Safety Issues on Hyperbaric Oxygen Therapy

Kun-Lun Huang

Undersea and Hyperbaric Medical Institute
Tri-Service General Hospital
National Defense Medical Center
Hyperbaric Oxygen Therapy

![Diagram showing the effects of hyperbaric oxygen therapy on different tissues and PO2 levels.

- Capillary
- Interstitium
- Cell

PO2, mmHg

- 0
- 5
- 10
- 15
- 20
- 25
- 30

0 500 1000 1500 2000

Shunt flow

Normal

Capillary Interstitium Cell

Sechrist, Perry, etc.

Total

Hgb-bound

Dissolved

PO2, mmHg

- Normal
- 1 ATA
- 2 ATA
- 3 ATA

PO2, mmHg

- edema

Sechrist, Perry, etc.

PO2, mmHg

Sechrist, Perry, etc.

Sechrist, Perry, etc.
HBO$_2$ Therapy - Pressure Profiles

Hyperbaric oxygen

Pressure (atm abs)

Time (min)
<table>
<thead>
<tr>
<th>Depth, ft</th>
<th>Time, min</th>
</tr>
</thead>
<tbody>
<tr>
<td>180</td>
<td>0</td>
</tr>
<tr>
<td>160</td>
<td>50</td>
</tr>
<tr>
<td>140</td>
<td>100</td>
</tr>
<tr>
<td>120</td>
<td>150</td>
</tr>
<tr>
<td>100</td>
<td>200</td>
</tr>
<tr>
<td>80</td>
<td>250</td>
</tr>
<tr>
<td>60</td>
<td>300</td>
</tr>
<tr>
<td>40</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td></td>
</tr>
</tbody>
</table>

- **Compressed air**
- **Hyperbaric oxygen**
Complications of HBO$_2$

- **Pressure-related**
  - Pneumothorax, cerebral gas embolism
  - Epistaxis (paranasal sinus squeeze)
  - Eardrum rupture
  - Decompression sickness

- **Oxygen-related**
  - Acute CNS O$_2$ toxicity - vomiting, seizure
  - Chronic pulmonary O$_2$ toxicity
  - Cataracts
Barotrauma

- **Pulmonary problems**
  - Pneumothorax
  - Pneumomediastinum

- **Otological problems**
  - External ear canal
  - Middle ear - Tympanic membrane
  - Inner ear - Round window

- **Paranasal sinus**
Barotrauma (Squeeze)
Severe Pulmonary Barotrauma
Pulmonary Barotrauma - Etiology

- **Compression phase (technical-related)**
  - Endotracheal intubation or tight breathing mask
  - Pressure reducer failure – high pressure
  - Build-in Respiratory System (BIBS) – high flow
  - Ventilator failure

- **Decompression phase (disease-related)**
  - Spontaneous pneumothorax
  - Pulmonary blebs or cysts
  - Airway obstruction at any generation of bronchus
  - Breath-holding
Pulmonary Barotrauma - Consequence

- **Air into pleural cavity**
  - Small amount – simple pneumothorax
  - Large amount – tension pneumothorax
  - Check valve – tension pneumothorax

- **Air to lung parenchyma**
  - Pneumomediastineum
  - Pneumoperitonea
  - Subcutaneous emphysema

- **Air to pulmonary circulation**
  - Cerebral gas embolism
  - Coronary artery embolism
Tension Pneumothorax

☠️ The only possible fatal complication during hyperbaric oxygen therapy
Pulmonary Barotrauma - Management

- **Air into pleural cavity**
  - Tension pneumothorax - convert into simple pneumothorax
  - Simple pneumothorax – chest tube drainage

- **Air to lung parenchyma**
  - Conservative treatment

- **Air to pulmonary circulation**
  - Cerebral gas embolism – USN Table 6A
  - Coronary artery embolism – USN Table 6A
Gas Uptake and Elimination

