

# Hyperbaric Oxygen and TBI: What Does Science Tell Us

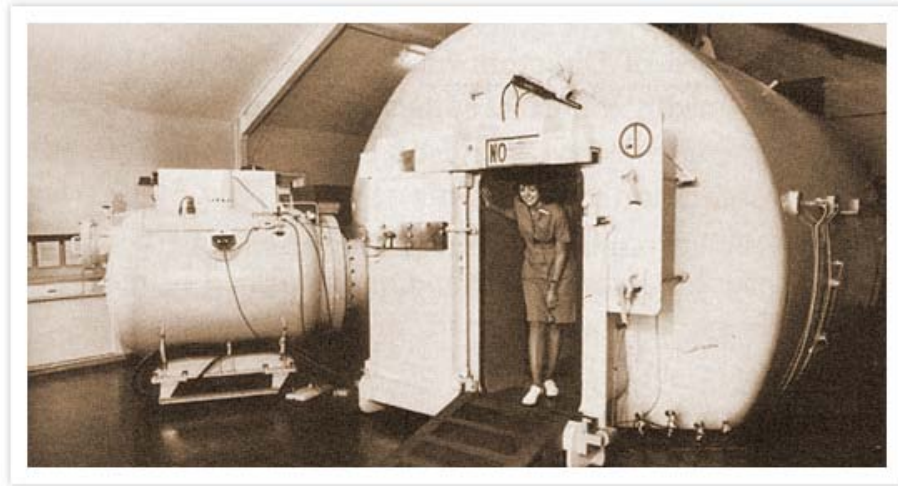
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- Look at scientific research on using hyperbaric oxygen treatment and neurofeedback treatment to improve outcomes after TBI
- Discussion
- No conflicts of interest to report (neither Dr. Bell or Zumsteg receives any money from anyone connected with these topics)

# History of HBOT

**Circa 1960's**



**2011**



# Decompression Illness – The “Bends”



Brooklyn Bridge 1883

# Current Indications for HBOT

Air or gas embolism

Gas gangrene

Crush injury

Compartment syndrome

Acute peripheral ischemias

Decompression sickness

Enhanced healing in selected problem wounds

Exceptional blood loss anemia

Necrotizing soft tissue infections

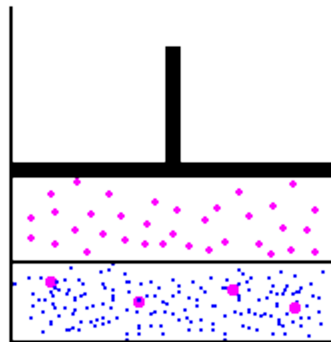
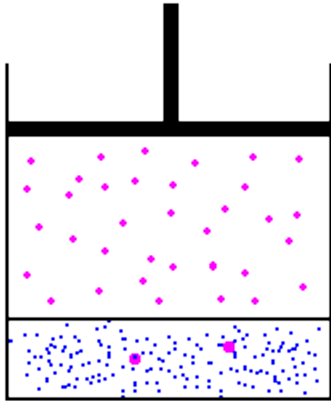
Osteomyelitis

Delayed radiation injury (soft tissue and bony necrosis)

Compromised skin grafts and flaps

Carbon monoxide poisoning

# Ideal Gas Laws



## Henry's law

The amount of gas dissolved in a liquid is equal to the partial pressure of the gas exerted on the surface of the liquid. By increasing the atmospheric pressure in the chamber, more oxygen can be dissolved into the plasma than would be seen at surface pressure

# What does this mean for oxygen and the body?

- At sea level, the atmospheric pressure surrounding the body is “1 atmosphere (or ATM)” (or 14.7 psi)
- At 33 feet below sea level, “1.5 atmospheres (or ATM)”
- Most treatments for HBOT
- Pressure used for animal studies 1.5-3 ATM and duration of treatment is 1-3 hours

# Neural Tissue and HBOT

- In animal and human experiments, HBO has resulted in
  - Temporary increase in oxygen pressure in the brain
  - Changes in blood flow
  - Reduced intracranial pressure
  
- \*\*All of these experiments were done after ACUTE brain injury



# Animals with Stroke

- In animals with a variety of stroke types, acute HBOT resulted in:
  - ↓ size of brain stroke,
  - ↓ brain swelling,
  - Stabilization of barrier between the brain and blood circulation
  - ↓ cell death,
  - improved glucose uptake,
  - improved neurobehavioral scores

- However, the results decreased the longer that ischemia (or decreased blood flow) lasted
  - In fact, some studies demonstrated worse outcome

