The THAI Journal of SURGERY 2010;31:81-85.
Official Publication of the Royal College of Surgeons of Thailand

Original Article

The Role of Hyperbaric Oxygen Therapy in Wound Management

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Abstract **Hyperbaric oxygen (HBO) serves as primary or adjunctive therapy for a various range of medical conditions. Most of the efficacies of HBO are explained by the simple physical relationships determining gas concentration, volume, and pressure. The therapy's purpose is to increase the amount of oxygen in the blood. Problematic wounds are the challenging medical conditions. Hyperbaric oxygen is a new modality of treatment that is used for hypoxic wounds.**

Keywords: **hyperbaric oxygen therapy, wound management**

What Is Hyperbaric Oxygen Therapy?

Hyperbaric oxygen therapy (HBOT) is a high dose oxygen inhalation therapy in which a patient breathes pure oxygen while inside a pressurized hyperbaric chamber at an atmospheric pressure greater than normal sea level (1 ATA). At the same time, the pressure surrounding the patient's body is slowly increased to two to three times normal atmospheric pressure. HBOT allows the blood to carry more oxygen to the tissues. This helps all the functions of body that require oxygen. A high level of oxygen in the blood helps to promote new tissue and blood vessel growth, and assists in the healing process by promoting skin graft taking or second intention healing. In addition, it helps to fight infections caused by a variety of bacteria, some that only live in the absence of oxygen. It also enables white blood cells to destroy many kinds of bacteria more efficiently. HBOT is a non-invasive course of treatment. It used for various conditions and illnesses such as clostridial gas gangrene, carbon monoxide poisoning[1] and decompression sickness (DCS). Traditionally used to treat diving complications, hyperbaric oxygen therapy now has new indications from the specialties of: Surgery, Plastic Surgery, Maxillofacial & Oral Surgery, Orthopedics, Infectious Disease, Radiation Oncology and Emergency Medicine. Hyperbaric oxygen acts as a drug, eliciting varying levels of response at different treatment depths, durations, and dosages and has proven effective as adjunctive therapy for specifically indicated conditions.

What is the hyperbaric chamber?

The hyperbaric chamber is a steel cylinder in which the air is compressed to a pressure greater than

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normal sea level. The patient can be administered systemic oxygen via 2 basic chambers: Type A, multiplace; and Type B, monoplace.[2,3]

Multiplace chamber (Figure 1A-B)

Multiplace chambers treat multiple patients at the same time, generally with a nurse or another inside observer who monitors the patients and assists with equipment manipulation or emergencies. Patients in a multiplace chamber breathe 100% oxygen via a mask or close-fitting plastic hood. All equipment used with patients, such as ventilators and intravenous lines, is put into the chamber with the patient. The chamber is designed with comfortable seats. Patients can read books and magazines, watch TV or listen to music during treatments.

Monoplace chamber (Figure 2)

A monoplace chamber treats one person at a time. The gas used to pressurize the vessel is usually 100% oxygen. To enhance patient comfort, music or movies can play during treatments (Figure 3). The patient lies in a body-length transparent tube. A two-way intercom allows the patient to speak with a doctor or a nurse outside the tube.

Indications for HBOT

Utilizing knowledge gained from clinical experience and basic sciences research, the Undersea and Hyperbaric Medical Society's Committee on Hyperbaric Oxygen has approved the use of HBOT as adjunctive or primary treatment for the following diseases and conditions:

The Hyperbaric Oxygen Committee of the Undersea and Hyperbaric Medical Society (UHMS) has approved treatment in 2009 for these conditions.[4]

