Clinical Indications for Hyperbaric Oxygen Therapy in 2011

Part 1

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What is HBO therapy?

“Breathing oxygen under pressure for therapeutical purposes”

- Increase of oxygen transport
- Increase of oxygen delivery

- Oxygen “as a drug”
  - Indications, dose, side effects
How to administer HBO?

- “Monoplace” hyperbaric chambers
How to administer HBO?

- "Monoplace" hyperbaric chambers
- "Multiplace" hyperbaric chambers
How to administer HBO?

- “Monoplace” hyperbaric chambers
- “Multiplace” hyperbaric chambers
- Pressure of at least 2 ATA
- Duration of at least 60 minutes of $O_2$
How to administer HBO?

- Pressure of at least 2 ATA
- Duration of at least 60 minutes of O2
- “Topical” application of oxygen is NOT HBO Therapy!
Effects of breathing oxygen at pressure

- Increase of $P_{(alv)} \text{O}_2$
- Increase of $P_{(art)} \text{O}_2$
- Increase of $P_{(ven)} \text{O}_2$

- Hemoglobin saturation in venous blood = 100%
Oxygen transport in blood

\[ \text{Ca}(\text{O}_2) = (\text{Hb} \times \text{SaO}_2 \times 1.34) + (\text{PaO}_2 \times 0.003) \]

Figure 6.1. Oxygen dissociation curve (solid line) for pH 7.4, P\text{CO}_2 40 mm Hg, and 37°C. The total blood O\textsubscript{2} concentration is also shown for a hemoglobin concentration of 15 gm/100 ml of blood.
Oxygen transport in blood

\[
Ca(O_2) = (Hb \times SaO_2 \times 1.34) + (PaO_2 \times 0.003)
\]
**Oxygen transport in blood**

- **Physiological O$_2$ consumption**

![Table](image)

**TABLE 14-1.—MEAN VALUES FOR BLOOD O$_2$, CO$_2$ AND pH IN HEALTHY RESTING YOUNG MEN**

<table>
<thead>
<tr>
<th></th>
<th>Arterial Blood</th>
<th>Mixed Venous Blood</th>
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</thead>
<tbody>
<tr>
<td>O$_2$ pressure (torr)</td>
<td>100</td>
<td>40</td>
</tr>
<tr>
<td>Dissolved O$_2$ (ml O$_2$/100 ml W.B.$^\dagger$)</td>
<td>0.3</td>
<td>0.12</td>
</tr>
<tr>
<td>O$_2$ content (ml O$_2$/100 ml W.B.)</td>
<td>20.3</td>
<td>15.5</td>
</tr>
<tr>
<td>O$_2$ combined with Hb (ml O$_2$/100 ml W.B.)</td>
<td>20.0</td>
<td>15.4</td>
</tr>
<tr>
<td>O$_2$ capacity of Hb (ml O$_2$/100 ml W.B.)</td>
<td>20.6</td>
<td>20.6</td>
</tr>
<tr>
<td>% saturation of Hb with O$_2$</td>
<td>97.1</td>
<td>75.0</td>
</tr>
<tr>
<td>Total CO$_2$ (ml CO$_2$/100 ml W.B.)</td>
<td>49.0</td>
<td>53.1</td>
</tr>
<tr>
<td>(mmoles CO$_2$/L)</td>
<td>21.9</td>
<td>23.8</td>
</tr>
<tr>
<td>Plasma CO$_2$ (ml CO$_2$/100 ml plasma)</td>
<td>59.6</td>
<td>63.8</td>
</tr>
<tr>
<td>a. Dissolved CO$_2$ (ml CO$_2$/100 ml)</td>
<td>2.84</td>
<td>3.2</td>
</tr>
<tr>
<td>b. Combined CO$_2$ (ml CO$_2$/100 ml)</td>
<td>56.8</td>
<td>60.5</td>
</tr>
<tr>
<td>c. Combined CO$_2$/dissolved CO$_2$</td>
<td>20/1</td>
<td>18.9/1</td>
</tr>
<tr>
<td>d. CO$_2$ pressure (torr)</td>
<td>40</td>
<td>46.5</td>
</tr>
<tr>
<td>Plasma pH</td>
<td>7.40</td>
<td>7.376</td>
</tr>
</tbody>
</table>


$^\dagger$W.B. = whole blood.
“Life without blood”?