- Fast tissue
- Intermediate
- Slow tissue

Supersaturation
Bubble Formation and Growing

\[ P_1 V_1 = P_2 V_2 \]
Iatrogenic DCS

- M/33, diving fisherman
- Type II DCS with CNS symptoms of confusion
- Treated with USN Table 6A without O_2 breathing
- Delirium and crutis marmorata after surfacing
- Coma and profound chock during surfacing in the second course of Table 6A treatment
- Endotracheal intubation and sedation and then recompression therapy
- Stayed in the hospital for one week
USN Treatment Table 6A

**Depth/Time Profile**

- **Depth (fsw)**
- **Breathing Media**
  - Green = Oxygen
  - Blue = Air
- **Descent Rate**
  - 20 ft/min
- **Ascent Rate**
  - 3 ft/min
  - 1 ft/min
- **Total Elapsed Time:**
  - 350 Minutes
  - (Not Including Descent Time)
Iatrogenic DCS

- M/33, diving fisherman
- Type II DCS with CNS symptoms of confusion
- Treated with USN Table 6A without O₂ breathing
- Delirium and crustis marmorata after surfacing
- Coma and profound chock during surfacing in the second course of Table 6A treatment
- Endotracheal intubation and sedation and then recompression therapy
- Stayed in the hospital for one week
USN Treatment Table 4

Depth/Time Profile

Depth (fsw)

Descent Rate 20 ft/min

Ascent Rate 1 ft/min

Patient begins oxygen breathing at 60 ft. Both patient and tenders breathe oxygen beginning 2 hours before leaving 30 ft.

TotalElapsed Time:
39 Hours 6 Minutes
(30 minutes at 165 fsw) to
40 hours 36 minutes
(2 hours at 165 fsw)

Breathing Media

= Oxygen

= Air

Time at Depth (minutes)
Iatrogenic DCS

- M/33, diving fisherman
- Type II DCS with CNS symptoms of confusion
- Treated with USN Table 6A without $O_2$ breathing
- Delirium and crutis marmorata after surfacing
- Coma and profound chock during surfacing in the second course of Table 6A treatment
- Endotracheal intubation and sedation and then recompression therapy
- Stayed in the hospital for one week
Oxygen Toxicity

- Lipid peroxidation
- Protein denaturation
- Enzyme inactivation
- Membrane transport inhibition
Pulmonary $O_2$ Toxicity

- Damaged endothelium
- Increased vascular permeability
- Decreased vital capacity
Pulmonary Oxygen Toxicity

Symptom intensity vs. VC, percent change

Exposure hours

2.5 ATA 2.0 ATA 1.5 ATA
Pulmonary O$_2$ Toxicity

- CNS limits:
  - -2%
  - -4%
  - -6%

- Pulmonary limits:

Duration of oxygen breathing, hr

P$_{\text{IO}_2}$, ATA
Unit Pulmonary Toxic Dose

\[ \text{UPTD} = t_x \left( \frac{P_{102} - 0.5}{0.5} \right)^{0.83} \]

\( t_x \): duration of exposure in min
Equivalent UPTD values and average decrements in vital capacity (adapted from Wright 1972)

<table>
<thead>
<tr>
<th>Equivalent UPTD units</th>
<th>Average decrement in vital capacity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>615</td>
<td>2</td>
</tr>
<tr>
<td>825</td>
<td>4</td>
</tr>
<tr>
<td>1035</td>
<td>6</td>
</tr>
<tr>
<td>1230</td>
<td>8</td>
</tr>
<tr>
<td>1425</td>
<td>10</td>
</tr>
<tr>
<td>1815</td>
<td>15</td>
</tr>
<tr>
<td>2190</td>
<td>20</td>
</tr>
</tbody>
</table>
Pulmonary $O_2$ Tolerance

VC, percent change

Oxygen exposure hours at 2 ATA

Continuous

Intermittent
Contraindications of HBO₂ (I)

- **Absolute contraindications**
  - Untreated pneumothorax
  - Obstructive lung diseases

- **Relative contraindications**
  - Acute URI
  - Seizure disorders
  - Reconstructive ear surgery
Contraindications of HBO₂ (II)

- Relative contraindication

  Pregnancy
  High fever
  Seizure disorders
  COPD
  Alcoholism
  Sickle cell anemia
  Congenital spherocytosis
Thank You