Hyperbaric oxygen therapy for treatment of diabetic foot ulcers

This adjunctive therapy promotes wound healing and may eliminate the need for amputation.

By Carrie Carls, BSN, RN, CWOCN, CHRN; Michael Molyneaux, MD; and William Ryan, CHT

Every year, 1.9% of patients with diabetes develop foot ulcers. Of those, 15% to 20% undergo an amputation within 5 years of ulcer onset. During their lifetimes, an estimated 25% of diabetic patients develop a foot ulcer. This article discusses use of hyperbaric oxygen therapy (HBOT) in treating diabetic foot ulcers, presenting several case studies.

HBOT involves intermittent administration of 100% oxygen inhaled at a pressure greater than sea level. It may be given in a:
- multi-place chamber (used to treat multiple patients at the same time), compressed to depth by air as the patient breathes 100% oxygen through a face mask or hood
- monoplace chamber (used to treat a single patient), compressed to depth with oxygen. Patients breathe 100% oxygen in the chamber itself. Depending on the treatment depth, patients may wear a mask for medical air breaks for short periods.

Typically, HBOT is given 5 days a week for at least 20 treatments, although the number of treatments varies from 20 to 60. Be aware that HBOT is an adjunctive therapy and must be used in conjunction with normal wound care treatment. It doesn’t replace good wound care.

How it works

HBOT improves tissue oxygenation by increasing the amount of oxygen dissolved in the plasma, thus stimulating healing of chronic diabetic ulcers. Oxygen is essential to wound healing, playing an important role in each wound healing stage. The wound healing rate relates directly to the level of tissue oxygenation; wound ischemia is the most common cause of failure of wounds to heal. Hypoxia in wounds and the wound’s responsiveness to oxygen are determined from transcutaneous oximetry monitoring (TcPO₂). When measured at the distal lower extremity of a diabetic patient, a normal TcPO₂ reading is 30 mm Hg. The decision whether to use HBOT commonly hinges on whether TcPO₂ measurements of the periwound area increase significantly with an oxygen challenge.

In this country, HBOT is used with pressures of 2.0 to 3.0 atmospheres ab-
solute, and partial pressures of arterial oxygen (Pao$_2$) of 1,200 mm Hg can be attained. At this Pao$_2$, hemoglobin is fully saturated (arterial oxygen saturation of 100%), indicating an increased amount of oxygen dissolved in the plasma. Oxygen is perfused into the end-arterioles and tissues, resulting in healing.

Many studies have found beneficial effects of HBOT. Multiple theories address the HBOT mechanism. Known benefits of HBOT in wound healing include enhanced periwound tissue oxygenation, decreased edema, enhanced oxidative killing of bacteria, enhanced cellular energy production, antibiotic potentiation, neovascularization promotion, enhanced epithelial migration, improved collagen production, and enhanced granulation-tissue formation. The effects of cytokines, prostaglandins, and nitric oxide on tissues also may play a major role in how HBOT works. Some literature suggests HBOT mobilizes stem cells derived from bone through a nitric oxide–mediated pathway; these stem cells then migrate to the ulcer and promote healing.

**Indications**

The Undersea and Hyperbaric Medical Society recommends HBOT for adjunctive treatment of selected problematic wounds, including sufficiently perfused lower-extremity diabetic ulcers. Eligibility guidelines from the Centers for Medicare & Medicaid Services state that patients must have type 1 or 2 diabetes with a lower-extremity ulcer caused by diabetes and classified as a Wagner grade 3 or higher; also, the patient must have failed an adequate course of wound therapy. (See Wagner ulcer classification system.)

**Contraindications**

HBOT has few absolute and several relative contraindications.

- **Absolute contraindications** include untreated pneumothorax and use of

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**Wagner ulcer classification system**

The Wagner system is one of the most commonly used foot ulcer classification systems. This chart describes the five grades in this system.