Boerema 1959

[Image of a graph showing changes in blood parameters over time, with annotations in Dutch.]
Life without blood!
Effects of hyperbaric hyperoxia

- Increased $O_2$ transport in blood
Effects of hyperbaric hyperoxia

- Increased $O_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
Effects of hyperbaric hyperoxia

- Increased $O_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)

Variations in volume

![Graph showing volume changes at different pressures and depths.](image)
Effects of hyperbaric $O_2$

- Increased $O_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases
Effects of hyperbaric $O_2$

- Increased $O_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

$pO_2$ (cap) 40mmHg

Krogh’s Capillary Model
Effects of hyperbaric O$_2$

- Increased O$_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

\[ pO_2 \text{ (cap) } 40\text{mmHg} \]

Krogh’s Capillary Model
Effects of hyperbaric O₂

- Increased O₂ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

Krogh’s Capillary Model

\[ pO_2 \text{ (cap) } 40\text{mmHg} \]
Effects of hyperbaric O₂

- Increased O₂ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

Krogh’s Capillary Model

\[ pO₂ \text{ (cap) } 40\text{mmHg} \]
Effects of hyperbaric O\textsubscript{2}

- Increased O\textsubscript{2} transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

Krogh’s Capillary Model

\( pO_2 \text{(cap)} 300\text{mmHg} \)
Effects of hyperbaric O$_2$

- Increased O$_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

$pO_2$ (cap) 300mmHg

Krogh’s Capillary Model
Effects of hyperbaric O$_2$

- Increased O$_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases

Krogh’s Capillary Model

$pO_2$ (cap) 300mmHg
Effects of hyperbaric $O_2$

- Increased $O_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases
- Anti-infectious defense mechanisms
  - Direct (anaerobic bacteria)
  - Indirect (white blood cell function, ATB)
Effects of hyperbaric O₂
Effects of hyperbaric O$_2$

Infection rate in 153 operative surgical patients at high risk for infection - correlation with SC pO2 (FiO2 = 0.5)

Greif R et al. NEJM 20;342(3):161-7 2000
Supplemental perioperative oxygen to reduce the incidence of surgical-wound infection.

Roseau E Presse Med 29(12):656 2000  Peritoneal infections: preventive effect of perioperative supplemental oxygen administration

Hopf HW et al Arch Surg 132(9):997-1004 1997 Wound tissue oxygen tension predicts the risk of wound infection in surgical patients
Effects of hyperbaric O$_2$

Fig. 5. Effect of hyperbaric oxygen on average survival time in septic rats treated with vancomycin, clindamycin, or metronidazole. (See Fig. 4 for explanation of symbols.)
Effects of hyperbaric O$_2$

- Increased O$_2$ transport in blood
- Pressure effect (Boyle-Mariotte’s law)
- Diffusion distance of oxygen increases
- Anti-infectious defense mechanisms
  - Direct (anaerobic bacteria)
  - Indirect (white blood cell function, ATB)
- Stimulation of granulation tissue
"Oxygen as a drug": Indications

- Any disease where oxygen (maybe) plays a role?
- Any disease where no other good treatment is available?
- "A therapy in search of diseases" (Chest, 1987)
Evidence Based Medicine

- **Level I evidence**
  - Multiple RCTs of good quality: prospective, placebo controlled

- **Level II – III – IV evidence**
  - Small RCTs without placebo
  - Retrospective studies with patients as their own historical controls
  - Retrospective studies, uncontrolled
  - Case series
  - Animal studies
HBO Therapy Indication

