THERAPEUTIC USES OF HYPERBARIC OXYGEN THERAPY

BY

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INTRODUCTION

- HBOT has been used to treat ‘Decompression Illness’ among divers since early 20th century.
- Has also been used to treat other illnesses where:
  - ischemia is the main component pathology
  - hyperoxygenation main stay of treatment
- Recognized & accepted as an effective modality in medical therapeutics in last one decade
UNITS OF PRESSURE

01 ATA (760mmHg)

EARTH

ATMOSPHERE
WHAT IS HYPERBARIC OXYGEN

Hyperbaric oxygen therapy (HBOT) is a form of treatment in which a patient breathes 100% oxygen at higher than normal atmospheric pressure i.e. greater than 1 atmosphere absolute (ATA) - following prescribed protocols.
HOW IT IS GIVEN

- Monoplace chambers
- Multiplace chambers
# Physical Basis of HBOT

## Alveolar Gas Pressures

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OXYGEN PARTIAL PRESSURES AT DIFFERENT LEVELS

At 1 ATA (760 mmHg)
Total Pressure = 760 mmHg (PO2 = 160 + PN2 = 600)

- Atmospheric Air PO2 = 160 mmHg
- Air in Trachea PO2 = 150 mmHg
- Air in Lungs PO2 = 100 mmHg
- In arterial blood PO2 = 100 mmHg
- In venous blood PO2 = 40 mmHg
- Extracellular PO2 = 20 mmHg
- Intracellular PO2 = 4.5–8 mmHg
### PHYSICAL BASIS OF HBOT cont..

- **Effect of pressure on Arterial O₂**
  - Oxygen Combined with Hb (97% saturated) = NO CHANGE
  - Oxygen dissolved in plasma

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<th>TOTAL PRESSURE</th>
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1. HYPEROXGENATION

- The **10-18 fold** $\uparrow O_2 \rightarrow$ **four fold** $\uparrow$ in the diffusing distance of oxygen from functioning capillaries

- **Clinical Utility** - Crush injury, compartment syndrome, graft and flap salvage (decreased perfusion) Edema (increased diffusion barrier), Severe blood loss anemia

2. NEOVASCULARIZATION

- Enhanced Oxygen dependent - fibroblast proliferation & Capillary angiogenesis

- **Clinical Utility** - Graft & flap salvage, osteoradionecrosis, radiation endarteritis obliterans, Other radiation-induced injuries, Ch wounds, Refractory osteomyelitis.
3. **ANTI MICRROBIAL ACTIVITY**
   - Hyperoxia → ↑ phagocytosis and white cell oxidative killing.
   - Toxin inhibition and toxin inactivation in clostridial perfringens infections (gas gangrene).
   - Fluoroquinolones, Amphotericin-B and Aminoglycosides use oxygen to transport across Cell membrane

4. **DIRECT PRESSURE**
   - ↓ Nitrogen gas bubble size
   - **Clinical Utility** - DCS and AGE

5. **VASOCONSTRICTION** (without component hypoxia)
   - → ↓edema **Clinical Utility** - Burns, compartment syndrome, Ac. ischemias in injured extremities, grafted tissue.
ABC of oxygen: Hyperbaric oxygen therapy

Necrotising infections and osteomyelitis

should be discussed with the nearest regional centre. A single session of hyperbaric oxygen therapy will usually reverse the acute, potentially life threatening effects of carbon monoxide poisoning, but additional treatments may be needed to reduce the extent of damage.

References

8 online articles that can be found at http://bmj.com/cgi/dx/17/7166/1140

Skin grafts, flaps, and wound healing

In poorly vascularised tissue hyperbaric oxygen improves both graft and flap survival compared with routine postoperative surgical care alone. The effect of normobaric 100% oxygen was not examined in these studies. In the United States problem wounds are the commonest indication for a trial of adjunctive hyperbaric oxygen therapy and include diabetic and other small vessel ischaemic foot ulcers. Several studies have shown improved healing and a lower incidence of amputation with 4-30 sessions.

Post radiation damage

The higher partial pressures achieved with hyperbaric oxygen may stimulate new vessel growth and healing in damaged irradiated tissue which has lost the capacity for restorative cellular proliferation.
EVIDENCE BASED GUIDELINES FOR THE INPATIENT MANAGEMENT OF ACUTE DIABETES RELATED FOOT COMPLICATIONS.

