The Curespot

A Publication of the Advanced Wound Center

Center for Advanced Wound Healing
Community Hospital Anderson

Hyperbaric Oxygen: Mechanics of Healing

Problem:

Acute wounds often fail to close due to a defect in the healing cascade. The sequence of events included in this cascade are: *hemostasis, inflammation, angiogenesis, epithelialization, and scar formation*. Problematic or chronic wounds do not follow this sequence due to a number of host factors. Patients with diabetes present additional challenges in wound management due to their many etiologies which promote poor wound healing.

The role of an experienced wound healing team is to assess and recognize these factors in order to heal chronic problematic wounds.

Reason:

There are many factors which may cause a wound to become chronic. Of primary concern is the presence of infection, tissue ischemia/hypoxia, inadequate local wound responsiveness, and unrelieved pressure. Correction of any and all of these factors is critical for the resolution of many non-healing wounds.

Tissue hypoxia plays one of the most important roles in reducing the effectiveness of a wound's response to infection. The ischemia also presents an impediment to the processes of angiogenesis, fibroblast replication and collagen deposition.

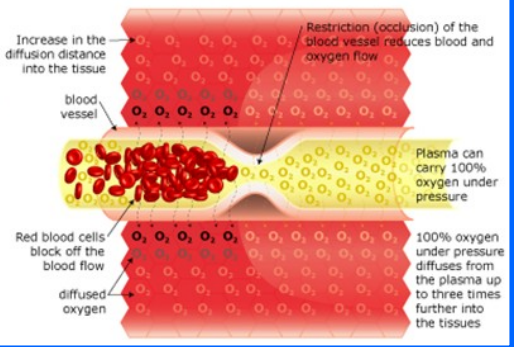
Non-healing amputations, ulcers due to vascular insufficiency and diabetic foot wounds all share the problem of tissue hypoxia, which is usually due to ischemia from vascular disease.

Solution:

Hyperbaric oxygen therapy (HBOT) is a daily treatment, in which a patient breathes 100% oxygen under pressure in a hyperbaric chamber. HBOT systemically delivers 100% oxygen to the patient at **2-3 times** greater than atmospheric pressure. This elevated pressure within the chamber results in a **10-15 fold** increase in plasma oxygen concentration, which translates to arterial oxygen values of between 1,500 and 2,000 mmHg. The steep oxygen gradient provided by HBOT produces a 3 fold increase in the diffusing distance of oxygen from functioning capillaries.

3 Hyperbaric oxygenation

Breathing 100% oxygen under pressure causes the oxygen to diffuse into the blood plasma. This oxygen-rich plasma is able to travel past the restriction, diffusing up to 3 times further into the tissue. The pressurised environment helps to reduce swelling and discomfort, while providing the body with at least 10 times its normal supply of oxygen to help repair tissue damaged by the original occlusion or subsequent hypoxic condition.



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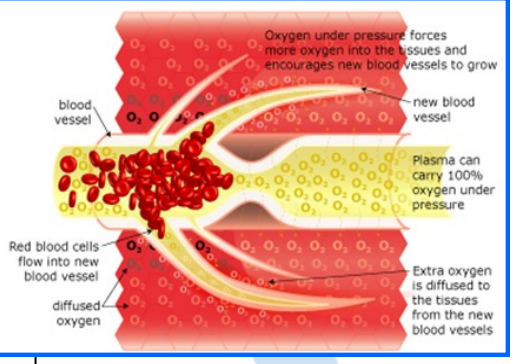
This produces a number of physiological benefits including *correction of tissue hypoxia, stimulation of fibroblast replication, support of collagen synthesis and angiogenesis, reduction of local edema,* and *improving the toxic effects of anaerobic organisms.* In addition, HBOT encourages the formation of new blood vessels which results in the delivery of even more oxygen to the affected area.

4 Blood vessel regeneration

Hyperbaric Oxygen Therapy (HBOT) forces more oxygen into the tissue, encouraging the formation of new blood vessels. As these new blood vessels develop, the red blood cells start to flow, delivering even more oxygen to the affected area. This creates the optimal environment for the body's natural healing processes to repair damaged tissue.



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The evidence supporting the beneficial physiologic effects of HBOT is encouraging:

1. Decreased local tissue edema
2. Improved cellular energy metabolism
3. Improved local tissue oxygenation
4. Improved leukocyte killing ability
5. Increased effectiveness of antibiotics
6. Promotion of collagen deposition
7. Promotion of neoangiogenesis
8. Enhanced epithelial migration

Adjunctive HBOT cannot improve healing in all problem wounds. However, those demonstrating reversible local tissue hypoxia and other factors are prime candidates for a successful outcome with the addition of hyperbaric oxygen.

The **Center for Advanced Wound Healing at Community Hospital Anderson** offers a multidisciplinary approach to the management of these complicated wounds. Oftentimes the amount of care required for desirable outcomes surpasses the resources which any single physician can provide. Wound healing at the AWC is achieved in cooperation with referring physicians, surgeons, podiatrists, and other specialists as required. Treatment options include the utilization of advanced wound care modalities which have proven to improve healing. rates and prevent amputations.