1. Is there a (local or generalised) lack of oxygen?
2. Does this hypoxia cause or aggravate the disease?
3. Can HBO improve tissue oxygenation?
4. Is there evidence that improving tissue oxygenation improves the disease?
5. Is there a good “risk-benefit” ratio for this particular patient?
1. Air or Gas Embolism
2. Carbon Monoxide Poisoning (incl. CO Poisoning Complicated by Cyanide Poisoning)
3. Clostridial Myositis and Myonecrosis (Gas Gangrene)
4. Crush Injury, Compartment Syndrome and other Acute Traumatic Ischemias
5. Decompression Sickness
6. Arterial Insufficiencies (Central Retinal Artery Occlusion, Enhancement of Healing In Selected Problem Wounds)
7. Severe Anemia
8. Intracranial Abscess
9. Necrotizing Soft Tissue Infections
10. Osteomyelitis (Refractory)
11. Delayed Radiation Injury (Soft Tissue and Bony Necrosis)
12. Compromised Grafts and Flaps
13. Acute Thermal Burn Injury
<table>
<thead>
<tr>
<th>CONDITION</th>
<th>ACCEPTED</th>
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<tbody>
<tr>
<td></td>
<td>Level of Evidence</td>
</tr>
<tr>
<td></td>
<td>A</td>
</tr>
<tr>
<td><strong>Type I</strong></td>
<td></td>
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<tr>
<td>CO intoxication</td>
<td></td>
</tr>
<tr>
<td>Crush Syndrome</td>
<td></td>
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<tr>
<td>Prevention of Osteoradionecrosis (dental extraction)</td>
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<tr>
<td>Osteoradionecrosis (mandible)</td>
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<tr>
<td>Soft Tissue Radionecrosis (cystitis)</td>
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<tr>
<td>Decompression Accident</td>
<td></td>
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<tr>
<td>Gas Embolism</td>
<td></td>
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<tr>
<td>Anaerobic or Mixed Bacterial Anaerobic Infections</td>
<td></td>
</tr>
<tr>
<td><strong>Type II</strong></td>
<td></td>
</tr>
<tr>
<td>Diabetic Foot Lesion</td>
<td></td>
</tr>
<tr>
<td>Compromised Skin Graft and Musculocutaneous Flap</td>
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<tr>
<td>Osteoradionecrosis (other bones)</td>
<td></td>
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<tr>
<td>Radio-induced Proctitis / Enteritis</td>
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<tr>
<td>Radio-induced Lesions of Soft Tissues</td>
<td></td>
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<tr>
<td>Surgery and Implant in Irradiated Tissue (preventive action)</td>
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<tr>
<td>Sudden Deafness</td>
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<tr>
<td>Ischemic Ulcer</td>
<td></td>
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<tr>
<td>Refractory Chronic Osteomyelitis</td>
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<tr>
<td>Neuroblastoma Stage IV</td>
<td></td>
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<tr>
<td><strong>Type III</strong></td>
<td></td>
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<tr>
<td>Post-anoxic Encephalopathy</td>
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<tr>
<td>Larynx Radionecrosis</td>
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<td>Radio-induced Oropharyngoesophageal Ulcer</td>
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<tr>
<td>Post-vascular Pneumothorax</td>
<td></td>
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<tr>
<td>Limb Re-implant</td>
<td></td>
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<tr>
<td>Burns &gt;20 % of Body Surface Area of Burns</td>
<td></td>
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<tr>
<td>Acute Ischemic</td>
<td></td>
</tr>
<tr>
<td>Selected Non-healing Fractures Secondary to Inflammatory Processes</td>
<td></td>
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<tr>
<td>Pneumatosis Cystoides Intestinalis</td>
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</table>

Conditions where the use of HBO2 was supported by level A, B or C evidence were considered as accepted indications.

- **Level A:** At least 2 concordant, large, double-blind, controlled randomized studies with no or little methodological bias.
- **Level B:** Double-blind controlled, randomized studies but with methodological flaws; studies with only small samples, or only a single study.
- **Level C:** Consensus opinion of experts.
“Military” indications

(Ref RTG-192 NATO Working Group)

- Decompression Sickness
  - Air embolism
- Crush injury
- Carbon Monoxide Poisoning
- Acoustic (noise) trauma
- Burns
- Anaerobic soft tissue infections
Air embolism
Air embolism
Air embolism
Air embolism
Air embolism
Crush injury
CO Poisoning
Anaerobic infections

- Animal studies
- Amsterdam Experience
3 Depth degrees of cutaneous burn
Burns

- 3 Depth degrees of cutaneous burn
Burns

- 3 Depth degrees of cutaneous burn
- Increasing burn depth over 24 hours
- Jackson concept of 3 zones

**Superficial Dermal Burn**

**Characteristics**
1. Necrosis confined to upper third of dermis
2. Zone of necrosis lifted off viable wound by edema
3. Small zone of injury
Burns

- 3 Depth degrees of cutaneous burn
- Increasing burn depth over 24 hours
- Jackson concept of 3 zones
Experimental evidence

- Animal litterature ++
- 1996 CHBO Study on rats
- 2000 CHBO Study 2 on rats
Experimental evidence

Piracetam and HBO in the acute treatment of burns

HYPOTHESIS:
Piracetam and/or Hyperbaric Oxygen Therapy can prevent the progressive deepening of burn injury.

