

Topical Oxygen Therapy Treatment of Extensive Leg and Foot Ulcers

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The authors present a study of 15 patients with extensive leg ulcers of at least a grade III out of five grades, who were treated with topical oxygen treatment. A 73.3% healing rate was obtained. Three patients required further amputation and one patient eventually died. Failures to heal were associated with severe ischemic diseases and tissue hypoxia. Management of severe wound infections of the limbs required multidisciplinary treatment, which included the use of high-pressure oxygen treatment.

A great landmark in medical history was the discovery of oxygen in 1775 by Priestly, who demonstrated that oxygen maintains the vitality of a candle light and suggested its usefulness to human life.¹ This great event was followed by the introduction of a hyperbaric chamber by the British physician, Henshaw.² Henshaw's hyperbaric chamber may rank in importance with such medical achievements as the discovery of antibiotics, blood transfusion, and anesthesia. The progress of the hyperbaric chamber culminated in 1879 with Fontaine's use of a hyperbaric operating room. "With this chamber," Fontaine claimed, "one can do surgery in hospitals, sanitoriums, and private homes."² Thanks to our colleagues in military medicine, the use of hyperbaric oxygen has finally gained its long-overdue recognition in clinical practice.³

A major development in the field of hyperbaric oxygen treatment is the delineation of its specific indication by the Hyperbaric Oxygen Committee of the Undersea Medical Society, which in the 1970s defined four categories of clinical usage. Categories

I and II illustrate the value of oxygen in wound healing and the management of difficult, if not incurable, wounds.^{4,5} The use of the hyperbaric oxygen chamber varies in many forms, ranging from the traditional model of huge and complicated walk-in chambers to the use of a small plastic or metal chamber.⁴ However, this method of providing oxygen to a local open wound is complicated, expensive, and fraught with potential dangers and probable life-threatening adverse effects.⁵

Olejnicjak originally reported in the mid 1960s the application of high-pressure oxygen delivered topically to injured extremities.^{6,7} More recently, the use of soft, vinyl, inflatable sleeves, which are disposable, for application of topical oxygen treatment have been tried.^{8,9} To gain wider acceptance of its clinical usage, high-pressure oxygen treatment should be provided in a simple, safe, and inexpensive system of delivery supported by clinical studies.^{6,7,10}

The purpose of this paper is to demonstrate that topical high-pressure oxygen treatment, when combined with multidisciplinary treatment approach, offers an effective management of severe limb wounds.

Methods

A study of the clinical application of topical high-pressure oxygen treatment, given to patients with

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extensive limb ulcers in a large community hospital, was performed.

Patient Evaluation. Work-up of the patients included serial blood counts, blood chemistries, and serial cultures of the wound and the blood. Routine x-rays and bone scans were usually obtained. Doppler studies and arteriography were done according to the discretion of the attending physician or surgeon. The authors obtained adequate evaluation of the extremities, including assessment of the vascular integrity, and complete pictorial documentation of the size of the ulcers and the progress of response to the treatment procedure. Outpatient follow-up ranged from 6 to 14 months.

Wound Classification. Wounds were classified into five categories:

I. Small and superficial ulcers.

II. Ulcers extending into the deep fascia, tendons, and ligaments, and into the superficial joints.

III. Deeper and more extensive ulcers involving at least a quarter of the foot with a deep abscess or osteomyelitis.

IV. Extensive involvement with gangrene of some portion of the foot. The presence of severe vascular disease and systemic sign of infection placed a wound in this category.

V. Ulcers involving at least half of the foot and where amputation was strongly considered.

The authors focused on grade III, IV, and V wounds of the limb because it was believed that these were the kinds of wounds that would best benefit from intensive treatment procedures.

Treatment Protocol. All patients were treated by a wound care team, and received multimodalities of treatment procedures. The multidisciplinary team consisted of the primary physician, usually a surgeon; an internist, ie, infectious disease consultant; surgical consultants, including a plastic surgeon and an orthopedic surgeon; a podiatrist; a physiatrist; and a physical therapist. The services of nurses and other allied health personnel, namely, nutritionists and social workers, were also used in the treatment.

The medical treatment consisted of the control of diabetes mellitus and other inherent metabolic problems, correction of proven electrolyte imbalance, reversal of malnutrition and correction of anemia, and the use of properly chosen intravenous antibiotics. Surgical intervention on these patients consisted of liberal debridement, usually under general anesthesia, and ostectomies as indicated. The skin coverage was achieved with the use of split thickness skin grafting and rotational flap as indicated.

The physical treatment consisted of the use of topical high-pressure oxygen therapy, and an exer-

cise program at a later stage. Whirlpool treatment was occasionally used. The use of topical oxygen treatment was deemed necessary in the extensive ischemic ulcers of the lower extremities, and was delivered with the use of a disposable, inflatable, vinyl sleeve applied twice a day, maintaining a 16 to 20 mm/Hg pressure for 45 min each session.

Results

Fifteen patients satisfied the clinical criteria of having at least grade III ulcers. All but three had diabetes mellitus. Ten of these diabetics were out of medical control on admission to the hospital. Five patients had severe vascular arterial or venous disease by clinical and arteriogram criteria. One had a severe venous disorder with elephantiasis. Three patients had severe neuropathic abnormalities of the lower extremities. Two of these patients had Charcot's joint of the foot. Twelve patients had acute osteomyelitis. Two of these patients had dormant, chronic, osteomyelitis of the involved limb prior to the recent onset of illness. All wounds were locally infected with mixed flora.



Figure 1. Deep ulcer, left leg, before treatment with topical oxygen.



