Hyperbaric Oxygen as an Adjunct Treatment of Freezing Cold Injury

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ABSTRACT

Although there is general agreement that the initial treatment of freezing cold injury (FCI) should be rapid rewarming to prevent direct injury from intracellular ice formation and protein denaturation, there is less conformity in the clinical intervention after rewarming. Medical treatment is directed towards the prevention of additional injury due to microvascular damage. With the exception of freezing cold injury, hyperbaric oxygen therapy is now accepted as an adjunct therapy for the management of all other acute traumatic peripheral ischaemias, such as crush injuries, compartment syndrome, thermal burns, compromised skin grafts and flaps, and threatened replantations. The present report documents our experience of using HBO as an adjunct therapy in the treatment of 10 FCI patients. All patients were experienced alpinists, which received their injury during expeditions in the Alps, Andes, Himalayas, and Pamir. All received field medical attention upon returning to base camp, and regardless of location managed to return to Ljubljana within a few days to a week for further treatment, which also included HBO therapy (HBOT). During HBOT patients were compressed to 2.5 ATA for 90 min and breathed 100% oxygen via an oro-nasal mask. During the 90-min therapy, subjects inspired 100% oxygen for 25 min followed by a 5 min air break. This was repeated 3 times. Bone scintigraphy was performed prior to the HBO treatment protocol in 7 patients. The number of HBOTs ranged from 11 to 30 per patient. In all cases, patients presented with oedema in the afflicted digits. Some patients also had haemorrhagic blisters and/or some necrosis. The progression of their recovery, and results of HBOT are largely dependent on the time between injury to the onset of HBOT, the magnitude of the injury, and the field treatment. In general, oedema subsided by the 3rd to 5th day of HBOT, and revitalisation of the affected region was evident on the 2nd day of HBOT. HBOT also caused the demarcation line to move distally. The efficacy of HBOT in the treatment of FCI depends on the time to treatment following injury. Accepting that frostbite is due, in part, to anoxia of the tissues, as a consequence of diminished circulation, then HBOT should certainly be considered as an adjunct therapy to enhance the rate of healing of the afflicted tissue, and reduce tissue loss.

1.0 INTRODUCTION

Cold-induced injury is a result of inappropriate thermal protection in hostile environments. Frostbite occurs at temperatures below 0^{o} C, and is a clinical term for what is physiologically referred to as freezing cold injury (FCI). The incidence of FCI is highest for the feet and hands and less for other peripheral tissues (ears, cheeks and nose). Frostbite results in poor outcome without appropriate treatment.

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Various methods for improving the outcome of FCI have been introduced in the past. Best results have been achieved with methods which improve the microcirculation, since vein and capillary thrombosis is the main cause of tissue damage (1). Hyperbaric oxygen therapy (HBOT) is successfully used in various microcirculation-compromised acute traumatic peripheral ischaemias (ATPI: burns, diabetes-induced peripheral ulcers, trench foot, immersion foot). The effect of HBOT on damaged tissues is complex. HBOT diminishes micro-organism proliferation, activates antimicrobial agents, activates the immune system and significantly improves PO_2 in reversibly damaged peripheral tissues (2, 3).

»Frostbite in January, amputation in June« is an old adage that cannot be afforded nowadays. Early scintigraphic scanning performed subsequently during the first 8 days after injury enables early diagnosis of deep tissue viability and encourages extended conservative treatment in cases of preserved microcirculation (4). In contrast, in cases of bone circulation pathology, early scintigraphy predicts necrosis of deep tissues and surgery can be performed earlier.

Our experience with early diagnostics, adjunct HBOT and pharmacological treatment is encouraging.

2.0 METHODS

Subjects

10 Slovenian expedition mountain climbers were diagnosed and treated in Slovenj Gradec General hospital, Clinical centre Ljubljana and Institute Jozef Stefan in Ljubljana. The classification of frostbite degree proposed by Cauchy (4) was used. The majority of these patients were treated by proper first aid protocol at the site of injury; this included rapid rewarming. The time between frostbite-event and evaluation varied between 1 and 7 days.

