

Frostbite – a really rare diagnosis?

MUDr. Jaroslava Říhová

Institute of Sports Medicine, General University Hospital, Prague

Summary: With increasing availability of outdoor activities, often in extreme conditions, the frostbite cases are hardly a rare diagnosis. The frostbite—the tissue damage by exposure to low temperatures—combines problems of an acute inflammatory response induced by a physical factor with long-term healing of a chronic wound resulting from the frostbite of higher degrees. The article gives an overview of the pathophysiology, clinical picture and frostbite classification, which is fundamental for appropriate therapeutic procedures. It stresses the importance of timely treatment (commenced in the field), which is offensive, complex and requires a lot of time.

Key words: frostbite, pathophysiology, classification, prevention and treatment, case report.

With the growing popularity of outdoor activities practised in winter (skiing, ski alpinism, snowboarding, mountaineering, alpine tourism), when misadventure, sudden weather changes, or injuries cannot be excluded, frostbite cases are not a rare diagnosis. However, the frostbite is not only a "winter" diagnosis. A patient with higher grade frostbite can appear at the doctor's office during the summer as well, because at this time, the mountain tourist season, often in exotic destinations, approaches its maximum. Tourists and athletes pursue quite often these activities without necessary experience and equipment and they do not take into account the risk of frostbite, which sometimes can result in an amputation.

Typically, general practitioners often lack the experience with frostbite treatment and general surgeons tend to opt for quick solutions (cutting the blisters, early amputations). Nevertheless, it should be remembered that the treatment of frostbite must be always long-term and requires a considerable amount of patience of both, the physician and the patient. The old rule says: *"frostbite in January, amputation in June"*.

For a good treatment result, the most important is to start the treatment early—at the best provided by the layman in the field, who is equipped with the necessary material and knowledge. Subsequent professional healthcare should be supervised or consulted with an expert experienced in frostbite treatment.

The frostbite is an acute localized tissue damage induced by temperatures below the freezing point, however, in case of adverse climatic conditions even by higher temperatures. The severity of frostbite depends on duration of the cold exposure and other risk factors (humidity, wind velocity, personal equipment). Predilection body regions are peripheral parts of upper and lower limbs, face, chin, nose, and ears. Risk factors include inappropriate and wet

clothing (tight shoes, gloves), tight crampons or snowshoes, insufficient hydration and caloric intake, exhaustion, smoking, alcohol intake, and insufficient acclimatization in high altitude. Some diseases (peripheral artery disease, vasoneurosis, Raynaud disease, diabetes mellitus, hypothyroidism) or the use of certain drugs (beta-blockers) can also predispose to frostbite development (1,2,3).

Frostbite pathophysiology

The effect of cold produces physical changes in the tissues (ice crystals formation first extracellularly, later intracellularly), resulting in water and ion movements into the interstitial, and also cell membrane disruptions. The damage of the endothelial cells triggers the coagulation cascade and production of inflammatory mediators. This results in thrombi formation and microcirculation disorders. In these changes in microcirculation, a variety of vascular reactions to the cold is involved, namely alternating vasoconstriction and vasodilation (*"vascular hunting reaction"*) resulting in the **reperfusion damage**.

The vascular response leads to the final vasoconstriction and resulting tissue ischemia (progressive skin ischemia). It should be noted that the formation of thrombi in blood vessels can continue for several hours following rapid tissue reheating. Haemoconcentration and increased blood viscosity, which belongs to the pathophysiological picture of the frostbite, contribute to the tissue damage.

The result of the above mentioned processes is an **inflammatory response and oxidative stress** with overproduction of oxygen radicals. Further changes due to increased vascular permeability cause swelling, which can worsen microcirculation and healing for long time (1,2,3).

Clinical picture and frostbite classification

Initially, all frostbite have a similar appearance—initial symptoms include pale and cold skin, which loses its sensitivity. The full clinical picture, that allows determination of the damage depth, develops within a few days. Visual assessment and palpation of the affected tissue (assessment of the sensation, skin colour, presence of blisters or necrosis), and skin ability to be deformed by gentle pressure can aid the classification. Historically, frostbite has been divided into four degrees, similar to burns grading (2):

- **First-degree:** skin either with erythema, or white, cool, insensitive skin; fully reversible state.
- **Second-degree:** clear or milky coloured blisters forming within 3–24 hours, with maximum of 3 days, erythema and swelling around the area. Only the epidermis is damaged (transition between reversible and irreversible damage).
- **Third-degree:** the final clinical picture emerges after a few days—swelling, grey to black blisters, the skin can turn black, harden, can become insensitive. Deep subcutaneous tissues are damaged; in case of rapid treatment, the damage may be almost reversible.
- **Fourth-degree:** affects all skin layers, causes mummification and irreversible damage to deep tissues—tendons, muscles, bones, joints; always the healing results in tissue defects.