Figure 2. Leg ulcer after treatment with topical oxygen. The wound progressed to complete healing.

The authors were able to achieve complete healing in 11 patients (73.3%) (Figs. 1 and 2). Four patients failed to respond to the treatment. There was one death in the failures. This case was a diabetic, septicemic patient, who refused initial surgery and was given oxygen treatment. All failures to heal were associated with severe vascular disease (one elephantiasis and two severe arterial insufficiencies of the lower extremities). Patients with acute osteomyelitis requiring surgical decompression went on to heal satisfactorily. Secondary skin coverage was obtained by skin grafting and occasional skin rotational flap. Of the 73% of the patients who healed well, three patients subsequently had recurrent, severe foot ulcers, but not necessarily in the same region of the primary involvement. One of these patients required a below the knee amputation, and the other two required a transtarsal and metatarsal amputation. Five of the good responders eventually were able to function well and walk on the involved limb. Three patients (27.2% of the good responders) were wheelchair bound, partly because of problems with the other limb involved

(below the knee amputations and severe neuropathic disorders). There was complete healing in 73% of the cases, and a functional limb in 30% of the cases treated.

Discussion

The authors' study confirms the findings of Fisher, Olejniczak, and Elliot of the clinical value of topical high-pressure oxygen in the management of severe limb ulcers.^{2, 6-8, 11} This research focused on the most severely injured limbs of the extremities of grades III to V, since these ulcers, when treated in the usual traditional manner, probably would result in more amputations and less desirable clinical results.^{4, 9}

Nearly all of these patients were locally infected, and six were septicemic, including the only death in this series. There was no doubt that antibiotics were indispensable with specific treatment and provided a killing or arresting power systemically.⁴ However, the possibility that local killing and arrest of growth of microorganisms by topical high-pressure oxygen treatment definitely exists.^{8, 12, 13} Irvin et al¹³ showed that, during treatment with surface oxygen, significant growth inhibitions of both *Staphylococcus aureus* and *Pseudomonas pyocyanea* in guinea pigs were observed during the treatment. The work of Diamond, Fisher, and Olejniczak showed significant arrest of bacterial growth with the use of topical oxygen treatment in human beings with satisfactory clinical results.^{6, 7, 11}

Oxygen is thought to inhibit bacterial growth by raising the redox potential and stimulating white cell production, and increasing the phagocytic defense system.^{14, 15} It is likely, therefore, that the use of topical high-pressure oxygen in the control of local wound infection plays a far more major role from what has previously been demonstrated.^{8, 14, 16} Clinical research in this particular area is greatly needed to confirm the above hypothesis.

Surgical debridement in this study included resection of locally infected necrotic tissue, bone curettage, and resection.^{4, 9} While liberal debridement is often indicated and, indeed, mandatory, the already fragile microcirculation and soft tissue may undergo further ischemic changes.^{4, 5} High-pressure oxygen probably bridges the survival gap and provides the optimal oxygen reach environment needed to cure these severe ulcers.^{8, 7, 11, 13, 14, 17, 18} Nhnikowski et al¹⁸ clearly demonstrated the value of oxygen in promoting and increasing the rate of wound healing.

The rate of wound healing is known to be a function of the arterial pO₂ over a certain physio-

logic range.^{15,16} The recent demonstration that hypoxia occurs and probably represents a major contributing factor in the pathogenesis of infected wounds and osteomyelitis supports this hypothesis.^{4,14,15,17,19} The critical wound pO₂, below which the accumulation of collagen is definitely impaired, is known to be approximately 20 mm/Hg.¹⁴⁻¹⁶ Most wounds, especially severely traumatic and ischemic injuries, will have very low oxygen tension and enhance non-healing.^{14,15,20} The increasing local oxygen saturation, therefore, will enhance the wound healing, other factors being considered.^{6,14,15}

The application of topical oxygen treatment in the present known local chamber has proven effective in providing high oxygen saturation in the plasma covering of the ulcers and in the superficial layers of granulation tissue.⁶⁻⁸ This supplements oxygen to the tissue of the ulcer which is not sufficiently supplied by the blood stream either because of peripheral vascular disease or local injury to the microcirculation.^{8,13,14,21,22} The authors' study, therefore, together with many previous clinical reports, has now provided the evidence of the clinical usefulness of topical oxygen in stimulating wound healing. It does so by four probable mechanisms^{8,13-15,17}:

1. Enhancing synthesis of new cells and fibroblast differentiation.
2. Increasing the synthesis of collagen
3. Increasing the rate of epithelialization.
4. Increasing activities of leukocytes and phagocytosis.

The authors observed that bare bones will ultimately show some form of granulation when acute osteomyelitis is controlled and if this wound was given topical high-pressure oxygen treatment. It is easy to postulate from this observation that increased oxygen delivery to the bone by local or systemic route will enhance healing of osteomyelitis if this is combined with the use of properly chosen antibiotics and bone curettage and debridement of severely devitalized tissue.^{4,8,9,15}

Summary

A study of 15 patients with extensive open wounds and osteomyelitis treated with topical high-pressure oxygen was performed in a community hospital. A 73.3% healing rate was obtained. Three patients required further amputations, and one patient eventually died. Failure to heal was related to severe ischemic diseases and tissue hypoxia. The management of severe wound infections of the limbs required a multidisciplinary treatment regi-

men, which included topical high-pressure oxygen, surgery, and often led to prolonged, expensive medical care and extensive orthotic devices. In some cases, early, adequate amputation may be a better choice than saving a deformed and poorly functioning limb.

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