Revision:

Department of Diabetes and Endocrinology
Clinical Epidemiology & Health Service Evaluation Unit

The Royal Melbourne Hospital
REVIEW ARTICLES

MEDICAL PROGRESS

HYPERBARIC-OXYGEN THERAPY

PATRICK M. TIBBLES, M.D.,
AND JOHN S. EDELSBERG, M.D., M.P.H.

HYPERBARIC oxygen — 100 percent oxygen at two to three times the atmospheric pressure at sea level — can result in arterial oxygen tension in excess of 2000 mm Hg and oxygen tension in tissue of almost 400 mm Hg. Such doses of oxygen have a number of beneficial biochemical, cellular, and physiologic effects, and today there are 259 hyperbaric facilities in the United States with 344 single-occupant (“monoplace”) hyperbaric-oxygen chambers. In this article, we review the mechanisms of action, evidence of clinical efficacy, and risks of therapy with hyperbaric oxygen.

Physiologic Effects

For hyperbaric oxygen, pressure is expressed in multiples of atmospheric pressure. Hyperbaric oxygen therapy results in an increase in arterial oxygen tension and reduces the percentage of arterial carbon dioxide tension. Because arterial oxygen tension is increased and arterial carbon dioxide tension is decreased, the oxygen-to-carbon dioxide ratio in arterial blood is increased. In addition, the oxygen-to-carbon dioxide ratio in venous blood is increased in proportion to the increased arterial oxygen tension. This increased oxygen-to-carbon dioxide ratio in both arterial and venous blood enhances oxygen delivery to and extraction from tissues.

Free radicals are formed during oxygen transport and oxygenation of tissues. Oxygen radicals are responsible for cellular injury and may be involved in the pathogenesis of diseases. Hyperbaric oxygen decreases the production of free radicals, and this decrease may contribute to the therapeutic effects of hyperbaric oxygen. Hyperbaric oxygen also decreases the production of oxygen radicals during cellular injury and may reduce the severity of injuries that occur as a result of cellular injury.

Local hypoxia leads to poor wound healing. Adequate oxygen tension is a prerequisite for the formation of collagen matrix, which is essential for angiogenesis. In irradiated tissue, hyperbaric oxygen is more effective than normobaric oxygen in increasing the partial pressure of oxygen to a level that promotes the formation of collagen matrix and angiogenesis. Whether hyperbaric oxygen is superior to 40 to 100 percent normobaric oxygen in improving wound healing in nonirradiated tissue is not clear.

Reperfusion injury can worsen crush injuries and compartment syndromes and cause skin flaps and reattachment procedures to fail. Neutrophils have been implicated as the prime endogenous culprit in reperfusion injury. Adhering to the walls of ischemic vessels, they release proteases and produce free radicals, leading to...
Relationship of oxygen dose to angiogenesis induction in irradiated tissue.

Marx RE, Ehler WJ, Tayapongsak P, Pierce LW.
Division of Oral and Maxillofacial Surgery, University of Miami School of Medicine/Jackson Memorial Medical Center, Florida.

This study was accomplished in an irradiated rabbit model to assess the angiogenic properties of normobaric oxygen and hyperbaric oxygen as compared with air-breathing controls. Results indicated that normobaric oxygen had no angiogenic properties above normal revascularization of irradiated tissue than did air-breathing controls (p = 0.89). Hyperbaric oxygen demonstrated an eight- to ninefold increased vascular density over both normobaric oxygen and air-breathing controls (p = 0.001). Irradiated tissue develops a hypovascular, hypocellular hypoxic tissue that does not revascularize spontaneously. Results failed to demonstrate an angiogenic effect of normobaric oxygen. It is suggested that oxygen in this sense is a drug requiring hyperbaric pressures to generate therapeutic effects on chronically hypovascular irradiated tissue.

PMID: 2240387 [PubMed - indexed for MEDLINE]
Hyperbaric oxygen results in increased vascular endothelial growth factor (VEGF) protein expression in rabbit calvarial critical-sized defects.

Fok TC, Jan A, Peel SA, Evans AW, Clokie CM, Sándor GK.