For the determination of the prognosis based on the clinical picture, the frostbite can be sort out as **superficial** frostbite injuries (1st and 2nd degree frostbite, when no tissue loss occurs) and **deep** frostbite injuries (3rd and 4th degree, healing mostly with tissue defect) (2).

Using a technetium-99m (^{99m}Tc) bone **scintigraphy** helps to estimate the possible tissue losses and the prognosis of the injury. In a retrospective study of French authors, correlation was found between the level of the isotope of ^{99m}Tc accumulation and absence with levels of amputation required. On the basis of the isotope absorption during the scintigraphy performed 2–4 and 7–10 days after the frostbite acquirement, we can come to a conclusion regarding the frostbite healing or deterioration. In the course of the treatment, the scintigraphy can help to identify osteomyelitis. This can be verified by increased radioisotope accumulation in the blood pool. If the accumulation occurs in the bone phase, it is a sign of an ongoing bone reparation (4,5,6).

Prevention and treatment

Prevention

In case of the frostbite injury, the golden rule *"Prevention is better than treatment"* applies more than in other conditions. It means that trips to the mountains or other risky environments should pursue only properly informed and equipped individuals. It is necessary to know the warning signs of imminent frostbite (pale, cool skin with sensitivity disorder) and not to underestimate them. In case of their occurrence, it is essential to take the necessary steps (see below — they are the same as the initial treatment), alternatively to consider return to a safe place (14).

Treatment

The basic rule is to start the treatment as soon as possible, preferably within 5 hours, not later than in 5 days. The injured person should start own initial treatment, therefore it is necessary to be equipped with appropriate drugs. The frostbite cases often take place in remote areas, far away from any hospital.

Primary measures are non-pharmacological — warming up of the affected parts using body heat (in the armpits and groins), restriction of further heat losses, seeking a warm shelter, replacing wet clothing, fluid intake, preferably hot beverages. The frostbite rewarming is carried out in a warm water bath with water temperature maintained at 38–40 °C, but only if further tissue freezing can be excluded. As a matter of principle, direct dry heat is not used and rubbing of the insensitive tissue has to be avoided.

The first pharmacological aid in the field, several drugs with an anti-aggregation, anti-inflammatory and analgesic effect (aspirin, ibuprofen) are used. The ideal first aid drugs for lay use are over the counter sold medicaments for systemic enzymatic therapy (Wobenzym or Phlogenzym). These drugs combine anti-oedematous and anti-inflammatory action with positive effect on blood rheology (anti-aggregatory and fibrinolytic effect) that improves the peripheral microcirculation. The above mentioned effects imply also a secondary analgesic effect (7, 8, 9). It was demonstrated in an experiment that the enzymatic therapy can reduce the negative effects of free oxygen radicals during the ischemia / reperfusion syndrome (10). In the initial treatment, maximal doses are recommended (Phlogenzym 3–4 tablets three times a day, Wobenzym 7–10 tablets three times a day). Laypeople with proper instructions can even use pentoxifylline (11,12,13). In general, blisters should not be perforated, sterile coverage and soft loose dressing should be applied. The detailed first aid algorithm can be found on the website of the Czech Mountaineering Association (14).

Treatment initiated in the field should be pursued until medical care facility is reached and until the clinical picture has stabilised. In case the frostbite occurred abroad, the treatment initiation should not be postponed until homecoming. Any treatment delay increases the risk of amputation / tissue losses (12).

The above mentioned treatment is sufficient for the 1st and 2nd degree frostbite injuries which can be dealt with in an outpatient clinic without permanent sequelae.

The treatment of the 3rd and 4th degree frostbite injuries are more complicated. Some cases of the 3rd degree frostbite can be treated as an outpatient case, based on the clinical findings, often resulting in complete healing; however, more extensive 3rd and 4th degree frostbite require inpatient care with parenterally administered drugs (2,3). The basic treatment is firstly fluid administration in order to increase the circulating volume and to achieve haemodilution (dextran IV), administration of drugs with anti-aggregatory, anticoagulant and fibrinolytic effect (pentoxifylline, heparin, streptokinase, urokinase) for rheological blood properties, blood flow and microcirculation

enhancement. Hyperbaric oxygen therapy has been proved efficient too (15,16).

In specialised departments, prostaglandin based medications (alprostadil or iloprost) are administered (2,3). As a prevention of tissue losses, thrombolytic treatment—the plasminogen tissue activator (tPA)—can be applied intravenously or intraarterially, occasionally in a combination with heparin or prostaglandins. The success of this drug depends on an early initiation (17,18). Antibiotics are necessary for prevention or therapy of infections; tetanus revaccination is also vital (2,3).

