

# Topical Hyperbaric Oxygenation in the Treatment of Recalcitrant Open Wounds

## A Clinical Report

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This clinical report 1) discusses various conventional wound-care treatments, 2) discusses the effectiveness of topical hyperbaric oxygenation (THO) in treating ischemic lower extremity ulcers and preventing amputation of the limb, 3) provides treatment guidelines for improving the quality of wound care for recalcitrant cases, and 4) presents two case studies supporting the efficacy of THO. Although other factors in the treatment have important effects, I attribute the success and improved rate of healing to THO therapy in these two cases. Further studies are needed of the effectiveness of THO therapy in improving circulation in ischemic lower extremity wounds, thus preventing amputation and the loss of independence, mobility, and self-esteem.

**Key Words:** Oxygen, Physical therapy, Skin ulcer, Wound healing.

Oxygen is essential to wound metabolism for energy production, collagen synthesis, and cell proliferation.<sup>1</sup> A lack of oxygen to the tissue often results from a decrease in circulation caused by atherosclerosis. This is primarily a disease process in which lipid deposits, or atheromatous plaques containing substantial amounts of cholesterol, infiltrate the subintimal layer of the arteries, causing degenerative changes in the arterial wall.<sup>2</sup>

Atherosclerosis is clinically important because it affects primarily the coronary, cerebral, and peripheral arteries. It develops insidiously and probably is caused by a combination of environmental and hereditary factors.<sup>2</sup> Peripheral vascular disease (PVD) is a common form of atherosclerosis that extends into the peripheral arteries. Ischemia usually develops in the affected lower extremity, resulting in edema with areas of redness of the skin. As deeper layers of the skin are affected, an ulcer forms.<sup>3</sup>

Oxygen metabolism plays an important role in the healing of ulcers.<sup>4</sup> A decrease in oxygen available to the wound, which already is apparent in patients with atherosclerosis, therefore, may result in poor healing. Other factors that limit healing are cigarette smoking

because it interferes with oxygen metabolism<sup>5</sup> and concentrations of bacteria greater than 100,000 per gram of skin.<sup>6</sup> Because oxygen metabolism also suppresses bacterial growth, it promotes healing.<sup>1,7,8</sup> If therapeutic wound care is unsuccessful for patients with ischemia in their distal lower extremities, amputation may be imminent, and a difficult postoperative course often ensues, especially for elderly patients.<sup>9</sup>

The purposes of this clinical report are to 1) discuss various conventional wound-care treatments, 2) discuss the effectiveness of topical hyperbaric oxygenation (THO) in treating ischemic lower extremity ulcers and preventing amputation of the limb, 3) provide treatment guidelines to improve the quality of wound care for recalcitrant cases, and 4) present two case studies supporting the efficacy of THO.

### CONVENTIONAL WOUND TREATMENTS

Numerous conservative treatments have been suggested for facilitating wound healing. Abramson et al reported the effectiveness of histamine by ion transfer in the treatment of patients with progressive systemic sclerosis, sickle cell anemia, and neurotrophic and venous stasis ulcers.<sup>9</sup> No signs of healing, however, were reported in patients with ischemic ulcers. In a study by Mester et al, wound healing was stimulated by laser radiation.<sup>10</sup> This increased rate of epithelial growth may promote neoplastic growth<sup>10</sup>; however, further research is needed to support this hypothesis.

Many topical agents have been found to be successful in promoting the healing of ulcers. Romasz et al reported treating suppurative ulcers with dextranomer beads (Debrisan<sup>®</sup>) to improve healing, but their findings of its effect on ischemic ulcers were inconclusive.<sup>11</sup> Rao et al reported collagenase ointment (Santyl<sup>™</sup>) to be useful in decreasing necrotic tissue.<sup>12</sup> This finding correlated with an increase in granulation tissue and a decrease in pus, odor, and inflammation.

In a clinical investigation by Gupta and Saunders, chronic leg ulcers in elderly patients were treated successfully with bed rest.<sup>13</sup> Although their sample was small (N = 6) and included one ischemic ulcer, four of the wounds healed completely and the remaining wounds decreased in size by 50%. The authors, however, failed to specify which wounds healed completely.

