The use of hyperbaric oxygen therapy for wound healing in people with diabetes

Alexandra Kotsovos

Hyperbaric oxygen therapy (HBOT) is used to treat poor-healing wounds through the inhalation of oxygen, which increases tissue oxygenation, promotes neovascularisation and eradicates bacteria at the wound site. This article examines the scientific evidence for the application of HBOT for the treatment of lower-extremity wounds in individuals with diabetes and its effectiveness. Four studies were examined, and each demonstrated that HBOT improved wound healing; however, the extent of the healing depended on adequate vascularisation of the surrounding tissue as measured by transcutaneous oximetry. Specialist nurses, the author argues, should use HBOT in conjunction with standard wound care therapies for individuals with diabetes to treat lower-extremity wounds.

Article points

1. Hyperbaric oxygen therapy (HBOT) has enhanced the treatment of lower-extremity wounds in people with diabetes, preventing further infection and amputation.
2. Pure oxygen revascularises the wound and eradicates bacteria; HBOT is safe, non-invasive and effective, with few side effects.
3. Transcutaneous oximetry is used to measure tissue vascularisation and can indicate whether HBOT will enable the wound to successfully heal.

Key words

- Hyperbaric oxygen therapy
- Revascularisation
- Transcutaneous oximetry

Diabetes mellitus affects 170 million people throughout the world, and this statistic is projected to double by 2030 (Brem and Tomic-Canic, 2007). Diabetes comes with a barrage of complications; one of the most common and severe complication is foot ulceration, which can result in limb amputation if the infection is not treated quickly and appropriately.

Wound healing in people with diabetes is a serious problem because of multiple factors:

- Individuals with diabetes can get a wound and not be aware of it as a result of diabetic neuropathy, which is the loss of sensation in distal extremities. Decreased peripheral sensation means that wounds can develop an infection and become worse without the individual ever having any pain or sensation of a wound being present (Brem and Tomic-Canic, 2007).
- People with diabetes have an impaired ability to fight infection, which is related to a diminished ability to accumulate all components of the cellular response to injury, such as fibroblasts, endothelial cells and macrophages.
- Diabetes limits the body's ability to form new blood vessels or to perform neovascularisation (Brem and Tomic-Canic, 2007).

Approximately 4–10% of individuals with diabetes experience foot ulceration (Singh et al, 2005). These wounds are typically difficult to heal and can result in significant comorbidities, such as profound systemic infection and

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Page points

1. Hyperbaric oxygen therapy (HBOT) is simple to administer; it involves the delivery of pure oxygen to individuals by placing them in a compression chamber for an average of 20 4-hour sessions.
2. The high percentage of oxygen inhaled by the individual increases the partial pressure of oxygen (PO_2) in the blood, increasing the oxygenation of soft tissues and muscles, preventing tissue hypoxia and facilitating wound healing.
3. Increased oxygen delivery facilitates healing by promoting collagen synthesis, neovascularisation and epithelialisation, creating an ideal environment for wound healing.

amputation. Amputation decreases mobility and significantly reduces individuals' quality of life. These issues point to the significance of improving wound healing in people with diabetes.

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Literature review

A search for literature was conducted through PubMed using the keywords "hyperbaric oxygen therapy" and "diabetic lower-extremity wounds" to research studies from 2005 to 2009. In total, 23 studies were highlighted; of these, four of the most recent and comprehensive articles were reviewed to examine the effectiveness of HBOT in the treatment of lower-extremity wounds in individuals with diabetes (Zgonis et al, 2005; Fife et al, 2007; Duzgun et al, 2008; Ong, 2008).

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 was no clear stoppage of treatment if wounds did not improve. The authors found that individuals in the HBOT group had foot ulcers that were more likely to heal and had to undergo less severe amputations (distal to the metatarsophalangeal joint) compared with those receiving standard therapy. The study showed that foot ulcers healed in 66% of individuals receiving HBOT, compared with no healing in those receiving standard therapy. There were more individuals with comorbidities in the HBOT group than in the standard treatment group, so even when individuals were less healthy, smokers or obese, HBOT was still effective. Additionally, HBOT reduced the cost of overall wound treatment. The study did not specifically take into account transcutaneous oximetry measurements, which measure the oxygen level of subcutaneous tissue, to assess the adequacy of local perfusion; however, the study mentioned that transcutaneous oximetry should be used to aid clinicians in deciding if an individual is an appropriate candidate for HBOT (Duzgun et al, 2008).

