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Case report

Hyperbaric oxygen treatment in deep frostbite of both hands in a boy

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Abstract

An 11-year-old boy in good general health conditions suffered deep frostbite on six fingers while he was working without gloves as a beater during a hunt in Poland at an outdoor temperature of −32°C over a 4 h-period. Three days later he was first seen by a physician who planned to amputate the affected fingers. The patient was transferred by his family to our University Hospital in Aachen, Germany. We found third degree frostbite on four fingers of the right and on two fingers of the left hand. Because of the late beginning of the therapy, the patient was treated by HBO_2 according to the Marx-schema for problem wounds (2, 4 bar, total time at depth: 90 min, alternations of 100% O_2 and air breathing). HBO_2-treatment was repeated daily for 14 days. No adverse events were recorded during the course of therapy. A total recovery of the severe frostbite was observed after 14 days of HBO_2-treatment. Twenty-eight months after the injury the patient reports fully regained sensibility and no pain. The plain X-ray after this period showed no premature closure of the epiphyses or sclerosis of the metaphyses. *Conclusions:* Because of the low risk associated with HBO_2, and its potential therapeutic efficiency, HBO_2 should be recommended as adjunct therapy in the treatment of deep frostbite.

Keywords: Frostbite; Hyperbaric oxygen therapy

1. Introduction

Frostbite is an injury that results from exposure to temperatures that are low enough to cause crystal formation in the exposed tissue. There is risk for tissue exposed to temperatures below −2°C [1]. Frostbite develops after exposure to these low temperatures for more than 1 h [2] and usually when protection from the environment is insufficient [3]. The severity of a frostbite depends on numerous factors beside the ambient temperature like wind velocity, altitude, duration of exposure, wetness of the tissue, patient's vascular status and previous exposure to cold injury [1].

Cold injury has been classified according to four degrees different from the burn depth [4]:

First degree (superficial skin): Erythema, edema and hyperemia develop in the injured areas, blisters and tissue loss do not occur.

Second degree (full-thickness skin): Erythema, vesicle formation and superficial skin sloughs occur, no deeper necrosis develop.

Third degree (full thickness and subcutaneous tissue): Local edema and grayish-blue discoloration occur and is followed by skin loss down to the subcutaneous level.

Fourth degree: Deep cyanosis without development of vesiculation or local edema is observed. There is necrosis of subcutis or below down to muscle, tendon and bone.

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A modification of the classification was introduced to compare superficial (1st and 2nd degree) and deep (3rd and 4th degree) frostbites [1]. Unfortunately there is no prognostic method which is positively accurate in the primary post-thaw period [5]. Acute phase treatment consists of rapid rewarming in a water bath (38–44°C) not warmer than 44°C over 15–30 min. The injured parts are elevated and usually blisters are debrided. Tetanus prophylaxis is executed, analgesics and antibiotic prophylaxis are given, the involved areas should keep protected and should be observed [1].

Good results have been reported in the treatment of problem wounds and frostbite by hyperbaric oxygenation [3,6] (HBO_2) but no reports on treatment frostbites using hyperbaric oxygen have been published in the last two decades. A case is presented and hyperbaric oxygen treatment for frostbite is discussed.

2. Patient

An 11-year-old boy in good general health conditions suffered deep frostbite at 28/12/1996 while he was working without gloves as a beater in Poland at an outdoor temperature of −32°C over a 4 h hunt. Six fingers were injured and rewarmed over an oven at home. With thawing the patient complained cyanotic appearance of the affected fingers and intensive pain. In the following days there was discoloration of the finger tips. He remained without medical treatment for 3 days. The surgeon of the district hospital recommended amputation of all involved fingers at the 4th day after the injury because there was no vascularisation of the involved fingertips (written report of the treating physician). The patient's uncle, who lives in Germany, asked for help in our department and we suggested to transport the patient to our hospital. The patient presented at the Department of Plastic Surgery and Hand Surgery-Burn Centre of the University Hospital in Aachen at 4/1/1997. One week after the injury there was discoloration, and there were cold fingertips and dark and white blisters (Fig. 1) at D II and D III of the left hand and at D I–D IV of the right hand. On specific examination there was two-point discrimination at the finger tips of more than 15 mm. Third degree frostbite on four fingers of the right and on two fingers of the left hand was diagnosed.

