Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/apme

Review Article

Hyperbaric oxygen therapy heals diabetic wounds

Tarun Sahni [a,b,*], Gupta Shweta [c], Verma Sapna [a,c]

[a] Internal & Hyperbaric Medicine, Apollo Hospital, New Delhi 110076, India
[b] Department of Internal and Hyperbaric Medicine, Indraprastha Apollo Hospital, Sarita Vihar, Delhi-Mathura Road, New Delhi 110076, India
[c] Department of Hyperbaric Medicine, Indraprastha Apollo Hospital, Sarita Vihar, Delhi-Mathura Road, New Delhi 110076, India

ARTICLE INFO

Article history:
Received 25 October 2013
Accepted 6 January 2014
Available online 1 March 2014

Keywords:
Diabetic feet
Hyperbaric oxygen therapy
Non-healing wound

ABSTRACT

With the increasing prevalence of diabetes in the community, morbidity and mortality as a result of diabetic feet has been increasing. Foot complications are one of the most serious and yet preventable complications of diabetes mellitus having an economic impact to the individual and adding the burden to the already inadequate healthcare resources. Complications associated with diabetes are often expensive to treat, and commonly include foot ulceration. While most diabetic foot ulcers heal with standard treatment, when standard treatment measures fail, adjunctive therapies must be considered. Use of systemic Hyperbaric Oxygen Therapy (HBOT) as an adjunctive treatment for chronic lower extremity diabetic ulceration is safe, reasonable and cost effective modality.

HBOT in diabetic wounds has confirmed its role in promoting oxygenation; enhance immune mechanisms, neovascular formation, fibroblast proliferation and other beneficial actions. It is now accepted as a useful adjunctive treatment in a select group of diabetic patients with severe or limb threatening wounds. HBOT has been demonstrated to be an effective treatment when combined with careful attention to underlying diseases and wound care including debridement, grafting, and control of infection. This article discusses the role of oxygen in wound healing, and place of HBOT in the modern multidisciplinary approach to the treatment of diabetic foot wounds.

1. Introduction

Diabetes has become a global epidemic and is rapidly increasing at an alarming rate. Developing countries like India harbor the majority of diabetic people and by the year 2030 AD India will have the largest number of diabetic patients. As the prevalence of diabetes has increased, so has the burden on the healthcare system to provide treatment for the complications associated with the disease. The loss of a limb or foot is one of the most feared complications of diabetes and yet foot problems remain the commonest reason for diabetic patients to be hospitalized. In India, the prevalence of diabetic foot ulcers in the clinic population is 3.6% of which patients with foot problem had to spend 32.3% of the total income towards treatment.[1]

* *Corresponding author*. Department of Internal and Hyperbaric Medicine, Indraprastha Apollo Hospital, Sarita Vihar, Delhi-Mathura Road, New Delhi 110076, India. Tel.: +91 9810038010; fax: +91 (0)11 26823629.
E-mail addresses: aimhu@live.in, sshwetaa0186@gmail.com (T. Sahni).
0976-0016/$ – see front matter
http://dx.doi.org/10.1016/j.apme.2014.01.001

Diabetic ulcers are chronic, complex, or problem wounds in people with diabetes, which fail to heal in three months and are usually considered chronic. Some take years to heal or never do.[2–5] Diabetic ulcers and other chronic wounds can be classified using the Wagner Grade Scale (Table 1).

Ulcers may develop over time as patients apply constant micro-trauma to the skin. Tissue ischemia, uncontrolled hyperglycemia, infection, poor nutrition, and improper shoe gear also contribute to chronic, on healing nature of diabetic ulcers (Fig. 1).

Diabetic ulcers require a healthy, oxygenated wound bed to heal. A lack of sufficient oxygen in the wound bed slows or stops the normal healing process[6–8] and is further complicated by poor blood circulation in the feet and legs.[6,7] Nerve disease may also cause a loss of sensation in the feet and legs, causing unnoticed small cuts, sore, or pressure ulcer.

