Continuous Local Oxygen Delivery Promotes Wound Healing - A Case Report

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Introduction

Wound healing is a complex biological process that requires the successful mobilization and integration of cells to repopulate the wound. This process is orchestrated, at least in part, by a number of growth factors. Optimal metabolic function of these cells is critical for the success of this process which implies that oxygen be available. Although it has been suggested that some degree of hypoxia may stimulate normal wound repair, chronic wound ischemia is a clearly pathological condition that inhibits normal wound healing.

Oxygen has a significant role in wound healing and may be the rate-limiting step in early wound repair. Oxygen is important in energy metabolism, polymorphonuclear cell function, neovascularization, fibroblast proliferation and collagen deposition and thus modulates key components of the wound healing process.

In some patients with chronic wounds oxygen supply may never meet oxygen demand so that the wounds persist. Supplemental oxygen has been shown to enhance healing of chronic wounds dependent on dose and frequency; however, excessive or continuous oxygen may impair the normal healing process. Although the issue is controversial, the existence of an enriched oxygen environment such as that created by hyperbaric oxygen therapy benefits some patients. Nevertheless, the logistics of hyperbaric oxygen therapy are cumbersome for the patient.

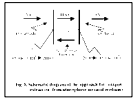
We have developed a system for the extraction of oxygen from atmospheric air and subsequent delivery of the oxygen to a wound environment at atmospheric pressure. In this report we present the case of a patient with a non-healing pressure ulcer of two years duration who subsequently developed osteomyelitis. In addition to standard of care, this patient was treated with continuous oxygen therapy delivered locally to the wound environment at atmospheric pressure. We suggest that this oxygen therapy was of pivotal importance in promoting wound healing in this patient.

Materials & Methods

Our approach to oxygen generation is the extraction of oxygen from the ambient air using an electrochemical reaction scheme in acid medium as shown below.

$$\text{Cathode: } O_2 + 4H^+ + 4e^- \rightarrow 2\,H2O \qquad E^o = 1.226\ V$$

$$\text{Anode: } 2H_2O \rightarrow O_2 + 4H^+ + 4e^-$$



In this scheme, oxygen in ambient air is reduced to water (by the application of current from an external power source, e.g., a Li battery) at an electrode held at a reducing potential using the protons supplied by an ionically-conducting membrane. The product, water, is moved through the membrane to the other electrode; this electrode, held at an anodic potential, oxidizes the water back to oxygen while releasing protons. The protons move through the membrane to the cathode side to make possible continued reduction of oxygen from air. Atmospheric nitrogen and carbon dioxide are electrochemically inert under the reaction conditions required for oxygen reduction and, thus, are effectively rejected at the cathode. The reduction product of oxygen alone moves through the membrane, resulting in near 100% pure oxygen on the anode. This process is illustrated in Figure 1.

The Ogenix transdermal, sustained oxygen therapy system, EpiFLO[SD] that was used in the treatment of the wound on this patient is composed of an oxygen concentrator unit, an oxygen delivery system and an oxygen containment dressing.

The oxygen concentrator unit concentrates oxygen from the atmosphere and produces 100% oxygen as described above. The size of the unit was approximately 53 x 37 x 23 mm and was worn around the ankle of the patient held in place by a Velcro strap. The oxygen concentrator unit was attached to the delivery system via a luer lock connector. The oxygen concentrator system delivered approximately 3.0 ml of oxygen per hour 24 hours per day.

The oxygen delivery system consisted of a cannula that attached to the EpiFLO[SD] device via a luer connector. At the opposite end of the cannula oxygen was delivered from the tip of the cannula into the wound bed environment.

The oxygen containment dressing was a fully occlusive Johnson and Johnson 3" x 4" island dressing.