The use of electrical currents also has been documented as successful in healing ulcers. Low frequency transcutaneous electrical nerve stimulation applied to the webspace between the first and second metacarpal bones has been found to be successful in improving microcirculation in ischemic limbs, thereby, decreasing pain in patients with Raynaud's phenomenon or diabetic polyneuropathy<sup>14</sup> and accelerating the healing of various chronic skin ulcers.<sup>15</sup> Low intensity, direct current (LIDC)

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<sup>®</sup> Johnson & Johnson Products, Inc, 501 George St, New Brunswick, NJ 08903.

<sup>†</sup> Knoll Pharmaceutical Co, 30 N Jefferson Rd, Whippany, NJ 07981.

treatment has been found to be effective in healing ischemic ulcers<sup>16</sup> by stimulating the proliferation of fibroblastic cells and microcirculation.<sup>17</sup> In a study by Carley and Wainapel, the wounds of patients who received LIDC treatment healed 1.5 to 2.5 times faster and required less débridement than those of patients who did not receive the treatment, and the scars of their healed wounds were more resilient.<sup>18</sup>

Whirlpool therapy has been used widely in the clinic for cleaning debris from skin and open wounds and for increasing the superficial skin temperature for the relief of pain.<sup>17</sup> Pain relief is achieved by the contact of the warm water bath with the skin causing certain reactions in the deeper lying tissues. If the temperature of the local blood supply is raised 0.1°C, the hypothalamus responds by causing vasodilatation of the deeper tissues underlying the area exposed to the intense heat, thereby increasing circulation to the local area.<sup>17</sup> If the patient has chronic arterial insufficiency in the segment being treated, the larger the area exposed the less the capability of adequate dilatation to supply the demand and the greater the chance of causing increased pain because of the vasospasm induced by rebound.<sup>17</sup>

## TOPICAL HYPERBARIC OXYGENATION

Topical hyperbaric oxygenation is among the many conventional treatments for open wounds. In a clinical study conducted by Kaufman et al, THO treatment of burn wounds promoted epidermal mitosis and migration, as well as collagen synthesis and contraction of the wound.<sup>4</sup> Kaufman et al also found that oxygen in excess of that required for tissue maintenance was required for tissue healing.<sup>4</sup>

Tan et al reported an increased survival rate for island skin flaps in rats with hyperbaric air (21% oxygen) and hyperbaric oxygen (100%) application.<sup>19</sup> Complete healing of intractable cutaneous ulcers including burns, pressure sores, venous stasis ulcers, and infected wounds with THO up to 25 mm Hg was reported by Fischer, but no signs of healing were detected in ischemic ulcers.<sup>20</sup> Despite these findings, THO was used in the following case studies as a treatment alternative to bed rest because of the latter's debilitating effects, an alternative to LIDC treatment because of the

extensive area requiring treatment using that method, and an alternative to low frequency TENS because its effectiveness in producing vasodilatation was unknown to me before this study.

Topical hyperbaric oxygenation is easy to apply and comfortable for the patient. A hyperbaric oxygen chamber† encloses the ulcer, and pressurized oxygen is applied topically to the wound at pressures up to 810 mm Hg in a cyclic fashion. For best results, necrotic tissue should be removed from the wound before THO is administered.<sup>14</sup>

The hyperbaric oxygen chamber is based on the principle that wounds will heal faster if more oxygen is available to the healing tissue. The hyperbaric oxygen unit externally saturates the tissue with oxygen, thus, reportedly facilitating healing.<sup>4,6,7,19,20</sup> It encourages the proliferation of granulation tissue, neovascularization of capillaries, and epithelium formation.<sup>1,20-22</sup>

Topical hyperbaric oxygenation therapy suppresses bacterial growth by increasing the redox potential and stimulating white cell production. It destroys anaerobic bacteria by increasing the production of superoxides and hydrogen peroxide. Its bactericidal effect on aerobic bacteria is attributed to the ability of oxygenation to strengthen the host defense mechanism.<sup>1,7,8</sup>

## TREATMENT GUIDELINES

Based on clinical experience, I propose the following treatment guidelines to improve the quality of care of recalcitrant ulcerations. Intractable wounds often will demonstrate some healing and then plateau. If this persists for a period of three weeks or longer, I recommend changing the treatment protocol according to the following guidelines:

1. Evaluate the condition and progress of wound healing daily.
2. Provide judicious wound care with débridement as often as needed.
3. Taper the present modality treatment frequency.
4. Add an alternative treatment modality.
5. Continue THO for a protracted period of time.
6. Prohibit smoking.

