

Topical Hyperbaric Oxygen Therapy For Lower-Extremity Wound Care: An Overview

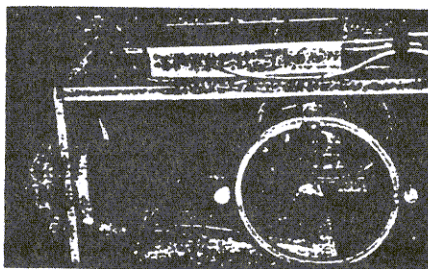
by Francis Rossi, D.P.M. and Elisabeth Elsinger, D.P.M.

Local wound care poses a constant challenge to the podiatric physician. With the arsenal of treatments available one must stay atop all modalities to guarantee his/her patient the best care possible. The health care market has recently skyrocketed in its product line coverage for local wound management. Some of the numerous products available include: wound cleansers, absorbent dressings, foam dressings, occlusive dressings, collagen-based particles, enzymatic debriding agents, hydrogels, hydrocolloids, porcine skin grafts, platelet-derived growth factors and topical hyperbaric oxygen. With so many possible treatment regimens it is of utmost importance that the podiatrist stay educated and up-to-date on all avenues of local wound care.

Ulcerations can develop due to several underlying medical pathologies, such as arterial and/or venous insufficiency, diabetes, sickle cell anemia, burns, infection, etc... Diabetes is the disease state most commonly associated with ulcerations and subsequent amputations. Current estimates by the American Diabetes Association state that there are at least 14 million diabetics in the United States, one half of whom are probably undiagnosed.⁽¹⁾ These studies go on further to reveal that the rate of lower extremity amputation among diabetics is greater than 40 times that of nondiabetics.⁽²⁾ It is estimated that 25% of all diabetics' hospital admissions are for pathologic conditions of the feet.⁽¹⁾ Other factors responsible for increasing risk of amputation include, but are not limited to, the following: peripheral neuropathy, peripheral vascular disease, a contralateral amputation, low levels of high density lipoproteins, poor patient compliance with the disease and impaired oxygen availability.⁽²⁾ With the above statistics mentioned it is obvious why excellent local wound care must be delivered.

One therapy option that has recently received much attention is hyperbaric oxygen, HBO. It has been in the clin-

ical setting since 1943, when systemic hyperbaric oxygen chambers were used by the United States Navy for decompression sickness and air embolism. Since that time there has been much speculation about its efficacy and safety because it was difficult to conduct double-blind, prospective trials. Nonetheless, the physiologic basis behind the



utilization of oxygen therapy has been studied extensively. Due to the recent demand for more effective treatments of open wounds, hyperbaric oxygen therapy has been more thoroughly investigated.⁽³⁾ Various experiments have been performed using HBO on open wounds caused by venous and/or arterial insufficiency, burns, diabetes, pressure/aging, trauma and various skin disorders. The results and conclusions of these trials have been quite encouraging and will be discussed in this article.

The primary indication for topical hyperbaric oxygen treatment is tissue hypoxia. Tissue hypoxia may stem from local as well as systemic processes. Large vessel disease is the most problematic cause of hypoxia and would need to be addressed on a different level, such as a bypass procedure. Hypoxic wounds may also be related to local causes, such as autonomic neuropathy, infection, or microvascular disease. These scenarios are not repairable with a bypass.⁽⁴⁾

Oxygen serves as a fundamental healing element for chronic wounds in many ways. Significant clinical research has been performed to determine the role of oxygen in healing wounds. Oxygen is considered vital in collagen synthesis, enhancement of fibroblasts, angiogenesis, upregulation of platelet-derived growth factor receptor (PDGF-R) mRNA activity and

leukocyte function.^(3,4,5) It has been shown that the oxygen level of an ulcer must be greater than or equal to 40 mm Hg for wound fibroblasts to begin normal collagen production.⁽⁵⁾ New capillary formation has been identified as early as 2 days after the onset of hyperbaric oxygen therapy.⁽⁴⁾

Tissue Oxygen tension is the major component in determining the progress of wound healing. Microbial killing capacity of the neutrophil have proven to increase linearly with increased oxygen tension. These neutrophils then have supranormal killing ability when exposed to the hyperbaric environment provided by HBO. Hyperbaric oxygen therapy is bactericidal for several anaerobes.⁽⁶⁾

Wounds can not differentiate the manner that oxygen is transported. Whether oxygen reaches the ulcer bed by hemoglobin or by dissolving through plasma is not important. "Providing an adequate oxygen gradient from the capillary to the hypoxic tissue bed is the only requirement that must be fulfilled in order for tissues to benefit."⁽⁷⁾ Hyperbaric oxygen is the modality of choice to raise tissue oxygen content.

An additional positive feature of topical hyperbaric oxygen therapy is its capacity to inhibit lipid peroxidation. HBO also increases the local tissue levels of superoxide dismutase, which neutralizes destructive free radicals.⁽⁴⁾ These damaging oxygen free radicals have been significantly involved in the pathophysiology of PVD, retinopathy, CVA and poor wound healing.