<table>
<thead>
<tr>
<th>Grade</th>
<th>Description</th>
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<tbody>
<tr>
<td>0</td>
<td>At-risk foot with pre-ulcer&lt;br&gt;No open lesions; intact skin&lt;br&gt;May show deformities, erythematos areas of pressure, or callus formation</td>
</tr>
<tr>
<td>1</td>
<td>Superficial ulcer&lt;br&gt;Skin disruption without extending into subcutaneous layer&lt;br&gt;May have superficial infection</td>
</tr>
<tr>
<td>2</td>
<td>Full-thickness ulcer that perforates through fat and subcutaneous tissue to tendon or joint capsule&lt;br&gt;No abscess or osteomyelitis</td>
</tr>
<tr>
<td>3</td>
<td>Deep ulcer with abscess, osteomyelitis, tendonitis, or joint sepsis; ulcer extends to these structures</td>
</tr>
<tr>
<td>4</td>
<td>Gangrene of geographic portion of foot (such as toes, forefoot, or heel)</td>
</tr>
<tr>
<td>5</td>
<td>Gangrene of whole foot beyond salvage, requiring limb- or life-saving amputation</td>
</tr>
</tbody>
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bleomycin, disulfiram, doxorubicin, and mafenide acetate. Contraindicated drugs must be discontinued before HBOT. Also, patients with a pneumothorax must have a chest tube inserted.

- Relative contraindications call for caution or consideration, but don’t prohibit HBOT. They include seizure disorders, emphysema with carbon dioxide retention, high fever, history of spontaneous pneumothorax, optic neuritis, upper respiratory infection, pregnancy, congenital spherocytosis, and implanted pacemakers or epidural pain pumps. Some types of chemotherapy also are relative contraindications. For example, the cancer chemotherapy agent doxorubicin (Adriamycin) is thought to become cardiotoxic when used concurrently with HBOT. However, the system clears the drug in 24 to 48 hours, so treating patients with HBOT after they’ve stopped doxorubicin for 2 or 3 days should be safe.

Risks and adverse effects
HBOT is one of the most benign treatments in health care. Nonetheless, it can cause adverse effects. The most common one is ear barotrauma, which occurs when the eustachian tubes close during pressurization, causing increased pressure against the tympanic membrane. Barotrauma effects may vary from tympanic membrane damage to eardrum rupture. Barotrauma damage is classified on the Teed Scale and ranges from grade 0 (no damage) to grade 5 (deep black or blue appearance of the entire ear drum and/or rupture). You can access photos and descriptions for the Teed Scale at www.docstoc.com/docs/68825188/TEED-SCALE-DESCRIPTIONS.

Other possible adverse effects include sinus squeeze, tooth squeeze if the patient has an air space under a filling, transient myopia, claustrophobia, oxygen toxicity and, rarely, seizures. In diabetic patients, HBOT has a hypoglycemic effect, reducing blood glucose levels an average of 50 mg/dL during treatment. Caregivers must check the patient’s blood glucose level before and after each treatment and postpone treatment if the pretreatment blood glucose level is 100 mg/dL or lower.

Patient considerations related to HBOT center on safety concerns and patient education. (See Patient considerations for HBOT.)

Patient considerations for HBOT

Although you may not be directly involved with hyperbaric oxygen therapy (HBOT) treatments, you’ll benefit by understanding safety and education considerations.

Safety
Before patients begin HBOT, they must be checked for potential fire hazards, because oxygen in contact with many items can trigger a fire inside the hyperbaric chamber. Patients should be free from hairspray or gel, makeup, aftershave, metal objects, cell phones, battery-operated devices, and medication patches. They may wear eyeglasses in a multi-place chamber if the glasses don’t contain titanium. They shouldn’t wear hearing aids because of the risk of fire and because pressurization may change the position of the hearing aid in the ear. Ear plugs are prohibited because they may become lodged in the ear canal.

