Hyperbaric Oxygen Therapy for Lower Extremity Problem Wounds

A Summary of its Science, Evidence and Practice

HyperBaric Oxygen KC
Wound Healing Center of Mid America

To refer a patient or speak with a member of our staff, please call 816.943.4600. Normal business hours are Monday-Friday 8:00 a.m. – 5:00 p.m.

Introduction

Deficient wound healing represents an enormous healthcare challenge, one that is expected to increase as its incidence and prevalence continues to climb. Billions of dollars are spent annually to treat chronic wounds and to support those patients whose care fails and amputation becomes necessary. Problem wounds exact equally enormous social tolls.

Normal wound healing is an orderly sequence of events, several of which are critically dependent upon availability of oxygen. Problem or chronic wounds are those that have failed to proceed along this orderly timeline. Common amongst several factors that compromise healing responses is inadequate oxygen delivery. *Hypoxia* is actually a normal and inevitable consequence of initial tissue injury, as wounding profoundly disrupts the local wound environment. *Ischemia,* on the other hand, imposes vulnerability to both infection and subsequent healing.

The underlying physiology and basic science supports the contention that hyperbaric oxygen (HBO) therapy is likely to be useful in a variety of problem wounds complicated by local ischemia. Certainly, best evidence exists for its treatment of advanced diabetic foot ulcers.

The following is a brief summary of the science and application of HBO therapy in several lower extremity problem wound etiologies:

Wound Healing and Hyperbaric Oxygenation

Adequate oxygen delivery is a major controlling factor in resistance to infection and bacterial killing. Oxygen is also a rate-controlling factor for fibroplasia, collagen synthesis, angiogenesis and epithelialization. In the presence of local ischemia and tissue hypoxia, most if not all of these processes are impaired. Even when central determinants of tissue perfusion are optimized (via regional blood flow augmentation), transcutaneous oximetry detectable tissue hypoxia may persist due to local macrovascular and/or microvascular disease.

In this situation, HBO therapy may be useful in improving wound oxygenation, as long as tissues are receiving at least some blood flow. At the supraphysiologic oxygen tensions achievable under hyperbaric conditions, healing deficiencies may not only be correctable, but actually enhanced beyond otherwise normal healing rates. These therapeutic aspects of hyperbaric oxygenation have been previously demonstrated. [1,2] So, too, the fundamental mechanistic basis of hyperbaric oxygenation in wound repair. It is now clear that HBOs effects are produced through nitric oxide mediated cell-signaling pathways.[3,4,5]

Diabetic Foot Wounds

The pathophysiology of diabetic foot ulceration, faulty healing, and lower extremity limb loss has been described elsewhere.[6] Likewise, its standard management, including identification and treatment of infection, surgical debridement, correction of large vessel insufficiency, off-loading and glycemic control, is also well described.[7] Over the past decade, a number of independent evidence-based reviews have addressed the clinical and economic effectiveness of the addition of HBO therapy to standard care. While specific patient selection criteria was not always identified, it can be reasonably concluded that most studies involved advanced (Wagner grade III or higher) ulcers.

Diabetic wound failed standard care. Reversible hypoxia demonstrated.

A 1999 Blue Cross Blue Shield Technology Assessment and the 2006 Medicare financed Technology Assessment on Hyperbaric Oxygen Therapy by the Agency for Healthcare Research and Quality concluded that there was sufficient evidence to support the use of HBO therapy in diabetic wounds.[8,9] Also in 1999, the American Diabetes Association[10] reported that *'it is reasonable…to use this modality to treat severe and limb-threatening wounds…particularly if ischemia cannot be corrected by vascular procedures.'* A 2005 Cochrane Collaboration review[11] of randomized controlled clinical trials determined that *'in people with foot ulcers due to diabetes, HBO therapy significantly reduced the risk of major amputation.'* Most recently, (2007), the Canadian Agency for Drugs and Technologies in Health published the results of a longitudinal clinical and economical analysis of adjunctive HBO therapy for diabetic foot ulcers.[12] Their conclusions were that, 1) HBO therapy was more effective than standard care alone, with major amputations decreased from 32% to 11%, and 2) HBO therapy was more cost-effective

Excellent response following 20 HBO treatments. Normalized tissue oximetry. Hold HBO.

Healed wound at six week follow-up.

than standard care alone, with a 19% reduction in overall health care costs over a 12 year period being realized. Not surprisingly, this report also documented a significantly higher quality of life enhancement in those treated with HBO therapy.

Not all diabetic foot ulcers require HBO therapy. Selection criteria includes those who have failed to respond to standard care, have reached Wagner grade 3 for Medicare and demonstrate briskly reversible local hypoxia, per transcutaneous oxygen testing.

