostbite-reduced reperfusion injury is possibly due to reduced endothelial adherence of neutrophils by $\beta 2$ integrins and improved microvascular endothelial oxidative stress resistance, cell proliferation, and

tube formation [8]. However, other investigations about dextran and hyperbaric oxygen therapy have not been fruitful [9,10]. Rewarming is beneficial if a partially or fully frozen part exists and is ideally accomplished using a whirlpool bath set at 38°C with added antiseptic solution (povidone-iodine or chlorhexidine). The period for optimal rewarming varies from 15~30 min to 1 h [11]. Noting the type of any blisters that form is important (they can be clear/cloudy or hemorrhagic). The recommended practice is the selective drainage of clear/cloudy blisters by needle aspiration (especially if bullae restrict movement) and to leave hemorrhagic blisters alone [12]. To prevent infection after blisters management, wound care consisted of cleansing and nanosilver dressing (Acticoat®) after the blisters were drained by needle aspiration every other day for second- to third-degree frostbite injury and are considered to be effective in preventing infection [13].

Intravenous injection of prostaglandin E1 (PGE1; alprostadil, 10 μ g/day) is a known vasodilator that increases tissue survival probably by enhancement of peripheral circulation [14,15]. Yeager et al. (1983) reported that clinical application for the use of PGE 1 in frostbite patients who have not undergone rapid rewarming was effective to prevent thrombotic injury [6,16]. Nonsteroidal anti-inflammatory drugs (NSAIDs) block the arachidonic acid pathway and decrease the production of prostaglandins and thromboxanes. These mediators can lead to vasoconstriction, dermal ischemia, and further tissue damage. Aspirin has been proposed as an option and is used in many parts of the world for anti-inflammatory and platelet inhibition effects. NSAIDs theoretically block the production of certain prostaglandins that are beneficial to wound healing [17]. Acticoat® is a range of dressings that utilize the antimicrobial properties of silver to provide an efficient and effective barrier to bacterial penetration [18]. Similar to blisters management of blisters in burn injury, wound care consisted of cleansing and nanosilver dressing (Acticoat®). Conducting a culture test following soft tissue infections and using empirical antibiotics is necessary in the event of severe edema, cellulitis, and uncontrolled infection [6].

Insidious progression of acute frostbite wounds usually showing the gray-bluish or white-colored edematous le-

sion surrounding the erythematous area are initially noted. Therefore, clear demarcation of nonviable tissue caused by frostbite should be waited on keeping with the conservative management. After clear demarcation of nonviable distal digits, autoamputation be frequently preferred. This also means that properly performed conservative treatment for a relatively long time should be considered to reduce tissue loss. According to the current study, patients with second-degree frostbite (92.6%) achieved a recovery with conservative treatment alone with a mean of 20.3 days healing time. Moreover, two patients with third-degree frostbite (7.4%) also showed a favorable clinical course after surgical reconstruction with a mean of 59 days of healing time.

Based on the current clinical experience and previous reports, the following treatment protocols for patients with frostbite injury are recommended.

First, clinicians should evaluate frostbite severity and the viability of affected tissue in the early onset stage. In addition, clinicians should use PGE1 agents, aspirin, and anticoagulants in initial frostbite management to prevent the possible occurrence of additional thrombotic injury. Moreover, NSAIDs were recommended to prevent inflammation and reduce pain. Furthermore, clinicians should use heparin, growth factors, and hyperbaric oxygen therapy in initial frostbite injury management to improve hemodynamic status. In addition, antibiotic ointment and dressing material were recommended to prevent infection on the affected wound. The clinicians should then wait for a sufficient period until the demarcation of wounds and decide on additional surgical procedures.

Ultrasound and computed tomography angiography tests can be done to assess peripheral blood circulation. In addition, magnetic resonance imaging scans to assess deep tissue damage, and laser imaging technology and Duplex flow scan for evaluation of the tissue's viability and perfusion should be done. Moreover, it is believed that the degree of frostbite will be more accurately estimated with the aforementioned examination at the early period of frostbite injury [19]. Finally, further prospective studies are warranted to examine various approaches to frostbite injury treatment, which is essential for establishing a treatment protocol.

