

## シンポジウムS2-1

## Wound Healing Using Hyperbaric Oxygen Therapy

Michael B. Strauss

Department of Hyperbaric Medicine Long Beach  
Memorial Medical Center

**Introduction** Healing presents challenges especially for chronic non-healing wounds (CNW). For healthy wounds these challenges go unnoticed. However, for CNW causes for non-healing need to be identified and corrected. Some of the factors that contribute to non-healing of the chronic wound include external factors such as the requirement for a moist healing environment while others are internal such as the need for growth factors. Inadequate wound oxygenation is one of a triad of principal reasons CNW fail to heal. Hyperbaric oxygen (HBO) can mitigate this problem. Current technology provides objectivity for determining which CNW need HBO to achieve healing.

**Background** After evaluating and managing thousands of wounds for nearly 35 years, it became apparent that there are three fundamental reasons CNW fail to heal.<sup>1</sup> These are 1) Deformity, 2) Unresolved infection and 3) Ischemia/hypoxia. I have labeled these “The Treacherous Triad.” Deformities need to be managed with off-loading and then surgical interventions when indicated. Unresolved infection includes osteomyelitis, infected bursa and infected cicatrix. Often they accompany and/or are a consequence of inadequate management of deformities. Antibiotics alone are usually unsuccessful in managing this component of “The Treacherous Triad” and surgical extirpation is required. Although hyperbaric oxygen (HBO) may compliment the other interventions for managing deformity and unresolved infection, it is unquestionably a primary consideration for managing the hypoxic/ischemic non-healing wound—especially when revascularization has been done, is not feasible and/or the results are not sufficient to meet wound healing oxygen demands. Evaluation of ischemia/hypoxia starts with the history and includes information such as non-healing, persistent infection, claudication, rest pain or combinations of these. Examination assessments consist of evaluation of pulses, skin coloration, skin temperature and capillary refill. Testing procedures for ischemia/hypoxia include Doppler blood flow information, juxta-wound transcutaneous oxygen measurements (TCOM) and angiography. In many respects the quantification of the ischemia/hypoxia component of “The Treacherous Triad” can be more objective than for the other two components of the triad.

**Strategic Elements Essential for Managing the Problem Wound and Where Hyperbaric Oxygen Is Utilized** A problem wound is a wound that is not healing and/or is not expected to heal in an expected fashion.<sup>1</sup> Chronic non-healing wounds, by the above definition, are problem wounds. Five interventions are needed to manage these wounds and are the strategic elements essential for the management

of problem wounds.<sup>1)</sup> The strategic elements include: 1) Management of the wound base (usually by debridements), 2) Protection and stabilization, 3) Medical management, 4) Selection of appropriate wound dressing agents and 5) Wound oxygenation. Interventions to manage wound oxygenation include edema reduction, optimization of cardiac function, revascularization, use of pharmacological agents to improve blood rheology and hyperbaric oxygen therapy. Whereas single interventions, that is to say tactics, are used for managing the first four of the five strategic elements, more than one wound oxygenation tactic is often used to manage wound hypoxia/ischemia with the effects being additive.

**The Algorithm for Evaluation and Management of the Chronic Non-healing Wound** A logical approach for the evaluation and management of the CNW where ischemia/hypoxia is a crucial component can be formulated into an algorithm (Figure 1). If the wound is not healing and the history and examination suggest ischemia/hypoxia is a contributing cause, juxta-wound TCOM should be obtained. If the TCOM is greater than 40 mmHg in room air, wound healing should occur without the need for HBO as long as the other two components of “The Treacherous Triad” are managed appropriately.

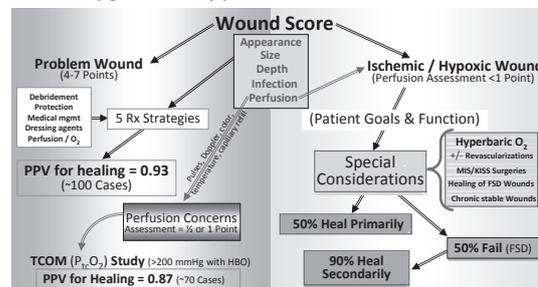
If less than 40 mmHg in room air, a hyperbaric oxygen challenge will differentiate which ischemic/hypoxic wounds will be benefited by HBO. If the TCOM with HBO at 2 atmospheres absolute exceeds 200 mmHg, there is almost a 90 percent likelihood the wound will heal with using HBO as an adjunct to wound healing.<sup>2)</sup>

**Conclusions** Five strategic interventions are needed to manage the CNW optimally. An algorithm identifies which CNW will be benefited by HBO. Whereas selection of the tactics used for management of CNW is much an art as a science, the decision to use HBO is highly objective and correspondingly largely a science.

## References

- 1) Strauss, MB, IV Aksenov, SS Miller, *MasterMinding Wounds*, Best Publishing Company, Flagstaff, AZ, 2010
- 2) Strauss, MB, BJ Bryant, GB Hart, Transcutaneous oxygen measurements under hyperbaric oxygen conditions as a predictor for healing of problem wounds. *Foot & Ankle Intl*, 2002; 23(10):933-937

Figure 1 Algorithm for Wound Healing Using Hyperbaric Oxygen Therapy



**Legend** The Wound Score is generated by summing 5 assessments each graded from 2 (best) to 0 (worst). If 4-7 points, we observed healing in 93% of the cases. If perfusion concerns arise because of a low perfusion grade (i.e. ½ to 1 point), then a TCOM with HBO is obtained. Almost 90% healing was observed if the TCOM was >200 mmHg with the HBO exposure regardless of the room air TCOM

If the perfusion assessment confirms the wound is ischemic/hypoxic, the goals and function of the patient must be ascertained. If these are satisfactory, healing with HBO occurs primarily in 50% of surgeries using MIS/KISS techniques. Of the 50% that fail, we ultimately observed healing in 90% of the motivated, functional patients

**Key** FSD = Failed, Sloughed Dehisced [wound], KISS = Keep it Simple & Speedy [surgery], HBO = Hyperbaric oxygen, MIS = Minimal Invasive Surgery, PPV = Positive Predictive Value, Rx = Treatment, TCOM = Transcutaneous O<sub>2</sub> Measurement