Blister debridement was performed without any anesthesia while the patient did not feel any pain. The wounds were locally treated with vaseline gauze (Jelonet®) and tetanus prophylaxis was given. Because of the late onset of therapy we decided to treat the patient by HBO_2 according to the Marx-schema for problem wounds (2, 4 bar, total time at depth: 90 min, alternations of 100% O_2 and air breathing). HBO_2-treatment was repeated daily for 14 days on an outpatient basis. After the first course of the treatment we observed rewarming of the injured fingers and pink colour at the borders of the affected parts (Fig. 2). Remarkable improvement of the wounds was seen in daily consultation. Cyanosis cleared and was limited to small areas. Three weeks after the injury the dark crusts came off. There was new epithelialised skin underneath and no loss of tissue. Five weeks after the injury there was complete healing (Fig. 3), slight erythema in the

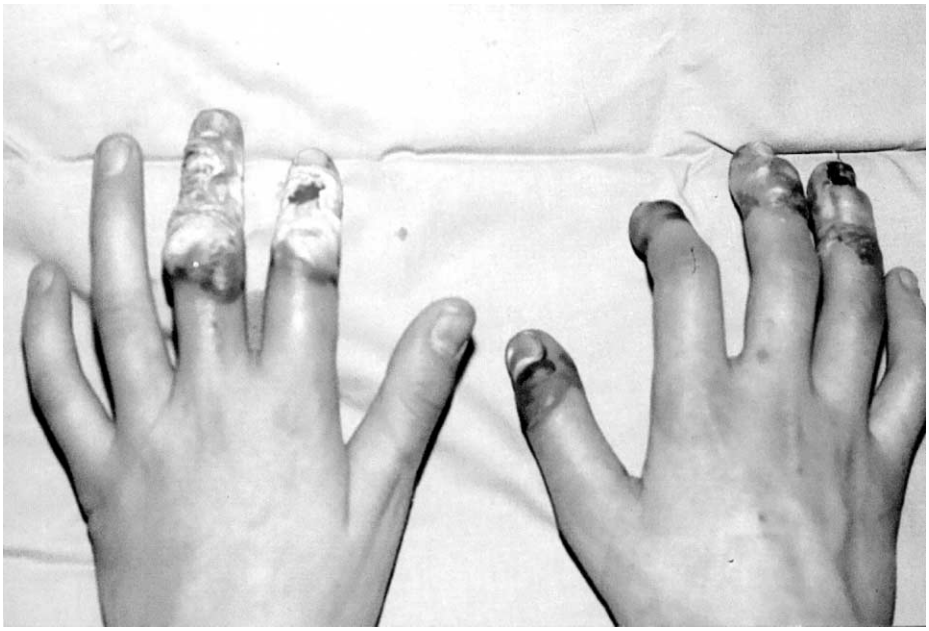

Fig. 1. Appearance of the hands at presentation to our department 7 days after cold injury, demonstrating deep frostbite.

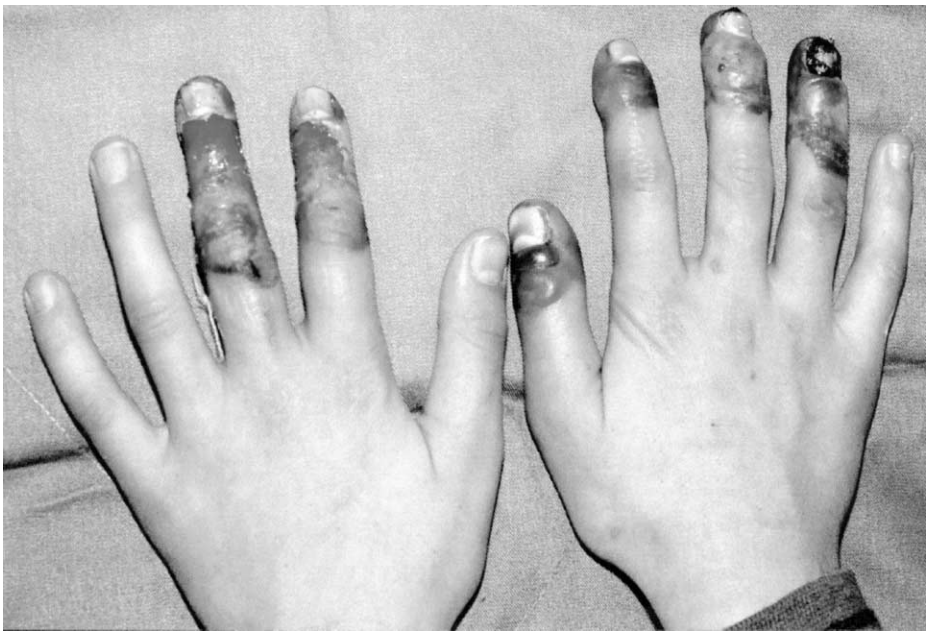

Fig. 2. Appearance immediately after debridement and first hyperbaric oxygen treatment. The affected fingers rewarm and some dark areas look better perfused.