Although these guidelines are extensive and may impose greater emotional

and financial demands on the patient than conventional treatment methods, they are worthy of consideration when other conservative treatments have been unsuccessful and amputation is imminent. Research is needed, however, to warrant their support.

## CASE 1

### Background

This patient was a 54-year-old man diagnosed as having arteriosclerotic cardiovascular disease (ASCVD), angina pectoris, adult onset diabetes mellitus, and PVD. His medical history included a right cerebrovascular accident with good recovery except for decreased sensation in the left foot, a left lumbar sympathectomy, and bilateral lower extremity angiography demonstrating a 90% blockage of the left femoral artery and total occlusion of the right common iliac artery.

### Status

The patient denied all medical problems except for his stroke and PVD. He neglected his diet and continued to smoke cigarettes throughout the THO therapy session, factors that probably delayed his healing process. He was not a good surgical candidate for grafting because of potential complications that could result because of his extensive ASCVD and PVD.

The patient had several ulcers on his distal left lower extremity of 10 months' duration that had been treated primarily with silver sulfadiazine creme (Silvadene®) before the THO treatment (Fig. 1). The foot ulcers had shown gradual healing, but the ulcers at the knee and tibia demonstrated poor healing. The patient reported progressively severe left foot pain of nine months' duration, limiting his ambulation to less than half a block and eventually confining him to a wheelchair for a month before the THO treatment. He initially was referred for whirlpool treatment of the proximal ulcers only.

Because whirlpool treatment of only the proximal wounds was impractical and his wounds were so extensive, THO was the best treatment alternative. Wound cultures were obtained and yielded negative results. The measure-

† Topox Corp, 2627 Kennedy Blvd, Jersey City, NJ 07306.

§ Marion Laboratories, Inc, Marion Park Dr, Kansas City, MO 64137.



Fig. 1. Left lower extremity of the patient in Case 1 before initiation of topical hyperbaric oxygenation treatment.

ments and condition of his skin ulcers were as follows before THO treatment:

1. The lateral forefoot wound was 2.75 cm in diameter and dry.
2. The dorsal ankle wound was 10 × 4 cm and dry.
3. The midanterior tibial wound was 9.5 × 7.25 cm and necrotic, with the tibia exposed.
4. The proximal anterior tibial wound was 2.25 × 1.75 cm and dry.
5. The lateral knee wound was 7 × 5.75 cm and necrotic.

### Treatment

Topical hyperbaric oxygenation treatment was applied five days a week, twice daily, for 60 to 90 minutes. Transcutaneous electrical nerve stimulation also was applied initially for two hours a day, five days a week, at high frequency as an adjunctive treatment for pain. The electrodes were positioned in a crisscross pattern at the medial and lateral aspects of the knee and ankle. The electrode at the lateral aspect of the knee was attached distal to the lateral knee wound. Although the patient doubted the effectiveness of TENS, he began ambulating short distances (under 50 ft) with a walker while it was applied. After two weeks of TENS treatment, he was placed on an independent TENS treatment program of the same regimen, but failed to follow through with it regularly.

### Results

After eight weeks of THO therapy, his pain decreased considerably and TENS was indicated no longer. His ambulation had increased to 200 ft with a walker. After three months of treatment, the dorsal ankle wound and lateral knee wound were healed completely and whirlpool therapy was initiated twice a week to assist in débridement of the remaining wounds. Whirlpool therapy was not initiated earlier because the patient's foot ulcers appeared to be healing.

The size and condition of the remaining wounds after three months of therapy were as follows:

1. The lateral forefoot wound decreased to 1.5 × 1 cm and was dry and about 75% healed. The percentage of healing in all wounds was determined by the parametric technique. The wound's surface or volume, whichever was an appropriate measure, was used. The surface or volume measurement after THO treatment was divided by the surface or volume measurement before THO treatment to the second decimal position. This measurement was subtracted from 1.00 and multiplied by 100 to give the percentage of healing.
2. The midanterior tibial wound decreased to 8 × 4.5 cm and was about 48% healed, with necrotic tissue centrally.