The 3rd degree frostbite treated unsuccessfully conservatively and in cases of the 4th degree injury, the amputation cannot be avoided, following the necrosis demarcation (2, 3,12,13).

In long-term local treatment of frostbite, other therapies are employed, like classical herbal baths (with salvia, harvest-lice, marigold), disinfectants and also modern materials for wet chronic wound healing, selected according to the wound state (dry, moist, granulating ...). A detailed list of these materials exceeds the scope of this publication. The systemic enzymatic therapy (Wobenzym, Phlogenzym) has demonstrated supporting effect in the treatment at this stage as well. The author has a good experience with their administration within a complex frostbite treatment for more than 15 years (11,12,13). Physiotherapy is essential too.

Case report

The following case report shows, how demanding and complicated the frostbite treatment in combination with polytrauma can be.

On 11 January 2020, a young woman (31 years) with two friends went hiking in the Austrian Alps. Following an unfavourable weather change, she wanted to return, but her friends persuaded her to continue. When she became exhausted, she slipped in the icy terrain and fell down approximately 500 m. The rescuers found her after 6 hours. During the fall, she suffered multiple fractures, developed hypothermia with gradual loss of consciousness and 3rd degree frostbite injury of her hands.

Subsequently, she was hospitalised in Graz (Austria), first treated for severe hypothermia with ventilation support, rewarming and complex medication. The frostbite management was handled by a plastic surgeon. Due to considerable

swellings of the hands with 3rd degree frostbite, which created a pressure on the neurovascular bundle (compartment syndrome), she required relieving operations of both palms on 13 January 2020 (Fig. 1). At the same time, intensive medical treatment of frostbite proceeded, using intravenous medication to improve microcirculation, thrombolysis and to reduce swelling.

On 22 January 2020, pelvis operation with stabilization of bone fragments followed. The palm stitches were removed on 31 January.

In the meantime, the patient's partner contacted the author and together they tried to find a clinic in the Czech Republic, which would be able to provide systematic physiotherapy after the pelvis surgery as well as long-term frostbite care.

On 7 February 2020 the patient was transported to the Czech Republic and hospitalised at the 1st Department of Orthopaedics in the University Hospital Motol. Here, the conservative treatment (antibiotics, pentoxifylline, Wobenzym, anti-diarrhoea micro-organisms Hylak, heparin SC) and local treatment of frostbite (special dressings Flamigel, Ialugen, Hemagel, and iodine ointment Braunovidone) continued. On 10 February 2020, she was transferred to the 1st Surgical Clinic of the General University Hospital in Prague, where hyperbaric oxygen therapy was also provided. She completed a total of 10 sessions (Fig. 2).

In the course of the treatment, necrotic tissue gradually demarcated, however, the ability to move the fingers was limited due to contractures, fixing the fingers in semi-flexion (Fig. 3). Therefore, the author contacted the Institution of Hand and Plastic Surgery in Vysoké nad Jizerou, Czech Republic. Since the second half of February, the patient was hospitalised several times in this hospital and commuted for outpatient check-ups. She underwent an intensive hand physiotherapy—special sleeves and bandages for straightening contractures were applied, electrostimulation and other therapeutic methods (local applications of the camomile ointment Azulen, complexion oil Bioil, herbal baths) were used.

The gradual stretching of tendons and loosening of contractures improved finger

Figure 1



Figure 2



Figure 3



Figure 4



movement and hand grip. Necrosis demarcated (Fig. 4) and since May, necrosis of soft tissues was gradually removed in the outpatient department of the 1st Surgical Clinic of the General University Hospital. Compared to its original extent, soft tissue losses were minimal and bone tissue was

not afflicted. The old golden rule was confirmed: the patient waiting, lasting up to several months, is recommended till final necrosis demarcation. The patience of the patient, all involved physicians, and outpatient frostbite specialists contributed to patient's recovery (Fig. 5).

Figure 5



Based on author's many years of experience, the patient used vasodilation medications (pentoxifylline) and Wobenzym until complete necrosis separation.

The challenging moment was to arrange an inpatient physiotherapy care following complicated pelvis fractures (insufficient pubic bone healing, damage to S1 nerve). Due to these complications, the patient had to undergo further operation at the Clinic of Spondylosurgery in mid June and her follow-up outpatient treatment took place in Centre of Physical Medicine in Prague.

During October and November, the patient continued with physiotherapy at the Department of Physiotherapy in the Beroun Hospital, practised mainly fine motor skills.