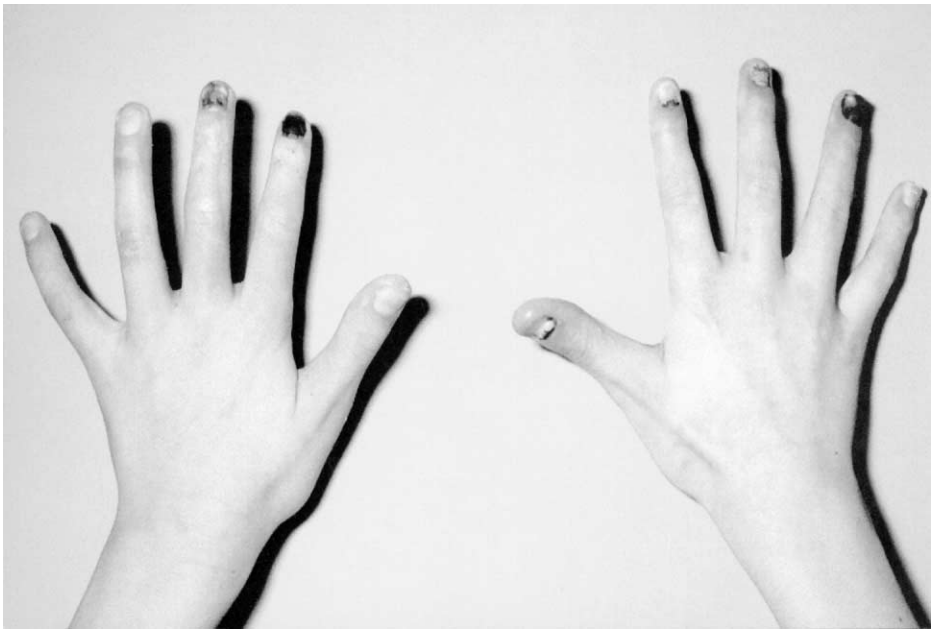

Fig. 3. Five weeks after the injury wounds are completely healed. The fingernails of D I–D III of the right hand were lost.

involved areas and fully regained sensibility. Two-point discrimination was 4–5 mm in the affected fingertips.

Twenty-eight months after the injury the patient reports no pain. The plain X-ray of both hands was obtained 28 months after the injury at his home and send to our department (Fig. 4). There is no premature closure of the epiphyses or sclerosis of the metaphyses.

3. Discussion

Outdoor winter activities like sporting [7] and moutaineering make cold injury a continued clinical problem even in Europe. Inadequate clothing, prolonged exposure due to alcohol abuse [1] [8], psychiatric disorders or accident [9] might lead to these injuries. Fingers, toes, nose and ears are most commonly involved. Immediate treatment consists of immediate re-

warming of the affected parts in warm water (40–42°C) [5]. This emergency treatment is widely accepted as well as elevation and splinting of the extremity [10]. Tetanus prophylaxis is given and analgesia as indicated, some consider antibiotic prohylaxis [1] for the first days. Local treatment concepts of the affected areas are different. Some reports consider early debridement of all blisters to be adequate [1] while other authors favour debridement only of the ruptured blisters [11].

The first case of hyperbaric oxygen treatment in cold injury was reported by Ledingham [12], further cases were reported from Perrin and Bossinnette [8] and another four cases were reported by Ward et al. [3] in patients who had suffered frostbite during mountaineering in the Alps. The treatment in this latter group started 5–10 days after the injury. Good results have been reported in the treatment of problem wounds and frostbite by hyperbaric oxygenation [3,6] (HBO_2) but no reports on frostbite treatment using hyperbaric oxygen have been published in the last two decades.

In the cold injured areas blood becomes viscous and the circulation in the capillaries slows. Vessel damage is leading to extravasation and blistering. Thrombosis may occur in the terminal arterioles. Although cellular dehydration and enzymatic damage undoubtedly contribute to the necrosis of frozen tissue, peripheral circulatory failure may play the major role in determining the extent of the eventual tissue loss [13]. Venules clott with thrombi within the first 10 min after thaw. Within 1 h, most of the capillaries are thrombosed and blood flow is maintained only from artery to vein through arterio-venous communications. Thus, while blood may continue to flow through the larger arterioles and venules, the tissues are not nourished [13]. Two different theories concerning the pathogenesis of frostbite are discussed:

1. Cold injury directly damages the tissue cells [14,15].
2. Cold produces injury to the endothelial lining of small blood vessels with a consequent increase in capillary permeability, loss of fluid from the circulation and intravascular, cellular aggregation in the injured area. The clumping of the red blood cells causes occlusion of small blood vessels with resulting tissue ischemia and necrosis [16–18].