Resident in Oral and Maxillofacial Surgery, Schulich School of Medicine and Dentistry, University of Western Ontario.

BACKGROUND: Hyperbaric oxygen therapy (HBO) promotes osseous healing, however the mechanism by which this occurs has not been elucidated. HBO may promote angiogenesis, which is vital for bone healing. Vascular endothelial growth factor (VEGF) is one of the key factors that stimulates angiogenesis. OBJECTIVE: The objective of this study was to investigate whether HBO altered VEGF expression during bone healing. METHODS AND MATERIALS: Archived samples from calvarial defects of rabbits exposed to HBO (2.4 ATA, 90 minutes a day, 5 days a week for 4 weeks) and normobaric oxygen controls (NBO) were analyzed by immunohistochemistry. RESULTS: VEGF expression in 6-week HBO samples was elevated compared to NBO (P = .012). Staining of the 12-week HBO samples was reduced compared to 6-week HBO (P = .008) and was similar to 6- and 12-week NBO control samples. CONCLUSION: HBO therapy resulted in increased VEGF expression in the defects even 2 weeks after the termination of treatment (6 weeks postsurgery).

PMID: 18206401 [PubMed - as supplied by publisher]
Hyperbaric oxygen prevents major amputation in diabetic patients with chronic wounds


What the study asked

Does hyperbaric oxygen therapy (HBOT) improve outcomes in patients with chronic wounds?

What the study found

In patients with diabetic foot ulcers, HBOT reduces the number of major amputations for up to 1 year. These data, however, are based on fewer than 200 patients among all six studies in the literature.

Level of evidence

1a—Systematic review of randomized trials displaying worrisome heterogeneity. The level-of-evidence scale runs from 1 (strongest) to 5 (weakest); for a complete description see www.infopoems.com/levels.html.

Synopsis of the study

Chronic wounds are the bane of many patients and their physicians. There are four main types, listed here in descending prevalence: diabetic foot ulcers, venous leg ulcers, arterial leg ulcers, and pressure ulcers. HBOT has been proposed as an adjunct to improve wound healing.

Methods

These authors systematically reviewed all randomized controlled trials that compared the effect of adjunctive HBOT with no HBOT or sham therapy for chronic wound healing. They searched several databases, relevant textbooks, and conference proceedings, and contacted experts in the field.

The investigators independently identified the included studies, extracted the data, and assessed the quality of the studies. Disagreements were settled by consensus. Finally, if data were missing, the researchers contacted the author.

Study results

Only six studies with a total of 191 patients were included. Five of the studies evaluated patients with diabetic foot ulcers and one included patients with venous ulcers. Only two of the studies of diabetic foot ulcers and the single study on venous ulcers were of good quality.

Probably the most important finding is that there were fewer major amputations in diabetic patients treated with HBOT up to 1 year after treatment (number needed to treat = 4, 95% confidence interval 3-11). The rate of minor amputations was unaffected.
INTERNATIONALLY APPROVED INDICATIONS OF HBOT
(FDA approved)

PRIMARY THERAPY
1. Cerebral arterial gas embolus
2. Decompression sickness
3. Carbon monoxide poisoning
4. Osteoradionecrosis

ADJUNCTIVE THERAPY
5. Problematic wounds
6. Acute ischemia and/or crush injuries
7. Necrotizing infections
8. Acute thermal burns
9. Compromised skin grafts or flaps
10. Radiation tissue damage
11. Osteoradionecrosis prophylaxis
12. Refractory osteomyelitis
13. Acute exceptional blood loss
14. Clostridial gas gangrene
“Off-Label” Uses for HBOT

- Cerebral Palsies
- Anoxic Brain Injuries
- Multiple Sclerosis
- Sports injuries (sprains, muscle injuries)
- Decreases healing time after surgery
- Sudden sensorineural hearing loss (SSHL)
- Lyme disease
- Bell’s palsy
- Arthritis
- Acne
HBOT AND INJURED BRAIN

- CP due to hypoxic-ischemic encephalopathies
- Other anoxic brain injuries

If the HBO increases oxygen at cellular level for burns, and debilitating wounds then why not in the injured Anoxic Brain?