Hyperbaric oxygen therapy is an effective adjunct to other wound care therapies, including topical cleaning; surgical removal (debridement) of dead skin and tissue; application of dressings, ointments, and biologics; and use of compression boots or stockings, vacuum or negative pressure wound therapy (NPWT) pumps, ultrasound, laser, and other emerging technologies.[4,5,9–11]

2. Physiological basis of HBO therapy

When we normally breathe air at sea level pressure, hemoglobin is 95% saturated with oxygen (O_2) and 100 ml blood carries 19 ml O_2 combined with Hb and 0.32 ml dissolved in plasma. At this same pressure if 100% O_2 is inspired, O_2 combined with Hb increases to a maximum of 20 ml and that dissolved in plasma to 2.09 ml. Most tissue needs of oxygen are met from the O_2 combined to Hb (Fig. 2).

This additional oxygen in solution is almost sufficient to meet tissue needs without contribution from oxygen bound to hemoglobin and is responsible for most of the beneficial effects of HBO therapy.

3. Role of oxygen in the healing process of diabetic foot wounds

Hyperbaric oxygenation is an important therapeutic adjunct in the management of wounds that exist in chronic oxygen deficiency and where the local oxygen tension is below that optimal for healing.[3,4,6–8] Measurements of tissue oxygen tensions in non-healing diabetic wounds have shown values far below those where healing could be expected. HBO therapy has been shown to increase tissue or transcutaneous oxygen tensions in diabetic patients with chronic wounds. The greatest benefit of HBO therapy is achieved in situations where the nutritive flow and oxygen supply to repair tissue are compromised, but in which the regional vascular network, a prerequisite for oxygen to reach tissues, is only partially impaired. HBOT delivers oxygen to the wound, allowing it to 'kick start' the healing process by promoting the development of new small blood vessels.[10] The main effects of HBO therapy on the healing of diabetic foot ulcers include:

- Enhanced periwound tissue oxygenation
- Decreased edema
- Enhanced oxidative killing of bacteria
- Enhanced cellular energy (ATP) production
- Potentiation of antibiotics
- Promotion of neoangiogensis
- Enhanced epithelial migration
- Enhanced collagen production, deposition

Table 1 – Wagner classification system for dysvascular foot lesions.

Grade 0	No ulcer in a high-risk foot
Grade 1	Superficial ulcer involving the full skin thickness but not underlying tissues
Grade 2	Deep ulcer, penetrating down to ligaments and muscle, but no bone involvement or abscess formation
Grade 3	Deep ulcer with cellulitis or abscess formation, often with osteomyelitis
Grade 4	Localized gangrene
Grade 5	Extensive gangrene involving the whole foot

Wagner, F., Levin, M., & O'Neal, L., 1983. Supplement: algorithms of foot care.

4. Systemic administration of HBOT

HBO is administered in either Multiplace or Monoplace hyperbaric chambers. The Multiplace chamber is pressurized with air and the patient breathes oxygen through a mask or head tent. The Monoplace chamber is pressurized with oxygen and the patient breathes pure oxygen directly. Normally, pressures of 2–2.5 atm absolute (ATA) are used (Fig. 3).[12]

5. Transcutaneous Oximetry for evidence based use of HBO therapy

Transcutaneous oxygen value ($TcPO_2$) is recognized as one of the most reliable and useful non-invasive method for evaluation of perfusion and selecting patients for HBOT. This helps by establishing the presence of tissue hypoxia and more importantly to demonstrate the reversal from hypoxic tissue oxygen levels to normoxic or hyperoxic levels with the administration of higher oxygen partial pressures.[13] Patients with Transcutaneous periwound $TcPO_2$ values greater than 40 mmHg on room air may heal without intervention while those with values less than 20 mmHg have poor prognosis. $TcPO_2$ values less than 10 mmHg indicate amputation will be unavoidable. An increase to 40 mmHg or greater while breathing 100% O_2 at room pressure (1ATA) or >200 mmHg inside a hyperbaric chamber indicates that HBOT will benefit the patient (Fig. 4).

6. Literature review

Duzgun et al (2008) compared HBOT ($n = 50$) with standard therapy without hyperbaric oxygen ($n = 50$) in individuals with diabetes and lower-extremity wounds. Participants in the HBOT group engaged in an average of 30–45 treatments; there