Education
Explain HBOT to patients, including its risks and benefits, related safety procedures, and what they can expect during therapy based on the type of chamber used. For patients who are overly anxious, consider obtaining an order for a sedative beforehand. Tell patients they will be monitored closely. Instruct diabetic patients to take prescribed medications and eat before HBOT appointments.
**Case studies: HBOT in action**

The case studies below highlight the value of HBOT in treating diabetic foot ulcers.

**Patient #1**

This 53-year-old male was referred for treatment of a nonhealing diabetic ulcer of the right foot after fifth ray resection for osteomyelitis and abscess formation in a Wagner grade 4 ulcer. Co-morbidities included diabetes mellitus type 2, chronic obstructive pulmonary disease, methicillin-resistant *Staphylococcus aureus* (MRSA), pedal edema, neuropathy, and stroke. Also, the patient was a smoker. The ulcer measured 6.2 cm × 4.6 cm, with a depth of 0.7 cm. TcPO₂ measurement showed a baseline of 56 mm Hg, increased to 187 mm Hg during the oxygen challenge, indicating the potential for a response to HBOT. Over 52 days, the patient received 26 HBOT treatments and three debridements, resulting in 100% wound closure.

**Patient #2**

This 79-year-old male had type 2 diabetes mellitus with a Wagner grade 3 diabetic ulcer of the left dorsal great toe. He’d had ulcers in the same toe 1 year and 2 years before, which had healed both times. Comorbidities included peripheral sensory neuropathy and colon cancer. Initially, he was referred by his podiatrist for evaluation and management. On presentation, he had an infection and bone was present at the proximal portion of the ulcer with undermining. The ulcer measured 0.7 × 1.0 cm, with a depth of 0.3 cm. TcPO₂ measurement showed a baseline of 48 mm Hg, increased to 198 mm Hg during the oxygen challenge, which indicated potential for a good response to HBOT. Initially, the patient was placed on oral antibiotics. During the course of HBOT sessions, he underwent five debridements; local wound care included Silvasorb gel and pressure off-loading.

**Patient #3**

This 70-year-old male with type 2 diabetes mellitus presented with a Wagner grade 3 diabetic ulcer of his right plantar great toe with cellulitis, after toe trauma caused by stepping on a nail that went through the sole of his shoe. He had a history of foot ulcers, necessitating amputation of the left second toe, as well as an ulcer on the right plantar foot. Comorbidities included hypertension, a mild stroke 21 years earlier, and arthritis. The patient exhibited sensory and motor neuropathy. He received both oral and I.V. antibiotics and a tetanus shot. Bone was exposed in the wound bed and X-rays confirmed osteomyelitis. Initially, the wound measured 0.5 cm × 0.4 cm, with a depth of 0.6 cm. During the course of HBOT treatments, he had three debridements and healed completely after 40 treatments.

**Patient #4**

This 50-year-old female was admitted with a Wagner grade 3 diabetic foot ulcer with abscess of the left foot, status post-incision and abscess drainage. A bone scan suggested osteomyelitis. Comorbidities includ-
ed diabetes mellitus type 2, MRSA infection, and sensory and motor peripheral neuropathy. Her history included two episodes of diabetic foot ulcers, which healed. Before HBOT, her ulcer measured 3.4 cm × 1.7 cm, with a depth of 1.3 cm. TcPO2 measurement showed a baseline of 40 mm Hg and a response to the oxygen challenge, demonstrating potential for healing with HBOT. She received I.V. antibiotics and had a total of six debridements during the course of HBOT treatments. After a series of 31 HBOT treatments, she progressed to healing.

**An important adjunctive treatment**

Systematic HBOT can bring significant reductions in the number of amputations needed, decrease the wound area, and promote healing. It has been effective in healing diabetic foot ulcers by establishing adequate oxygen availability within the vascularized connective tissue compartment around the wound. It also improves local host immune response and helps resolve infection. As the incidence of diabetes increases, HBOT will become an increasingly important adjunctive treatment to provide optimum outcomes and local wound care for patients with diabetic ulcers.

**Selected references**


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