- optimal 'classical' treatment
- realistic time lapse before 
- histological study

- development and validation of
- randomized, prospective, single

RESULTS

3. degree of inflammation

<table>
<thead>
<tr>
<th></th>
<th>control</th>
<th>pira</th>
<th>HBO</th>
</tr>
</thead>
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<tr>
<td>scale:</td>
<td>0 - 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.69</td>
<td>0.60</td>
<td>0.47</td>
</tr>
<tr>
<td>*</td>
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<td>*</td>
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</tbody>
</table>
Experimental evidence

Study Protocol

- Wistar rats 300-350g, general anesthesia, back shaved & depilated
- 40%TBSA burn by immersion (70°C water, 30sec)
- IP Ringer’s Lactate 10mL
- randomisation 3 groups:
  - control sham burn
  - control burn no treatment
  - burn HBOT
- 4 measurement endpoints: 30, 120, 240 after burn

Conclusions

- paradoxically decreased MDA levels ~ less reperfusion damage
- CH50 values restored to ConNoBurn ~ less activation of complement system
- TNFa values within normal range throughout 6 hours

HBOT is a safe therapeutic procedure in this burn model
Experimental evidence

- Animal literature ++
- 1996 Study on rats
- 2000 Study 2 on rats
- Why not done?
  - Clinical human RCTs lacking
  - Optimal environment HBO and ICU lacking
Acoustic Trauma

- Frequent, both in military and in civilian youth
- Impulse noise vs longer exposure
- Emergency treatment with HBO & corticosteroids = promising
- RCTs lacking
  - Comparison to hearing before trauma?
  - Early (>36hr) treatment necessary
Acoustic Trauma

Lafere et al. *DHM 2010*

Comparison between the pure tone audiogram on enlistment into the army (baseline) and after acute acoustic trauma in the affected ear (all patients; ***$P < 0.0001$***)

68 Belgian soldiers with acute impulse noise (gunshot) acoustic trauma
Acoustic Trauma

Lafere et al. *DHM 2010*

Comparison between the pure tone audiogram on enlistment into the army (baseline) and after acute acoustic trauma in the affected ear (all patients; ***$P < 0.0001$***)

The average residual hearing loss in the three treatment groups (see text; *$P < 0.05$*)

- **kHz**
  - 0.25
  - 0.5
  - 1
  - 2
  - 4
  - 8

- **dB**
  - 0
  - 20
  - 40
  - 60
  - 80

- induction screening
- after acute acoustic trauma

- NO HBOT
- HBOT + IV
- HBOT + PO
Dangers of HBO therapy

- Transportation
- Compression
- Stay at Depth
- Decompression
Dangers of HBO therapy

- Haemodynamically unstable patients should not be moved!
- Barotrauma of the ears
  - Common (10-20%)
  - Preventable
  - Rarely serious
- Hyperoxic seizures
  - Seldom (1 in 1500-5000 treatments)
  - Unpredictable (but...)
  - No sequelae
Dangers of HBO therapy

- **Uncontrolled use**
  - Diseases with large impact of QoL
  - For which there is no cure
  - For which evaluation of effects is mainly subjective
  - Gives HBO “a bad name”

- **Examples...**
  - Multiple Sclerosis
  - Chronic Fatigue
  - Autism
  - Cerebral Palsy

- **Never say never...** But: proof must be given
Hi, I'm Dr. Harold Grams. I use the therapeutic approach of defeating autism now and protocols in my care of autistic children.

I've been successfully treating autism with hyperbaric oxygen for over 7 years. Are you going to a doctor's office for hyperbaric treatment? And are you looking for a way to control your costs and see the fastest possible improvements in your child's autism?

Please call me now to discuss how to get started with autistic hyperbaric treatments in your home as soon as possible.

I've helped people all over the U.S. and in over 10 countries worldwide to effectively use hyperbaric oxygen to significantly reduce symptoms and help their children's autism.