Bone Scanning

Bone scintigraphy is presently the most useful method of assessing frostbite injury and predicting tissue viability (5). This method is a powerful tool for the purpose of prognosis and treatment decision-making (5). Three patterns of perfusion can be discerned with this method: hyperaemic blood flow and normal delayed scans, absent blood flow and normal delayed scans, or absent flow and absent uptake on delayed images (6). The preferred diagnostic protocol is based on observations in three temporal phases: the arterial perfusion phase immediately after radiopharmaceutical application, 5-10 minutes delayed imaging of blood pool phase, and at least 3-4 hours delayed imaging.

Patients were injected with technetium 99m methylene diphosphonate, 740 MBq, and scanned with a planar gamma camera, equipped with a low energy high resolution collimator (256x 256 matrix). Perfusion imaging was performed after intravenous tracer application, one second frames for 60 seconds. Blood pool images of affected areas were acquired 5-10 minutes after tracer application and late imaging was performed approximately 4 hours later, 400, 000 counts per image.

Seven alpinists (2 females and 5 males; average age 36.5 yrs) with freezing cold injury were monitored during their treatment and recovery, over the last two years. In all clinically affected areas, in all patients, severe reduction to absence of arterial perfusion and radioactivity accumulation on blood pool scintigrams was observed. Also, good uptake of phosphonate was noted in all, but one, patients. In one patient only the distal phalanges of two fingers were not visualised. In most of the affected digits radiotracer uptake, reflecting osteoblastic activity, was increased. In both patients that had absent phosphonate uptake on delayed imaging, amputation had to be performed. In one, suffering severe frostbite with wet gangrene, the metatarsal bones were not affected, but all digits of the left leg had to be amputated. In the second patient only the distal phalanges on one foot had to be removed. No follow-up or control scintigrams were done.

Treatment Protocol

- First aid protocol.
- Emergency medical protocol on site (platelet aggregation inhibitor, rheologic drugs (Pentillin), haemodilution (Dextrane), LMWH (low molecular weight heparin), antibiotics, blister removal.
- Hospital treatment protocol (same as emergency medical protocol + HBOT + Iloprost).

During the treatment the patients had an initial bone scan (between day 2 and 7).

HBOT comprised 90-minute exposures to 2.5 ATA. Patients were breathing pure oxygen during the treatment, and had 5-minute periods of breathing ambient air at 25-minute intervals. Patients received 10-30 subsequent therapies (one HBOT per day). Iloprost, at a dose of 0.5 ng/kg/min, was administered i. v. over a period of 7-10 days.

Grading the Extent of Lesion

The initial lesions on each digit were ranked using a scale of 0 to 5.

3.0 RESULTS

The results of our diagnostic and therapeutic procedures performed on 10 alpinists presenting with freezing cold injury (FCI), as well as the final outcome in terms of tissue loss, are presented in Table 1.

Table 1: Diagnostic and therapeutic procedures performed on 10 patients presenting with freezing cold injury.

Patients	Proper first aid	On - site medical care	Number of days to clinical evaluation	FCI Grade	Scintigraphy	HBOT	Ilomedine	Amputation
1	yes	yes	2	1	no	no	no	no
2	yes	no	7	1	no	no	no	no
3	no	yes	2	3	yes	yes	yes	yes
4	yes	yes	2	2	yes	yes	no	no
5	yes	yes	2	3	yes	yes	no	no
6	yes	yes	2	3	yes	yes	yes	yes*
7	yes	yes	4	3	yes	yes	yes	no
8	no	yes	7	3	no	no	yes	yes
9	yes	no	3	2	yes	no	no	no
10	yes	yes	2	1	no	no	no	no

* wet gangrene

4.0 CONCLUSIONS

- Proper and immediate field first aid (rapid rewarming) of FCI is essential.
- Scintigraphy provided relevant information regarding tissue viability, and appears to have accurately predicted the lesions that later needed surgical intervention. It should be promoted as a standard diagnostic tool for FCI. If possible, the first scan should be performed on day 2, and the second, if needed, on day 8.
- HBOT:
    - Is an adjunctive therapy.
    - Should commence immediatelly, or as soon as possible, to achieve good results.
    - Further data are needed to determine the optimal dosage of HBO.
    - The demarcation line moved distally in all patients treated to date.
    - Tingling and burning sensations were reported in frostbitten areas by the patients.
    - Controlled animal model studies have to be performed to establish exact value of HBOT.

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