Topical hyperbaric oxygen therapy, when delivered intermittently at positive pressures, can reduce edema by elevating tissue pressure in the affected area. Venous blood and lymphatic flow are subsequently increased, thus allowing for increased movement of fluids out of the area.⁽⁴⁾

Hyperbaric oxygen therapy can be delivered in 2 manners: full body chambers, or portable units for local application. Full body units can be further subdivided into multiplace chambers—which simultaneously treat sev-

eral patients who breathe pure oxygen from masks—or monoplace chambers which are designed for single patient usage.⁴¹ Two types of portable hyperbaric oxygen devices are commonly utilized for extremity application: a disposable one-piece chamber made of polyethylene bags; and a chamber consisting of rigid Plexiglass that is hermetically-sealed, with oxygen delivery occurring through rubber tubing. In the rigid chamber, latex sleeves surround the limb, creating a seal around the extremity. In both of the above-described portable devices the flow rate and pressure of oxygen are controlled.⁴²

The Undersea and Hyperbaric Medical Society has given approval for systemic hyperbaric oxygen to be used to treat the following disorders: air/gas embolism, burns, carbon monoxide poisoning, clostridial myonecrosis, compartment syndromes, decompression sickness, necrotizing fasciitis, osteomyelitis, compromised skin flaps and open wounds.⁴³ Disorders that commonly benefit from topical hyperbaric oxygen include: osteomyelitis, open wounds, burns and necrotizing fasciitis.

Central nervous system and pulmonary toxicity associated with systemic hyperbaric oxygen therapy have been reported. These toxicities, however, are isolated to systemic, not topical therapy.

Topical hyperbaric oxygen dissolves through the superficial tissues of an ulceration; therefore it does not result in systemic absorption of oxygen. In addition, since the oxygen is in direct contact with the ulcer, lower oxygen pressures are required to achieve wound healing. In contrast, systemic hyperbaric therapy for open wounds is accomplished through the dermal capillaries to the periphery of the ulcer and finally to the granulation tissue.⁴⁴ With systemic therapy, oxygen has a much farther distance to diffuse before reaching the hypoxic ulcer bed. Problems associated with cross-contamination have also been reported with systemic oxygen chambers, due to the difficulty and cost of proper sterilization. Portable hyperbaric chambers do not have this drawback.^{45,46}

Fischer⁴⁷ performed several investigations on the efficacy and safety of topical hyperbaric oxygen in the 1960's and 70's. In a 1969 study of top-

ical hyperbaric oxygen treatment, he found no adverse reactions and had 52 patients with ulcers heal successfully, with only 6 failures. He chose subjects with ulcers due to various etiologies: diabetes, venous stasis, pressure, trauma and vascular disease. In a similar 1975 experiment, Fischer found equally promising results. In both studies, Fischer used a hermetic chamber with pressure settings maintained at less or equal to 22 mm Hg and with an oxygen delivery rate of 4 liters/minute. He concluded that the therapy was safe, inexpensive and simple.⁴⁸

Heng performed an investigation in 1984 utilizing the disposable polyethylene bags for topical hyperbaric oxygen treatment on 27 chronic arterial ulcers on 6 men. She had 10 similar ulcers on 5 men act as controls. Her results revealed that 18 of 27 ulcers (5 of 6 men) healed within a maximum of 21 days

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with 7 of the remaining 9 open wounds reducing in size by 50-90%. None of the control group ulcers healed. In Heng's study oxygen was delivered at a rate of 15 liters/minute for 4-6 hours during each treatment. Therapy was administered for four consecutive days each week for 2-3 weeks. This study demonstrated that even ulcers of ischemic origin can benefit from HBO.⁴⁹

Studies by Attinger, Basile and Delaney, on patients with partially gangrenous Achilles tendon, were done utilizing topical hyperbaric oxygen as an adjunctive method in preparing the wounds for split thickness skin grafting. They used topical hyperbaric oxygen set at 50mm Hg intermittently. Their preliminary results have demonstrated that topical HBO therapy is a successful wound care option.⁵⁰

Transcutaneous oxygen measurements (TCOM) serve as an effective way to monitor the progress of topical hyperbaric oxygen therapy. Critical oxygen

levels necessary for wound healing have been established. The majority of studies reveal that oxygen pressure greater than or equal to 40mm Hg leads to uncomplicated healing; between 30-40mm Hg gives an inconsistent response and measurements below 30mm Hg are almost always associated with failed or retarded healing. When utilizing Hyperbaric oxygen therapy on patients, it is ideal to use TCOM to monitor for incremental increases in wound oxygen levels.⁵¹

Topical hyperbaric oxygen therapy can serve a major role in the wound care market. It has been shown that regardless of the etiology of an open wound, topical hyperbaric oxygen can be effective. With so many patients confined to hospitals, nursing homes and like facilities due to debilitating ulcers, topical HBO provides a viable treatment option.

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