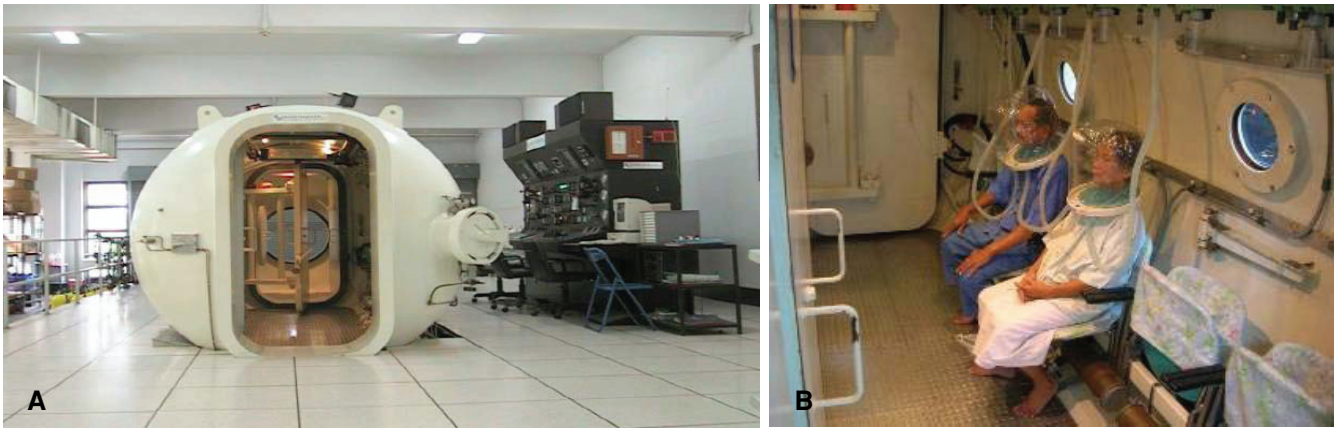

Figure 1 A. Cylindrical multiplace chamber.
B. Interior of the cylindrical multiplace chamber.

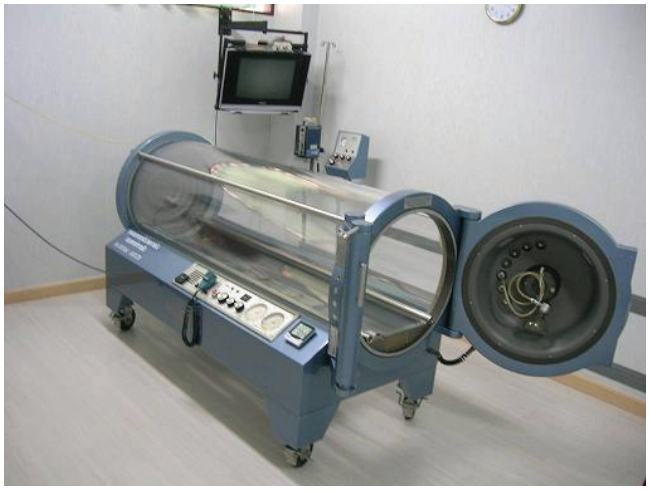

Figure 2 Monoplace chamber

Figure 3 Monoplace chamber

Primary treatment

1. Air or gas embolism
2. Decompression sickness (DCS)

Preferred treatment Carbon monoxide (CO) poisoning and CO poisoning complicated by cyanide (CN) poisoning

Adjunctive treatment

1. Clostridial myositis and myonecrosis (Gas gangrene)
2. Crush injury, compartment syndrome and other acute traumatic ischemia
3. Arterial insufficiencies
   - Central artery occlusion
   - Enhancement of healing in selected problem wounds
4. Exceptional Blood Loss (Anemia)
5. Intracranial abscess
6. Necrotizing soft tissue infections (subcutaneous tissue, muscle, fascia)
7. Osteomyelitis (refractory)
8. Radiation tissue damage (osteoradionecrosis, soft tissue radionecrosis)
9. Compromised graft and flaps
10. Thermal burns

The effects of HBOT in various conditions (Table 1)

The roles of HBOT in problematic wounds

Wound healing is arrested by decreased fibroblast proliferation, collagen production, and capillary angiogenesis in a hypoxic environment. Hypoxia also allows growth of anaerobic organisms, further complicating wound healing. Investigations of problem wounds in animal models suggested that elevation of