Perioperative Skin Graft Support

Wounds that have failed to heal by secondary intention may be considered for skin grafting. In order to successfully apply a split thickness skin graft, however, a sufficient amount of granulation tissue must be present in order to adequately host the graft. HBO therapy is employed in poorly granulating wounds, where transcutaneous oximetry testing demonstrates reversible local hypoxia. It should be noted that some insurers require a history of previous graft failure in order for HBO to qualify for reimbursement.

Non-healing traumatically-induced foot wound. Unresponsive to standard care, including hospitalization. Plan for skin graft coverage on hold. Reversible hypoxia demonstrated.

A course of 14-25 HBO treatments will invariably generate a rich bed of granulation tissue. In some cases, this healing response is such that generation of granulation tissue is accompanied by wound contracture and complete epithelialization. Grafting, therefore, becomes unnecessary. HBO may be continued twice daily immediately following grafting for five days in those considered at risk for graft failure. Examples include a history of graft failure, irradiated tissue, central and/or regional perfusion shortcomings and smokers. Otherwise, post-operative HBO therapy is usually unnecessary. The science and practice of HBO therapy is support of split thickness and full thickness skin grafts has recently been reviewed, along evidence-based lines.[13]

Wound appearance after 14 HBO treatments. Skin grafting scheduled.

Successful skin graft take; wound at two weeks post-graft.

Skin Flap Compromise

Amputations within the lower extremity secondary to non-reconstructible vascular disease or infection commonly involve primary closure via a rotational skin flap. On occasion, the skin flap will become threatened. This may occur acutely as dehiscence of the closure site or as random pattern ischemia. It may result from trauma, such as a fall. Should perfusion/oxygenation be sub-optimal, a chronic open wound may result at the site of the dehiscence or overt flap failure occur, respectively. Again, tissue oxygen testing may identify local and reversible hypoxia,

Traumatically dehised BKA, not responding to multiple debridements and antibiotics. Reversible hypoxic demonstrated.

Following 20 HBO treatments, excellent granulation. Normalized tissue oximetry. Hold HBO.

thereby providing the rationale for HBO to be employed. The role of HBO therapy in support of threatened skin flaps has been likewise exhaustively and encouragingly reviewed.[13] HBO therapy serves to both overcome tissue blood flow shortcomings within the flap and stimulate would healing at the dehisced flap, through the same cell signaling pathways described earlier in this report. Commonly, HBO therapy provided likely bid where the actual flap is threatened, reducing frequency to daily once flap appearance no longer regresses between treatments. In the dehisced flap, hyperbaric dosing is once daily until tissue oxygen values normalize and clinical evidence of secondary intention healing is apparent.

Continued healing responses with standard care.

Arterial Insufficiency Ulcers

Primary treatment of lower extremity arterial insufficiency ulcers is flow augmentation. In many cases, these procedures are completely effective. Flow is fully restored and in the absence of component small vessel disease, ulcer healing is achieved. In another group of patients, large vessel flow is restored but tissue oxygen valves remain below those required to support oxygen-dependent wound healing. It is in these latter cases, where chronicity persists, that HBO therapy should be considered.

Wound Oxygen Determination

Historically, HBO therapy was applied when standard measures had failed to result in the healing of selected refractory wounds. Little consideration was given to whether or not failed healing was the result of local ischemia and hypoxia and no clinically reliable method was available at that time to measure this potential complicating factor. The modern application of HBO therapy in lower extremity wound healing is vastly different. It is evidence-based and algorithmically applied. Central to this process is transcutaneous oxygen testing. Importantly, this non-invasive technology represents a physiologic rather than anatomic assessment of oxygen availability within the extremity and at the wound.

Transcutaneous oximetry technology will determine if local hypoxia is present to a degree likely to impair wound healing and whether the patient has the physiologic capacity to respond locally (wound) to the centrally (lung) delivered doses of hyperbaric oxygen. In those who are then selected to undergo HBO therapy, transcutaneous oximetry will identify responders early in the treatment course, as it indirectly measures developing angiogenesis. Finally, and no less importantly, transcutaneous oxygen testings helps identify a therapeutic endpoint. In contrast to providing HBO therapy to complete wound closure, its modern application is to normalize healing responses via the creation of a critical mass of angiogenesis. At this point the patient becomes locally host competent and the normal healing timeline is reestablished.

Transcutaneous oxygen testing of failed graft in a diabetic.

In Summary

There is basic science and clinical meta analysis support of a defined role for HBO therapy in refractory lower extremity lesions. In carefully selected patients and with the guidance of transcutaneous oxygen testing, otherwise refractory wounds will heal, or be suitably prepared for skin grafting. The modern application of HBO therapy, in that it is used to normalize healing responses rather than heal wounds, *per se*, does much to improve clinical outcomes while enhancing cost-effectiveness.

References:

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