Tired of the time, cost, and hassle of going to your doctor's office for hyperbaric treatments?

Now you can buy, or rent, a hyperbaric chamber and give your child much-needed treatments in the convenience of your home. This is the most affordable way to bring the healing power of hyperbaric oxygen to your child.

With a portable hyperbaric chamber in your home your child will get double or triple the number of treatments you might be able to schedule at your doctor's office. More treatment sessions mean a higher likelihood that your child's symptoms will improve faster. Plus you will save $1000s of dollars on treatments--and your valuable time.

Choose the best chamber for your personal size and for your budget. All our chambers work at 4 psi (pounds per square inch). Since all provide the same treatment...the only question is which size chamber is right for you? Which chamber fits your budget? And is it better to buy or rent?

VITAERIS 33.5 inches tall, 79" long, 190 cubic feet
Includes chamber, inner frame, mattress, bolster pillows to stabilize chamber, compressors and all hoses and attachments.

Oxyhealth chambers are the originals used and trusted by more DAN doctors worldwide than any other. These are FDA approved, medical grade quality.

Rental Savings: $3,405

Efficacy of Hyperbaric Oxygen Therapy for Autism

The use of hyperbaric oxygen therapy for the treatment of autism is relatively recent and so there is not a great deal of scientific evidence specifically related to it, but some positive study results are beginning to come in. At the same time, there are many testimonials from families that have used HBOT as an autism treatment for their autistic children and the results have mostly been encouraging.

To gauge the efficacy of HBOT, the brain can be monitored for its perfusion -- the extent to which it is supplied by blood -- and its activity. At the same time, we can monitor the behavior, response to stimuli (sensory function) and motor skills of the autistic individual, to determine if hyperbaric oxygen therapy has produced any positive results.

In addition, hyperbaric oxygen therapy has been used for many years -- and proven effective -- in the treatment of cerebral palsy, which involves serious damage to brain cells.

Brain SPECT scans

Monitoring of cerebral blood flow can be done with a Brain SPECT (Single Photon Emission Computed Tomography) scan. SPECT scans before and after mild HBOT sessions have shown dramatic improvements in cerebral blood flow that is sustained over time.
Hyperbaric Oxygen Therapy, Alzheimer’s and Dementia

by Rashmi Gulati, MD

Alzheimer’s is a progressive brain disorder affecting areas of the brain that control behavior, memory, and cognitive thinking skills. Alzheimer’s symptoms include loss of memory, difficulty performing familiar tasks, problems with language, disorientation to time and place, poor or declining judgment, difficulty with abstract thinking, and changes in personality. As the nervous system deteriorates there may be involuntary muscle reflexes.

Application for Healing

Some toxic metals like aluminum, arsenic, cadmium, lead, mercury, and nickel are taken into our bodies through the air, food, and water. The toxic effects of these metals can remain in our bodies for years, and have been linked to Alzheimer’s disease, aluminum toxicity, and mercury poisoning. Per million of aluminum in human blood can cause it to coagulate. This slows the flow of blood in smaller vessels. Brain cells will die without blood.

How it Works

Hyperbaric Oxygen Therapy can be used as an alternative treatment for Alzheimer’s disease. It involves the use of oxygen at higher pressures than what is usually experienced with atmospheric pressure. This process can help improve circulation and oxygen delivery to the brain, potentially reducing symptoms of Alzheimer’s.

How to look great on the beach!

Cellulite can be a real problem when you’re wanting to look good on the beach. But don’t send those high-cut summer shorts and flirty mini skirts to the charity shop just yet. There are therapies which can help with cellulite, and hyperbaric oxygen therapy is one of them.

But what is hyperbaric oxygen therapy and how does it work?

Hyperbaric oxygen therapy is also known as hyperbaric medicine, and involves the use of oxygen at higher pressures than usually experienced with atmospheric pressure.
Interest in HBOT by the equine industry is due to its ascribed beneficial effects on the healing of lower limb wounds, which remain a major health problem to man and horses worldwide. Slow-healing wounds or those that fail to heal can result in prolonged hospitalisation, numerous surgical interventions and time-consuming wound care. Slow healing is particularly inconvenient and challenging for high-performance human and equine athletes.
And even...