The concept behind HBO for the treatment of anoxic brain insult is describe as enhancing “DORMANT” or “IDLE” neurons.
Clinical effectiveness of treatment with hyperbaric oxygen for neonatal hypoxic-ischaemic encephalopathy: systematic review of Chinese literature

Discussion

The results of this systematic review suggest that treatment with hyperbaric oxygen may reduce mortality and neurological sequelae in term neonates with hypoxic-ischaemic encephalopathy. Hyperbaric oxygen has been used to treat various conditions for several decades and has been used in neonates. Although this form of treatment is controversial, it has developed rapidly in China over the past decade and is widely used there.

Data:

http://bmj.com/cgi/content/full/333/7564/374?DC1

References

This article cites 20 articles, 1 of which can be accessed free at:
http://bmj.com/cgi/content/full/333/7564/374#BIBL

2 online articles that cite this article can be accessed at:
http://bmj.com/cgi/content/full/333/7564/374#otherarticles

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Hyperbaric Medicine and Brain Injured Children

Prepared for the Committee on Government Reform for the May 6th, 2004 Hearing

By: Kenneth Stoller, M.D., F.A.A.P.
Chairman of the Pediatrics Committee, IHMA Foundation
Clinical Assistant Professor, University of NM, School of Medicine, Dept of Pediatrics
Diplomate, American Board of Hyperbaric Medicine
Diplomate, American Board of Pediatrics
SELECTED CASES
Total number of HBOTs given = 40
Before the start of HBOT

At HBOT No 40
# Radiometer ABL 700 Series Patient Report

**Patient Report**
- **Sample #**: 2039
- **Temp**: 37.0°C

**Identifications**
- **Patient ID**: 123456
- **Patient Last Name**: Smith
- **Patient First Name**: John

**Blood Gas Values**
- **pH**: 7.407
- **pCO₂**: 5.10 kPa
- **pO₂**: 13.4 kPa

**Oximetry Values**
- **ctHb**: 8.9 g/dL
- **sO₂**: 99.0%
- **tO₂Hb**: 74.2%
- **tFCO₂Hb**: 23.9%

**Temperature Corrected Values**
- **pH(T)**: 7.407
- **pCO₂(T)**: 5.10 kPa
- **pO₂(T)**: 13.4 kPa

**Oxygen Status**
- **ctO₂**: 9.5 Vol%
- **pSO₂**: 2.57 kPa

**Acid Base Status**
- **cBase(Ecf)**: -0.5 mmol/L
- **cHCO₃(P,st)**: 24.1 mmol/L

**Notes**
- Value(s) above reference range
- Value(s) below reference range
POSSIBLE COMPLICATIONS

1. EAR BAROTRAUMAS
2. SINUS BAROTRAUMA
3. PULMONARY BAROTRAUMAS
4. MYOPIA
5. OXYGEN TOXICITY (1.3 per 10,000 cases)
6. DECOMPRESSION SICKNESS
7. CLAUSTROPHOBI A
CONTRAINDICATIONS

1. Claustrophobia
2. Pneumothorax or History of spontaneous pneumothorax
3. Chronic obstructive pulmonary disease
4. Pneumonias
5. Seizure disorders
6. Pregnancy
7. Upper respiratory infection
8. Hyperthermia
9. Hereditary spherocytosis
10. Optic neuritis
11. Malignant tumors
12. Drugs (cis-platinum, Doxorubicin, Bleomycin, Steroids, Alcohol, Disulfiram)
HBOT - WHERE DO WE STAND

HYPERBARI C CENTERS AROUND THE WORLD

- USA - > 1000 (Jan 2007)
- CHINA - >2500
- RUSSIA - >2000
- UK - >400
- MALAYSIA - 10
- INDIA - 7
- BANGLADESH - 1
- PAKISTAN - NONE
Hyperbaric Oxygen Providers in the following countries:

AFRICA
P.E. Hyperbaric Unit
54 Admiralty Way
Summerstrand
Port Elizabeth 6013
South Africa
Phone +2782 927 5678
Fax: +2741 583 1189
Email: pehu@xsinet.co.za
The Hyperbaric Facility
P.O. Box 35

For Hyperbaric Oxygen Providers in the USA
FOR STATES: ALABAMA TO NEW MEXICO
CLICK HERE

FOR STATES: NEW YORK TO WYOMING
CLICK HERE

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ACADEMIC
Undersea and Hyperbaric Medicine Overview

The subspecialty of Undersea and Hyperbaric Medicine is a discipline that deals with the prevention of injury and illness due to exposure to environments in which the ambient pressure is increased, such as in diving or hyperbaric chamber exposure, and the therapeutic use of high environmental pressure and the delivery of oxygen under high pressure to disease. The scope of the subspecialty emphasizes the occupational, environmental, safety, and clinical aspects of hyperbaric chamber operations, compressed air work, and hyperbaric oxygen therapy.

