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Hyperbaric Oxygen Promotes Wound Healing and Reduces the Risk of Amputation

ABSTRACT

KEY WORDS: hyperbaric oxygenation, chronic wound, gangrene, chronic limb-threatening ischemia

BACKGROUNDS. The aim of this pilot study was to determine the benefits of hyperbaric oxygen (HBO) therapy for chronic wounds in patients with chronic limb-threatening ischemia (CLTI). **METHODS.** The study was performed as a retrospective cohort study, with five patients with CLTI included. Patients were treated with HBO after endovascular treatment (EVT). Treatment sessions involved daily exposure to high oxygen at higher-than-atmospheric pressures in a hyperbaric chamber. **RESULTS.** Out of five patients with CLTI, three had diabetes, while two did not. Following EVT, three patients underwent toe-level amputations, and two required a debridement of necrotic tissue. HBO therapy administered post-EVT enhanced wound healing, eliminating the need for further amputations in all five patients. **DISCUSSION.** The treatment of chronic wounds in patients with CLTI requires a multidisciplinary approach. HBO therapy can be used as an adjunctive therapy to the standard therapy modality, as it can increase the healing rate of wounds and reduce the number of amputations.

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BACKGROUNDS

Hyperbaric oxygen (HBO) therapy promotes the healing of ischemic wounds by utilizing high levels of oxygen to achieve antimicrobial effects and stimulating long-term neovascularization (1–3). This treatment can be particularly beneficial for patients with chronic limb-threatening ischemia (CLTI) and nonhealing wounds. The most common cause of peripheral arterial disease leading to CLTI is atherosclerosis, which is frequently associated with arterial hypertension, hypercholesterolemia, smoking, and diabetes mellitus. In these patients, non-healing wounds typically develop in areas of foot trauma caused by improperly fitting shoes or injuries (2). Treating nonhealing wounds in CLTI patients requires a multidisciplinary approach, with the primary goal being limb preservation. However, many patients still require amputation (3). Revascularization therapy (RT) can often limit the need for major amputations, instead resulting in minor amputations, such as at the toe level, which generally preserves ambulatory functions. Although revascularization is necessary, it can sometimes cause the spread of infection due to remaining gangrene or necrotic tissue. Consequently, early debridement of necrotic tissue or minor amputation of gangrenous areas is usually recommended soon after the revascularization procedure (3).

HBO therapy involves the intermittent inhalation of 90–100% oxygen at a pressure higher than 1 atm absolute. HBO therapy favourably increases the amount of oxygen dissolved in arterial blood and leads to hyperoxia even in poorly perfused tissues (4–6).

A minimal skin perfusion pressure (SPP) of over 40 mmHg is generally required for a planned minor amputation, such as at the toe level, after RT. However, higher perioperative SPP values in patients with SPP above 40 mmHg are associated with better success rates for the procedure (3).

The duration and number of HBO therapy sessions patients typically receive depend on specific protocols tailored to each individual. Each person and condition are unique, so the protocol is determined by a hyperbaric medicine specialist. Hyperbaric treatment sessions can range from one to two hours (7). Most treatments are administered once a day, five days a week, and can continue for several weeks. In severe cases, sessions may occur twice daily. Non-healing wounds typically require an average of 25–40 therapy sessions (7).

METHODS

The study was conducted as a retrospective cohort study. It included five patients with CLTI accompanied by ulcers or gangrene who received HBO therapy following successful endovascular treatment (EVT) at the University Medical Centre Maribor between December 2022 and November 2023. HBO therapy was administered at 1.5 atm with 90% oxygen for 90 minutes per session daily, except on weekends, for 20–40 sessions.

Wound healing was assessed at the end of HBO therapy and again six months after treatment. Outcomes were determined based on the results of wound healing. Complete wound closure without any leakage was considered a successful healing outcome. Both healing and minor amputations were regarded as favourable outcomes. Conversely, no improvement or major amputations were considered as unfavourable outcomes.

RESULTS

The study involved five patients with CLTI (three males, two females) with an average age of 64.2 ± 7.3 years (table 1), which were all previously treated at the University Medical Centre Maribor. There was no clinical improvement in any leg treated with technically successful EVT. The average number of HBO sessions was 42.0 ± 23.9 . HBO chamber treatments began a few days

after EVT for all but one patient, with an average start time of 8.7 ± 5.9 days post-EVT. Toe-level amputations were performed in three patients after EVT, and necrotic tissue debridement was required in two limbs.

All patients responded positively to the treatment. The introduction of hyperbaric oxygenation halted the progression of gangrene, and after three weeks of daily treatments, the wounds became clean and began to show signs of healing. Upon treat-

ment completion, the wounds were successfully healed (figure 1). Pain relief was typically achieved after an average of six sessions, and over 90% of patients experienced an improvement in their ability to walk without discomfort. In addition to standard wound healing assessments for the legs, we conducted quality of life evaluations through patient interviews. We observed improved vitality and well-being in all patients.

Table 1. Characteristics of patients. AH – arterial hypertension, HLP – hyperlipidemia, DM – diabetes mellitus, WC – Wagner Classification.

Patient	Age	AH	HLP	DM	Smoker	Obesity	Previous	Minor amputation	Major amputation	Pre-treatment WC	Post-treatment WC
1	65	yes	yes	no	yes	no	yes	yes	no	3	2
2	70	yes	yes	yes	no	yes	yes	yes	no	3	2
3	53	yes	yes	yes	no	no	yes	yes	no	2	1
4	62	yes	yes	yes	yes	no	yes	no	no	2	2
5	71	yes	yes	no	yes	no	yes	no	no	3	1



Figure 1. Clinical case from practice before (left) and after (right) hyperbaric oxygen (HBO) therapy, where successful healing was achieved after 40 sessions.

DISCUSSION

In patients with CLTI, persistent hypoxia prolongs wound healing. HBO therapy exposes the patient to an environment with elevated atmospheric pressure and increased oxygen concentration, leading to tissue hyperoxia. This can be beneficial due to antimicrobial effects and the increased activity of white blood cells (1–7). Additionally, HBO therapy may promote long-term neovascularization (1–3). It is essential to distinguish between oxidative stress and oxygen toxicity. While excessive reactive oxygen species (ROS) are associated with harmful effects, studies have shown that the body's antioxidant defences protect against the limited ROS generated during HBO therapy sessions (7).

Limitations

This study has some limitations. First, it was conducted as a retrospective cohort study with a small sample size and, second, there was no control group for comparison.

CONCLUSION

Our research suggests that HBO therapy could be beneficial for patients with CLTI and nonhealing wounds following successful EVT, regardless of whether they have diabetes or not. Hyperoxia might also aid wound healing in patients for whom EVT was unsuccessful. Further studies that include a larger number of patients are needed.

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