Table 1

Pathological conditions	Effects of HBOT
Clostidial Myositis and Myonecrosis	Suppression of toxin production Enhance neutrophil function Antibiotic potentiation
Necrotizing Soft Tissue Infection	Enhanced neutrophile function Antibiotic potentiation
Compromised skin grafts	Increased neovascularization Reduced edema
Compromised Flaps	Amelioration of ischemia-reperfusion injury Reduced edema
Crush Injury, compartment syndrome, and other acute ischemia	Amelioration of ischemia-reperfusion Injury Reduced edema
Osteoradionecrosis Soft Tissue radionecrosis	Increased neovascularization
Refractory Osteomyelitis	Enhanced neutrophil function Antibiotic potentiation Increased Osteogenesis
Problem Wounds	Increased neovascularization Increased collagen deposition Increased epithelization Reduced edema Reduced inflammation Enhanced neutrophil function
Diabetic Foot Ulcers (Wagner grade 3+)	Increased granulation Enhanced neutrophil Function Reduced edema
Acute Thermal Burn	Reduced edema Infection control Increased epithelialization and graft take

wound oxygen tension to normal enhanced wound healing. Sheffield and associates[5,6] confirmed hypoxia in chronic, indolent, human wounds and demonstrated elevation of wound oxygen tension with hyperbaric oxygen treatment. Transcutanous oximetry has become increasingly popular as a method of patient selection for hyperbaric oxygen treatment. Hyperbaric oxygen therapy provides a significant increase in tissue oxygen tension. It enhances fibroblastic proliferation, increases collagen synthesis, and promotes neovascularization and bacterial clearance in wounds. HBOT may be useful when underlying osteomyelitis is present or in improving the soft tissue envelope for reconstruction. However, HBOT is adjunctive to standard wound care.

Contraindications for HBOT

Absolute Contraindications[7]

1. Untreated Pneumothorax
2. Selected medications8

a) Doxorubicin (Adriamycin®) - chemotherapeutic agent

b) Mafenide Acetate (Sulfamylon®) - Antibacterial drug

c) Cis-Platinum - A cancer drug.

d) Disulfiram (Antabuse) - Used in the treatment of alcoholism

e) Bleomycin - chemotherapeutic agent

Relative Contraindications

1. Seizure disorder
2. Emphysema with CO2 retention
3. High fever
4. History of spontaneous pneumothorax
5. Upper respiratory infection, chronic sinusitis and otitis
6. History of thoracic surgery
7. History of otosclerosis surgery
8. Viral infections
9. Congenital spherocytosis
10. History of optic neuritis
11. Claustrophobia or dangerous behavior

Side effects and complications of HBOT

Hyperbaric oxygen therapy is generally safe and well tolerated. Most side effects are mild and reversible, although severe consequences can occur in rare cases.[9-13]

1. Effects of pressure (the most common side effect) (ear, lung, parasinus, dental, skin, head, body, gastrointestinal, etc.)

- Ears barotrauma
- Pulmonary barotrauma : pneumothorax, mediastinal emphysema, pulmonary tissue damage, air embolism
- Sinus barotrauma

2. Oxygen toxicity

- Central nervous system effects (Paul Bert effect)
- Pulmonary effects (Lorraine Smith effect)
- Ocular effects

3. Cardiovascular aspects of HBOT

Prevention of HBOT complications

1. Initial Medical Consultation
   - Medical history
   - Physical examination
   - Chest x-ray
   - Others :- EKG, Pulmonary function tests with spirometry
2. Chamber Attendant
   - Help patient to equalize ear pressure
   - Reassure patients and help to avoid any unsuitable behavior
3. Patient Education
   - Staff and equipment
   - Physiologic changes possibly experienced during HBOT
   - Functioning of the equipment
   - Ear pressure equivalization maneuvers
   - Safety: clothes, forbidden items, emergency measures in case of fire, urgent decompression
   - Restrictions: make-up, hairspray, perfume, vaseline or any other petroleum-based products are not allowed in the hyperbaric chamber

Conclusion

Hyperbaric oxygen is a drug with well defined physiological and pharmacological effects that is used for helping all the functions of the body that require oxygen. It offers many benefits, but there are also dangers associated with the procedure, and the treatment should only be administered under the close monitoring of highly trained physicians and nurses. HBOT is not designed to replace other proven methods of treatment but to supplement other forms

of treatment such as surgery, antibiotics and wound care. It should not be a replacement for other standard successful therapeutic measures. However researches are needed and are undergoing.

Acknowledgments

The author thanks Paul Sheffield, Jim Sheffield, and Robert Sheffield (International ATMO, Nix Wound Care&Hyperbaric Medical Center, San Antonio, Texas); Thanasawat Chaiyakul, M.D. (Underwater & Aviation Medicine Division, Naval Medical Department, Royal Thai Navy, Thailand).

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