CONCLUSION

From March 2010 to February 2021 in a 11-year single institution, we found that the predisposing factors of frostbite were greatly changed than before. In this study, the most common predisposing cause of frostbite was refrigerant accidents (44.4%), followed by outdoor activities (40.7%), misapplying icepack for treatment purposes (7.4%), barefoot walking on the cold ground (3.7%), and loss of consciousness in cold grounds (3.7%).

Among total of 43 frostbite sites in 27 frostbite patients, 55.6% of frostbite patients had multiple-site frostbite injury. And the most common prevalent site of frostbite injuries was the hand (58.1%), followed by the foot (32.6%), face (7.0%), and abdomen (2.3%). And in the winter season from the November to March, the incidence rate of frostbite injuries was high at 74.1%.

In our experiences in surgical treatment of frostbite, reconstruction should be usually waited on for more than 4~6 weeks for identification of clear demarcation of necrotic tissue caused by frostbite.

CONFLICTS OF INTEREST

The authors have no financial disclosures or conflicts of interest to declare.

REFERENCES

1. Gross EA, Moore JC. Using thrombolytics in frostbite injury. *J EmergTrauma Shock* 2012;5:267-71.
2. Hallam MJ, Cubison T, Dheansa B, Inray C. Managing frostbite. *BMJ* 2010;341:c5864.
3. Murphy JV, Banwell PE, Roberts AH, McGrouther DA. Frostbite: pathogenesis and treatment. *J Trauma* 2000;48:171-8.
4. Valnicek SM, Chasmar LR, Clapson JB. Frostbite in the prairies: a 12-year review. *Plast Reconstr Surg* 1993;92:633-41.
5. Woo EK, Lee JW, Hur GY, et al. Proposed treatment protocol for frostbite: a retrospective analysis of 17 cases based on a 3-year single-institution experience. *APS* 2013;40:510-6.
6. Choi JK, et al. Clinical analysis of frostbite. *J Trauma Inj* 2015;28:158-69.
7. Handford C, Buxton P, Russel K, et al. Frost bite: a practical approach to hospital management. *Extrem Physiol Med*. 2014;3:1-10.

8. Deepak A, Dwivedi, et al. Successful treatment of frostbite with hyperbaric oxygen treatment. *Indian J Occup Environ Med* 2015;19:121-2.
9. Mundeth ED, Long DM, Brown RB. Treatment of experimental frostbite with low molecular weight dextran. *J Trauma* 1964;128:246-57.
10. Finderle Z, Cankar K. Delayed treatment of frostbite injury with hyperbaric oxygen therapy: a case report. *Aviat Space Environ Med* 2002;73:392-4.
11. McCauley RL, Hing DN, Robson MC, Heggors JP. Frostbite injuries: a rational approach based on the pathophysiology. *J Trauma* 1983;23:143-7.
12. McIntosh SE, Hamonko M, Freer L, Grissom CK, Auerbach PS, Rodway GW, Cochran A, Giesbrecht G, McDevitt M, Imray CH, Johnson E, Dow J, Hackett PH. Wilderness medical society: wilderness medical society practice guidelines for the prevention and treatment of frostbite. *Wild Environ Med* 2011;22:156-6.
13. Ghumman A, Malic C. A novel application for Aquacell Ag in paediatric frostbite. *Burns Open* 2019;3:36-8.
14. Saito S, Shimada H. Effect of prostaglandin E1 analogue administration on peripheral skin temperature at high altitude. *Angiology* 1994;45:455-60.
15. Shin HK, Kim HC, Hong IK. Analysis of Frostbite (1), *JKBS* 2011;14:128-42.
16. Yeager RA, Campion TW, Kerr JC, et al. Treatment of frostbite with intra-arterial prostaglandin E1. *Am Surg* 1983; 49:665-7.
17. Scott E, McIntosh, et al. Wilderness medical society clinical practice guidelines for the prevention and treatment of frostbite: 2019 Update, *Wilderness Environ Med* 2019;30: 19-32.
18. Burrell, et al. Efficacy of silver-coated dressings as bacterial barriers in a rodent burn sepsis model. *Wounds* 1999;11:64-71.
19. John D. Millet, Richard K. J. Brown, Benjamin Levi, et al. Frostbite: spectrum of imaging findings and guidelines for management. *Radiographics* 2016;36:2154-69.