In 1989, the American Board of Preventive Medicine (ABPM) received approval from the American Board of Medical Specialties (ABMS) to offer a subspecialty certificate in Undersea Medicine to its diplomates. The first examination for certification was administered in November 1992. In 1993 several ABMS member Boards expressed an interest in char this certificate so that it would be available to diplomates of all ABMS member boards. During 1993, two meetings were held and a survey was sent to the membership of the Undersea and Hyperbaric Medical Society. Based on the results of these undertakings, on February 4, 1994, the ABPM filed a letter of intent to change the Certificate of Added Qualifications in Undersea Medicine to a Certificate of Special Qualifications with the ABMS. Since that time, the ABM discontinued the use and differentiation of CAQ and CSQ.

In March 1999, ABPM received approval to change the name of its subspecialty certification in Undersea Medicine to Undersea and Hyperbaric Medicine to more accurately reflect the expansion of practice during the past decade to include regular use of hyperbaric oxygen therapy for a variety of disorders.

In March 2000, ABEM received approval from ABMS to formalize a collaborative arrangement with ABPM to offer the Undersea and Hyperbaric Medicine subspecialty certification examination to its diplomates. Under this agreement, ABF also can offer this examination to other ABMS-member board diplomates who fulfill the eligibility requirements.

The Undersea and Hyperbaric Medicine Examination Committee has two representatives from ABEM and seven representatives from ABPM. ABPM is the administrative board for this subspecialty.

Revised 5/21/07
The Undersea and Hyperbaric Medical Society (UHMS) is an international, non-profit organization serving 2,000 members from more than 50 countries. The UHMS is the primary source of scientific information for diving and hyperbaric medicine physiology worldwide.

BlueCross/BlueShield Information

UHMS members receiving denials from regional BlueCross Blue Shield affiliates are requested to forward de-identified communications to Tom Workman.

Read More

2008 Annual Scientific Meeting

The UHMS presents its Annual Scientific Meeting in Salt Lake City, Utah, this year, June 26-28. Researchers and featured speakers will present session on both hyperbaric and diving medicine.

Read More
Chamber of secrets

By Tom Fordyce

Could England's hopes of regaining the Ashes after 18 years rest on a machine designed to treat divers suffering from the Bends?

Simon Jones, England's best bowler of the series, will spend large chunks of this week in a hyperbaric oxygen chamber in a desperate attempt to be fit for the deciding Test at The Oval starting on 8 September.

Jones faces a race against time after injuring his right ankle during the dramatic fourth Test at Trent Bridge, with coach Duncan Fletcher admitting: "I'm not confident that he will play."

As a result, the England medical team are utilising a piece of equipment more often used to treat decompression sickness or carbon monoxide poisoning.

"In basic terms, an oxygen chamber can get you fit again more quickly," explains Dr Des McCann, of London's Capital Hyperbarics.

"Hyperbarics works by increasing the amount of oxygen in the body's injured tissues. "The dissolved oxygen reduces swelling and stimulates the
VAUGHAN RECOVERY UNDER PRESSURE

England captain Michael Vaughan may resort to treatment in a hyperbaric oxygen chamber in an attempt to hasten his recovery from a broken finger.

Vaughan, 32, sustained an undisplaced fracture of his right middle finger after being struck on the hand by Hampshire’s Australia paceman Stuart Clark while batting for Yorkshire in their LV County Championship match at the Rose Bowl on Thursday.
CONCLUSION

The Hyperbaric Chamber is now an integral part of hospital services. Doctors in all fields must familiarize themselves with recent advances on this mode of therapy, so that their patients are not denied the gains of this modern treatment. The addition of HBO to conventional treatment in certain well defined conditions results in significant cost savings due to lesser stay in hospital, shorter course of illness and more complete recovery.
THANK YOU