Screening Potential Candidates:

The decision to consider hyperbaric oxygen therapy is dependent upon certain factors that must be identified in the screening process that incorporate the healing mechanisms of HBOT.

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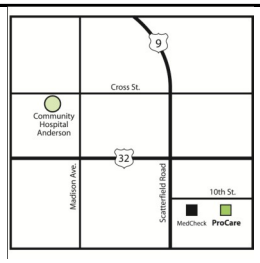
Mechanism [Ref #1]	References	Clinical Application
Hyperoxygenation*	Boerema I[5] Bassett BE[6] Bird AD[7]	DCS/AGE CO poisoning Crush injury/compartment syndrome Compromised grafts and flaps Severe blood loss anemia
Decrease gas bubble size	Boyle's law	Air or gas embolism
Vasoconstriction †	Nylander G[8] Sukoff MH[9]	Crush injury/compartment syndrome Thermal burns
Angiogenesis	Knighton DR[10]	Problem wounds Compromised grafts and flaps Delayed radiation injury
Fibroblast proliferation/collagen synthesis	Hunt TK[11]	Problem wounds Delayed radiation injury
Leukocyte oxidative killing ‡	Mader JT[12] Park MK[13] Mandell GL[14]	Necrotizing soft tissue infections Refractory osteomyelitis Problem wounds
Reduces intravascular leukocyte adherence	Zamboni WA[15] Thom SR[16, 17]	Crush injury/compartment syndrome
Reduces lipid peroxidation	Thom SR[18]	CO poisoning Crush injury/compartment syndrome
Toxin inhibition	Van Unnik A[19]	Clostridial myonecrosis
Antibiotic synergy	Mirhij NJ[20] Keck PE[21] Mendel V[22] Muhvich KH[23]	Necrotizing soft tissue infections Refractory osteomyelitis

The chart above provides a valuable summary of the clinical applications of HBOT as directly related to the mechanism at work.

Once a candidate has been identified, the assessment should focus on identifying the contributing factors to non-healing. With wounds, it is critical to identify an appropriate wound etiology for which evidence of HBO effectiveness is present. For lower extremity wounds, a complete vascular assessment should be performed as well as the verification that local hypoxia is present. Since periwound tissue hypoxia has been shown to be an important determinant of wound healing in many patients, the **Center for Advanced Wound Healing** staff can perform transcutaneous oxygen measurements ($PtcO_2$) when necessary.

Patients with demonstrated tissue hypoxia and an abnormal pulse examination will go on to further peripheral vascular evaluation and possible surgical intervention. Wounds with a $PtcO_2$ < 30 mmHg are predicted not to heal based on critical ischemia/hypoxia without the addition of HBOT. Wounds with a $PtcO_2$ of 30-50 mmHg might heal without HBOT, but on average they will take more than 12 weeks.[2]



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Treatment Decisions:

Once it has been determined that hyperbaric oxygen therapy can be used adjunctively with other procedures such as revascularization, or as a primary treatment when other options fail, several other treatment decisions must be made. The selection of the treatment pressure (depth) and duration (90-120 min) should focus on the oxygen dose desired. In addition, it must be determined if the patient is at risk for an oxygen seizure at the treatment depth selected. If so, an appropriate air break schedule must be ordered.

The decision to treat is two-fold; the AWC physician and the patient must both agree on a treatment regimen that the patient can accommodate. The number of treatments per week that the patient receives is an important component in the healing process. If the patient misses five consecutive days or 3 out of 5 days for two consecutive weeks , their treatment plan is considered "interrupted". Patients with an interrupted treatment plan may require more treatments to achieve the same result.

The decision of when to stop HBOT is dependent on the answers to a few questions:

1. Have transcutaneous PO_2 values risen to a level above the selection criteria indicating a return to a normal healing path?
2. Is the wound failing to respond?
3. Is the original indication no longer present?
4. Has the wound healing response plateaued?
5. Is the patient intolerant of the therapy or have other medical conditions that prohibit further treatment?

Patients can be referred to the Advanced Wound Center for aggressive, outcome-based wound management.

Regardless of the answer, it is important to periodically assess the patient's response to treatment and optimize all associated care.

When hyperbaric oxygen therapy is used in conjunction with standard wound care, researchers have demonstrated improved results in the healing of difficult or limb-threatening wounds in comparison to routine wound care alone.

References:

1. Latham, Emi; Hare, Marc; Neumeister, Michael. *Hyperbaric Oxygen Therapy*, Available at URL http://emedicine.medscape.com/article/1464149-overview
2. Marston WA, et al. Natural history of limbs with arterial insufficiency and chronic ulceration treated without revascularization. J Vasc Surg 2006; 44:108-114
3. Available from URL: http://www.HyperbaricWorx.com.
4. Available from URL: http://www.HyperbaricWorx.com.

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