$$|I R| = 0.3048 \text{ m.}$$

3. The proximal anterior tibial wound was 1 cm in diameter, dry, and about 80% healed. After four months of treatment, the proximal anterior tibial wound and the lateral forefoot wound healed and the patient began ambulating independently without pain. The THO treatment regimen then was tapered to once daily for 60 to 90 minutes with whirlpool treatment once a week. The size of the midanterior tibial wound after six months of treatment was 6.5 cm in length × 2.5 cm in width, and the wound was about 75% healed with



Fig. 2. Left lower extremity of the patient in Case 1 after six months of topical hyperbaric oxygenation treatment.

granulation throughout except for a small area over the anterior tibia (Fig. 2). Topical hyperbaric oxygenation treatment then was tapered to twice a week with whirlpool treatment as needed. A plastic surgeon examined the patient and determined that his healing was so great that a graft was not needed.

## CASE 2

### Background

A 69-year-old man was diagnosed as having severe PVD and ASCVD. His medical history included hypertension; atypical chest pain; bilateral saphenous vein femoral-popliteal bypass grafts that were redone with Gore-Tex grafts; an arterial embolus with left footdrop necessitating a thrombectomy of the left distal, external iliac, common femoral, profunda femoris artery; and a left Gore-Tex-Simon patch to a previous Gore-Tex graft with a fasciotomy of the left lower leg compartment. The patient had smoked cigars throughout most of his lifetime and continued to do so throughout his treatment program.

### Status

The left lower leg-compartment fasciotomy had never healed completely, developing an abscess at the left anterior tibia of eight months' duration. The patient also had distal left lower leg pain that limited his ambulation until eventually he was confined to a wheelchair for three months.

### Treatment

Prior whirlpool and Silvadene<sup>®</sup> dressing treatments of the abscess were unsuccessful; thus, surgical débridement was needed. After surgical débridement of the left lower leg compartment, an

open wound (about 28 × 6 × 2.5 cm) developed at the anterior tibia. Necrotic tissue developed at the peripheral aspect of the wound, and granulation tissue formed centrally.

The wound exhibited no infection, and whirlpool therapy 5 days a week was initiated. After 10 days of whirlpool therapy, the wound's width had decreased by 1 cm. The THO therapy was initiated twice daily for 60 to 90 minutes 5 days a week, and the whirlpool therapy was discontinued a couple of days later because the wound was devoid of necrotic tissue. The lower leg pain soon decreased slightly, and the patient began ambulating short distances (less than 50 ft) with a walker and a dorsiflexion-assisting splint.

### Results

During the first week of THO therapy, the patient developed a superficial heel decubitus 2.5 cm in diameter. After two weeks of THO therapy, the anterior tibial wound had decreased to 26.5 × 3 × 1.5 cm and the heel decubitus had healed completely. The THO therapy was discontinued and the wound was grafted with good results. After the grafting, the patient's ambulation gradually increased and he was discharged.

### DISCUSSION

In these case studies, THO treatment was accompanied by improved healing of recalcitrant leg ulcers caused by ischemia. In addition to THO treatment, judicious wound care (including daily evaluation, cleansing, débridement, and positioning) and medicinal agents were not detrimental factors in the success and rate of healing. Another important factor to be considered in both cases is that the patients continued to smoke, which may have delayed healing.

In Case 1, TENS was used at high frequency as an adjunctive treatment for pain. Although the patient denied its benefits, he appeared to ambulate with less difficulty when it was applied. The TENS therapy, however, probably was not effective in decreasing ischemia and inducing healing because it seldom was applied after the initial two weeks of treatment.

Whirlpool therapy was beneficial in wound débridement in both cases studied. In Case 2, whirlpool therapy may have induced healing because a decrease in wound size was recorded after 10 days of whirlpool therapy. A greater decrease in wound size, however, was apparent after two weeks of THO therapy.

### CONCLUSIONS

Topical hyperbaric oxygenation treatment of recalcitrant ischemic wounds in the lower extremity was used with good results. Although other factors such as judicious wound care, whirlpool therapy, medicinal agents, TENS, and smoking may have important effects, I primarily attribute the success and improved rate of healing in these two cases to THO therapy.

Further studies are needed of the effectiveness of THO therapy in improving circulation in ischemic lower extremity wounds, thus preventing amputation and the loss of independence, mobility, and self-esteem. Future studies also may investigate the efficacy of THO therapy in the prevention of ulcers by improving circulation in ischemic lower extremities.

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