At the time of the article preparation, after one year since accident, the patient still has hyposensitivity of the right index finger, so she is still not fit for her profession (administrative worker, she cannot write on the computer). Occasionally, she needs analgesics and everyday local skin care is essential. She cannot sit for a long time owing to the pelvis injury. Walking without support is only possible for shorter distances, for a longer distance she requires forearm crutches.

The insurance company has paid for the treatment abroad and repatriation, now after a year, permanent consequences of the accident should be evaluated, however treatment is still not finished

Conclusion

Certainly, patients with frostbite injury are not frequent cases, but the frostbite diagnosis is not rare either. It should be noted that the frostbite is not exclusively a problem of athletes, it often occurs also in the homeless, alcoholics, or otherwise intoxicated people or in soldiers. However, talking about athletes, most frostbite cases could be avoided by respecting the potential hazards of the environment, limits of own capabilities and using the right equipment and material.

A separate chapter is the optimal choice of insurance (especially for activities abroad) and insurance benefits in case of permanent frostbite sequelae, which are often successfully dealt with following regular interventions of specialists in frostbite treatment.

To conclude, we can say that the mountains are beautiful but rough, and we are not always lucky. We should reflect our own responsibility too.

References

1. Murphy JV, Banwell PE, Roberts AH, et al. Frostbite: Pathogenesis and Treatment. J Trauma 2000; 48: 171-8
2. McIntosh SE, Freer L, Grissom CK, et al. Wilderness Medical Society Clinical Practice Guidelines for the Prevention and Treatment of Frostbite: 2019 Update. Wilderness Environ Med. 2019; 30 (4S): S19-S32.
3. Handford C, Buxton P, Russell K, et al. Frostbite: a practical approach to hospital management. Extrem Physiol Med. 2014 Apr 22; 3: 7. Dostupné z <http://www.extremephysiolmed.com/content/3/1/7>
4. Cauchy E, Marsigny B, Allamel G, et al. The value of technetium 99 scintigraphy in the prognosis of amputation in severe frostbite

injuries of the extremities: A retrospective study of 92 severe frostbite injuries. J Hand Surg Am. 2000 Sep; 25 (5): 969-78.

5. Cauchy E, Chetaille E, Marchand V, et al. Retrospective study of 70 cases of severe frostbite lesions: a proposed new classification scheme. Wilderness Environ Med. 2001 Winter; 12 (4): 248-55

6. Manganaro MS, Millet JD, Brown RK, et al. The utility of bone scintigraphy with SPECT/ CT in the evaluation and management of frostbite injuries. Br J Radiol. 2019 Feb; 92 (1094): 20180545

7. Jezdinský J. Systémová enzymoterapie. In: Lincová D, Farghali H, eds. Základní a aplikovaná farmakologie, 2. vydání, Praha: Galén, 2007; 606-611.

8. Nouza K. Systémová enzymoterapie. Účinné látky, vstřebávání a mechanismus účinku. Remedia. 2015; 25: 206-210.

9. Nouza K. Systémová enzymoterapie II. Klinické uplatnění, registrované indikace. Remedia. 2015; 25: 287-294.

10. Neumayer C, Fögl A, Nanobashvili J, et al. Combined enzymatic and antioxidative treatment reduces ischemia-reperfusion injury in rabbit skeletal muscle. J Surg Res. 2006 Jun 15; 133 (2): 150-8.

11. Říhová J. Omrzliny - nikdy se nevzdávat. Med Sport Boh Slov 2005; 14: 21-5

12. Říhová J. trochu jiné chronické rány. Omrzliny v létě [online] Medical Tribune 2008 [cit.01-12_2020] <https://www.tribune.cz/clanek/12505-trochu-jine-chronicke-rany-omrzliny-v-lete>

13. Říhová J. Aktuality v léčbě omrzlin - neopakuje staré chyby. Med Sport Boh Slov 2009; 18 (1): 32-37

14. <https://www.horosvaz.cz/doporuceni-informace/>

15. von Heimburg D, Noah EM, Sieckmann UP, et al. Hyperbaric oxygen treatment in deep frostbite of both hands in a boy. Burns. 2001; 27 (4): 404-8.

16. Ghumman A, St Denis-Katz H, Ashton R, et al. Treatment of Frostbite With Hyperbaric Oxygen Therapy: A Single Centers Experience of 22 Cases. Wounds. 2019; 31 (12): 322-325.

17. Twomey JA, Peltier G L, Tera RT. An Open Label Study to Evaluate the Safety and Efficacy of Tissue Plasminogen Activator in Treatment of Severe Frostbite. J Trauma 2005; 59 (6): 1350-4

18. Bruen KJ, Ballard JR, Morris SE, et al. Reduction of the incidence of amputation in frostbite injury with thrombolytic therapy. Arch Surg. 2007 Jun; 142 (6): 546-51.