Fife et al (2007) reviewed 971 records of individuals with diabetes receiving HBOT; overall, 73.8% showed improvement in their lower-extremity wounds. Individuals who benefited from HBOT received a mean of 34 treatments. Those with a wound not showing signs of improvement with HBOT had a mean of 24 treatments; a reduction in the number of sessions was related to the practitioner stopping the treatment if the wound was not healing. The authors found that the greatest benefit of HBOT occurred within the first 15 treatments.

Examination of transcutaneous oximetry ($P_{tc}O_2$) showed that individuals with in-chamber measurements >200 mmHg had an 84% chance of benefiting from HBOT, whereas those with measurements <100 mmHg had only a 14% chance of benefiting from the therapy; individuals with $P_{tc}O_2$ measurements >25 mmHg outside the chamber had the best outcomes (Fife et al, 2007).

Ong (2008) reviewed the charts of 45 individuals with diabetes and lower-extremity wounds who received HBOT. HBOT resulted in successful wound healing in 71% of participants, thus reducing the risk of amputation; participants received a mean of 20 treatments. Individuals with a palpable dorsalis pedis pulse were twice as likely to be successfully treated. This study discussed the benefit of increased tissue oxygenation at the wound site, but did not directly research transcutaneous oximetry. Ong (2008) concluded that HBOT is cost-effective, as it is cheaper than repeated debridements, hospital

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stays or amputations related to lower-extremity wounds in individuals with diabetes.

Zgonis et al (2005) looked at the effect of HBOT on 35 people with diabetes who had lower-extremity wounds from partial foot amputations; 27 individuals in the sample received revascularisation before their surgery to improve oxygen perfusion to the wound. Patients had a mean of 20 treatments of HBOT. Seventy per cent of the sample had a successful course of treatment, meaning that their wound completely healed and their further amputation risk decreased. Similar to what was observed in the Fife et al (2007) study, all participants underwent preoperative transcutaneous oximetry measurements; the preoperative $P_{tc}O_2$ levels were significantly higher (>29 mmHg) in individuals whose wounds successfully healed after HBOT compared with those whose wounds did not heal (Zgonis et al, 2005).

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Although it was not measured in all studies, each study discussed the importance of transcutaneous oximetry measurements as a strong predictor of HBOT success. In the Zgonis et al (2005) and Fife et al (2007) studies, tissue transcutaneous oximetry measurements <25 mmHg resulted in no wound healing after HBOT as a result of poor oxygen perfusion.

The Wagner grading scale for wounds was used in the Duzgun et al (2008) and Fife et al (2007) studies; the scale classifies wounds from grade 0="no open ulcer, high risk" to grade 5="generalised gangrene". However, these studies stated that transcutaneous oximetry of wounds rather than the Wagner grading scale should be used because of its more objective and reliable results. The Wagner grading scale had no wound-staging cut-off for the use of HBOT that was relative to all studies – tissue oxygenation instead was used as a determinant of treatment. Another finding that was relative to all four studies was that if individuals did not show signs of wound healing after the first 15–20 treatments, further HBOT had little effect; thus an increased number of treatments does not correlate with increased healing (Ong, 2008).

Criteria for initiating treatment

It is important for the advanced practice nurse to ensure that individuals with diabetes and lower-extremity wounds meet the criteria for HBOT by considering the following:

- Have standard wound healing therapies, such as creams, dressings and antibiotic treatment, been an option for the individual, and have they failed?
- Does the individual have adequate vascularisation according to transcutaneous oximetry measurements? As Fife et al (2007) and Zgonis et al (2005) specifically researched, the wound must measure a $P_{tc}O_2$ of >25 mmHg to benefit from HBOT.
- Does the individual need revascularisation to the lower extremity that has the wound? As Zgonis et al (2005) discussed, individuals may need revascularisation surgery before HBOT can be effective for the treatment of their wounds if they have reduced circulation in that lower extremity.

Pertinent information that the advanced practice nurse must take into account is whether or not HBOT is available at a facility close to the individual or at a rehabilitation facility where that person can stay. Proximity affects the convenience of the treatment and also the cost to the individual. Advanced practice nurses must take into account the individual's condition and ability to travel to and from treatments, with consideration of the following:

- Does the lower-extremity wound hinder the individual's mobility?
- Is the individual on pain medication that would impair him or her from driving to treatments?
- Does the individual have someone available who can always take him or her to treatments if he or she cannot drive?

These factors are as important an indication for treatment to take into consideration as treatment criteria when prescribing HBOT.