Case Report

An 89 year old white male in generally poor health presented to his dermatologist with a pressure ulcer on his left medial foot. The patient was not a surgical candidate (CHF, pacemaker, edema) and was not diabetic. For two years the dermatologist provided standard of care therapies in treating the wound including regular debridements and Regranex therapy for 6 weeks. The wound remained unhealed. At the age of 91 the patient developed osteomyelitis that was confirmed by X-ray and blood cultures. A PICC line was inserted and standard antibiotic therapies were inaugurated. The pain in the foot was so severe the patient was unable to ambulate. The patient was alerted to the high probability of amputation.

In addition to the antibiotic therapy the patient agreed to have the wound treated with a continuous supply of oxygen delivered transdermally to the wound at a rate of 3 ml/hour from a device that derived pure oxygen from atmospheric air (EpiFLO[SD]). The oxygen therapy was used in conjunction with a fully occlusive Johnson & Johnson 3" x 4" island dressing. After three weeks of continuous oxygen and antibiotic therapies the patient was able to ambulate without pain. The wound bed was characterized by new granulation tissue and re-epithelialization. The scheduled amputation was postponed. The antibiotic treatment was discontinued after 30 days, but the oxygen therapy was continued until full wound closure 11 weeks later. The wound remained closed and the patient died 37 months later with the foot intact.

Figure 1a & b

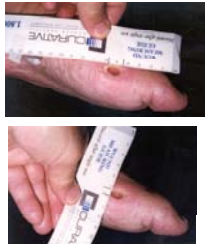


Figure 1 a and b: Appearance of pressure ulcer on left medial foot. This ulcer had not healed despite constant care and medical attention for two years and had progressed to osteomyelitis. The patient was in severe pain and unable to ambulate and amputation was scheduled.

Figure 2

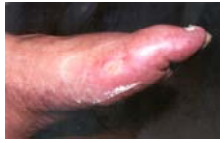


Figure 2: Following regimen of 4 weeks of antibiotics + 15 weeks of continuous oxygen therapy from the EpiFLO[SD] device (4 weeks concurrent with antibiotic therapy + 11 additional weeks) wound closure was achieved. The wound remained closed and amputation was avoided.

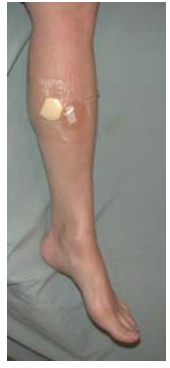
Discussion & Conclusions

This case report furthers the notion that therapeutic modalities such as transdermal, sustained oxygen therapy may be beneficial in promoting wound healing even in difficult clinical scenarios such as is exemplified by the patient in this case. Although any precise mechanism of action can only be speculative, it may be that the effectiveness of the antibiotics in this patient was potentiated by the supply of oxygen and that other oxygen-sensitive wound healing processes were enhanced by the availability of oxygen at this dosage. Clearly, further carefully controlled studies are required to clarify the underlying scientific mechanisms of this beneficial effect.

Device Application

Oxygen Delivery Bandage

- **FDA Approved in the Spring, 2003**
- **Clinical Applications:**
  - **Chronic non-healing wounds**
  - **Burns**
  - **Infected stumps**
  - **Frost bite**
- **Device introduction June 2004**

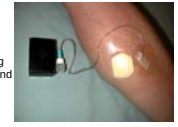


The EpiFLO[SD] generates 3 ml/hour of oxygen continuously for to seven days.

Use of an Oxygen Delivery Device for Venous Stasis Ulcers

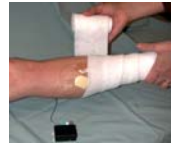
Step One:

Place the EpiFLO[SD] cannula beneath an occlusive wound dressing near the edge of the wound bed.



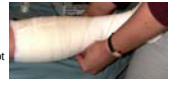
Step Two:

A protective gauze wrap is carefully wrapped around the leg. Care is taken not to kink the cannula.



Step Three:

A Profore ® compression dressing is secured to the leg. Again, care is taken not to kink the cannula.



Step Four:

The Profore ® dressing is covered with a protective bandage. Next, the EpiFLO[SD] device is secured into place with tape.

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