There is no accurate prognostic method in the primary post-thaw period [5] in superficial frostbite. Magnetic resonance imaging and bone scans are adequate diagnostic tools for early assessment of the level of demarcation [19,20] only in the 4th degree frostbite. The depth of the tissue damaged depends on multiple factors leading to early visible tissue necrosis. Also late effects of frostbite on the epiphyses in the growing hand have been described [21]. The extent of premature closure is correlated with the severity and is observed even in partial-thickness injuries [10].

No adjuvant intervention but hydrotherapy (daily 30–45 min at 40°C) [5] improves reliably vascularisa-

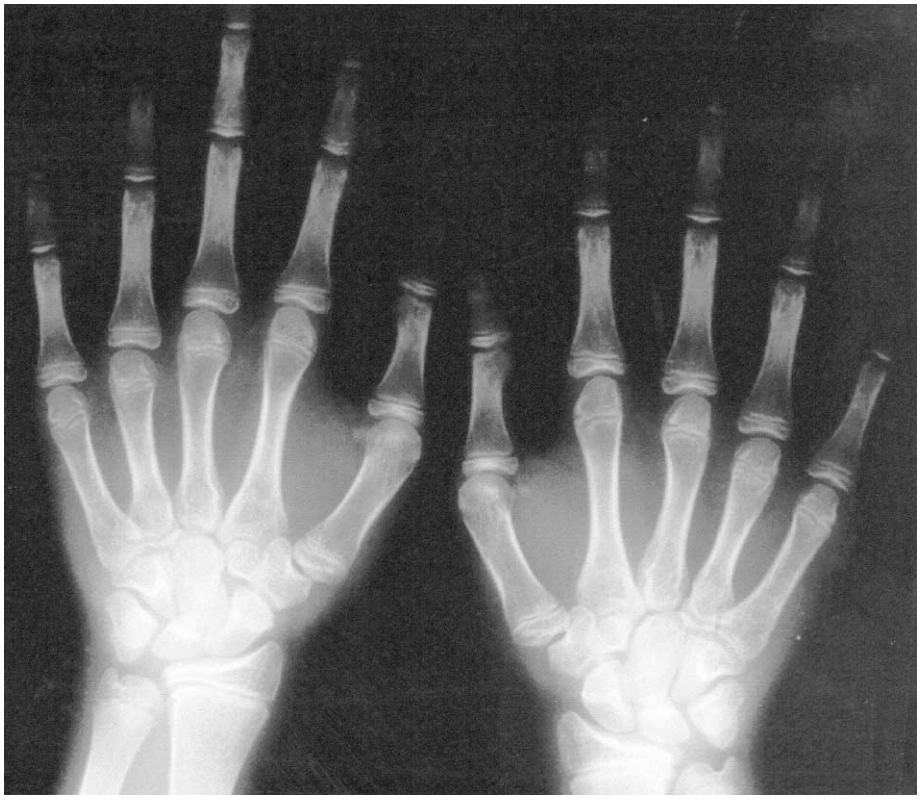

Fig. 4. Radiographs 24 months after the cold injury and HBO_2 treatment. Normal appearance of the epiphyseal structures.

tion of the affected tissues after cold injury. Heparinisation has been used to prevent intravascular thrombosis but the results have been inconclusive [14]. Pentoxifylline shows some beneficial effects in animal models [22] but it is not an accepted therapeutical agent. Inhibitors of the prostaglandin synthesis of inhibitors of free radicals such as superoxide dismutase are promising agents for the future [1,23].

The increasing local tissue oxygen tension by hyperbaric oxygen treatment improves and maintains the viability of the adjacent tissue. Therefore vascular and cellular regeneration occur at a faster way and is more efficient. Hyperbaric oxygen therapy could also be useful to prevent the late changes in the growing bones. In the present case there were no late changes in the epiphyses after more than 2 years. This conservative treatment helps to reduce hospital stay, allows early work start in the injured patients and protects from late skeletal changes. The therapy was successful in sustaining viability in the tissue following the cold injury. There are no guidelines for the treatment of frostbite by hyperbaric oxygen. The few cases do not allow establishment of a treatment plan. The Marx-schema was optimal in the present case. Daily treatment until no further improvement is observed (14 days in the present case) gave good results. Daily performed laser-doppler-flowmetry is an adequate method for assessment in the post-thaw method pre- and post-hyperbaric oxygen treatment in second and third degree frostbite. Triple-phase bone scanning [20] and magnetic resonance imaging [19] are accepted methods to assess tissue viability in fourth degree frostbite during the therapy. Standardised experimental studies on the treatment of frostbite with hyperbaric oxygen confirmed by objective measurements are necessary.

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