The advanced practice nurse should be aware of the common potential side effects of HBOT, such as aural barotraumas and visual disturbances. It is important to assess individuals for changes in vision or hearing by simple auditory and visual examinations, as well as by paying attention to any complaints about changes in hearing or vision. These side effects subside without treatment, and HBOT does not need to be interrupted if a person experiences them (Kranke et al, 2006). Advanced practice nurses should make people aware of these adverse effects before initiating treatment.

Initiating HBOT

People with diabetes and lower-extremity wounds who have tried other conventional wound treatment methods first, such as creams and dressings, are candidates for HBOT. Transcutaneous oximetry is the measurement that can be used to determine the extent of tissue oxygenation and whether HBOT would be beneficial (Duzgun et al, 2008); specifically, HBOT is more effective when the transcutaneous oximetry reading is >25 mmHg (Fife et al, 2007).

Individuals will attend roughly 20 sessions of HBOT to increase the healing of their wounds. Wound healing should be seen after the first 12–15 treatments; if this is not the case, HBOT is not likely to heal the wound (Fife et al, 2007).

Benefits of HBOT

The ability of HBOT to increase wound healing in a population with a history of poor wound healing is an important benefit of this therapy. Specifically, infection and amputation can be prevented because HBOT promotes wound healing and aids in the closure of wounds. HBOT has bactericidal and bacteriostatic effects through the action of a superoxide enzyme, which works faster at high oxygen tensions (Duzgun et al, 2008).

The use of HBOT can decrease the frequency of hospitalisations for wound care as well as overall expenditure for treatment of the wound. Ong (2008) showed that it was more cost-effective to treat an individual with HBOT than to perform repeated incision and drainage or soft-tissue removal of non-healing tissue from a diabetic wound. According to research from the Henry Spink Foundation (2010), the cost of a single HBOT treatment is between £10 and £20.

Ong (2008) showed that a positive long-term effect of HBOT is neovascularisation of hypoxic wounds. Neovascularisation refers to new blood vessel formation that occurs as a result of HBOT, improving blood flow to wounds and aiding in healing.

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It is important to note that HBOT is more economical than other more invasive surgical procedures to remove hypoxic wound tissue, including incision and drainage of wounds, debridement and amputation (Ong, 2008). As a prescriber of this treatment it is necessary to be certain this therapy is warranted and to find out if there is a HBOT centre located relatively close to the person requiring treatment to enable travelling to and from treatments with ease. Additionally, at this stage of wound acuity many individuals have limited mobility, and need to have access to transportation to treatments.

Adverse effects of HBOT

Although HBOT is relatively safe, there are some adverse effects from treatment, as noted earlier. Individuals can develop aural barotraumas from the increased pressure of the compression chamber while receiving HBOT. However, this adverse effect does not require termination of the treatment and heals on its own (Kranke et al, 2006).

Visual disturbance, specifically a reduction in visual acuity, can also occur as a result of HBOT. It is related to conformational changes in the lens of the eye from the pressurised chamber. This effect also improves on its own for most individuals (Kranke et al, 2006).

Oxygen-induced seizures are a rare adverse effect of HBOT. According to Ong (2008), oxygen-induced seizures only occur in 1 in 10000 people (as cited by Kindwall [1994]). The enclosed small chamber coupled with the treatment lasting 4 hours makes HBOT intolerable to individuals who are claustrophobic, which was not the case for the participants in the four studies reviewed.

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- Lower extremities not adequately vascularised.
- Ischaemic tissue.
- A transcutaneous oximetry measurement <25 mmHg.
- A comorbidity affecting individuals' peripheral vasculature, such as renal failure.

Conclusion

Further research of HBOT would improve outcomes of therapy. Further study of transcutaneous oximetry would determine a more precise measurement to ascertain whether the wound would heal with HBOT; Zgonis et al (2005) and Fife et al (2007) suggested that transcutaneous oximetry measurements between 25 and 29 mmHg are the lowest measurements of perfusion of tissue that will benefit from HBOT.

A second grading system of wounds that is objective could also help the specialist nurse determine if an individual's wound would benefit from HBOT; the Wagner classification is not used to do this because of its subjectivity.

HBOT has enhanced the treatment of wounds in individuals with diabetes by using pure oxygen to revascularise the wound and eradicate bacteria. It is a safe, non-invasive and effective technology, with few side effects (Ong, 2008). The specialist nurse should be knowledgeable of new technologies and therapies; HBOT plays a vital role in the treatment of diabetic wounds refractory to standard wound care therapy. ■

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