# Human Studies/Stroke

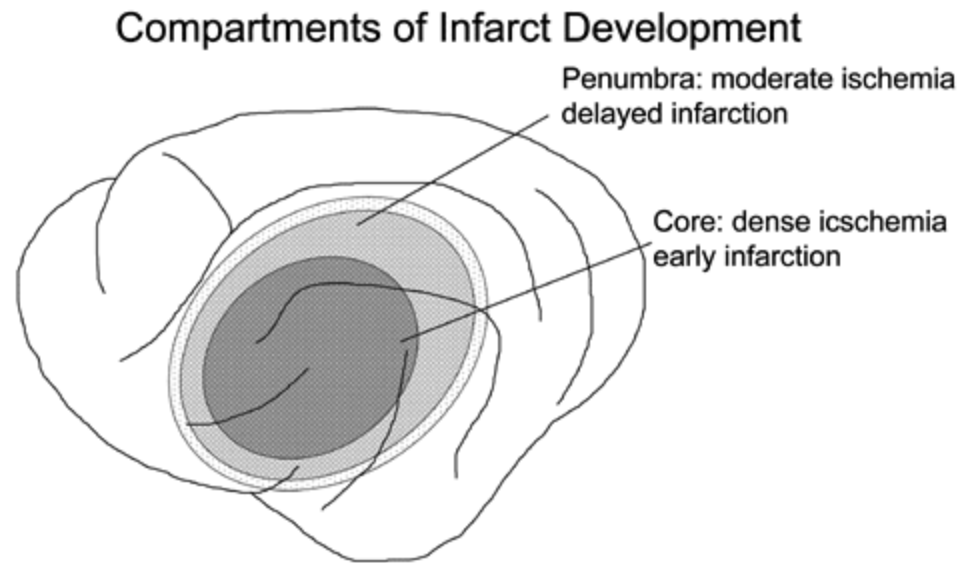
- Rusyniak (2.5 ATA x 1 hr) – No benefit at 24 hours, worse at 90 days
- Vila, 2005 Chronic cerebrovascular disease – improved motor and cognitive function
- Pretreatment CABG – improved neuropsychological scores postoperatively

# What are the theories for how HBOT works to reduce tissue damage?

- Increased oxygen content to the tissues which would have otherwise had lower oxygen

In strokes

- may also improve local metabolism
- Transient



- Reduce excitotoxicity
  - Decrease some of the toxic metabolites like lactate and glutamate
  - Reduce dopamine levels
  - Help to preserve dopamine levels
- Stabilizes the barrier between the brain and blood

- Reduces stress caused by oxidation (overly high levels of brain activation)
  - Decreases breakdown of membranes which release enzymes
    - Lipid peroxidase, NADPH oxidase, superoxide dismutase
  - Elevates magnesium levels

- Decreases indicators of inflammation
  - Less white blood cell infiltration
  - Less enzymatic activity
  - Less release of cellular inflammatory compounds
    - (e.g., prostaglandins, prostacyclins)

# HBOT and TBI

- Very few controlled studies
- Mostly case studies or case series



# HBOT and TBI

- Artru (1976)
  - 60 patients in coma randomized to standard care or treated with 2.5 atm 60 min daily for 10 days/off/10 days...until death or recovery of consciousness
    - 12 months: similar mortality, improved but not significant recovery of consciousness
    - Treatment DCd in 35% due to pulmonary complications

# HBOT and TBI

- Rockswold (1992)
  - 168 patients with severe acute TBI, 6-24 hours after admission random assignment
    - HBOT 1.5 atm 60 minutes q 8 hrs for 2 weeks OR brain death OR following simple commands (average 21 treatments)
    - 12 months: HBOT lower mortality but no difference in dead/severely disabled outcomes
    - Tx DCd in 12% due to adverse effects (also began doing myringotomies part way through study)

# HBOT and TBI

- Rockswold (2009)
  - 69 pts randomized for HBOT (60 min, 1.5 ATA) vs. normobaric hyperoxia (3 hrs, 100% O<sub>2</sub>, 1 ATA) vs. standard care – once daily for 3 days
    - Measured the amount of O<sub>2</sub> in brain tissue
    - Brain tissue O<sub>2</sub> significantly increased for both experimental conditions in a graded fashion
      - HBO more robust effect and lowered ICP more effectively

# HBOT and Chronic TBI

- Harch (2007)
  - 64 rats with unilateral cortical contusion tested with Morris Water Task 30 days post injury
    - 3 groups: untreated controls, HBOT (1.5ATA, 90 min, bid, 7 days/week – total 80 treatments), sham HBOT
    - HBOT: increased vascular density in injured hippocampus
    - HBOT: improved spatial learning

# HBOT and Chronic TBI

- Golden (2006)
  - Children, mixed diagnosis convenience sample vs. retrospective data from children with brain disorders (who had been through other types of treatments) and controls
    - Test-retest at 4-8 weeks (no comment on validity of retesting in short intervals)
  - Improvement on all scores for group, high variability

# Current Studies

- HBOT for PCS after mTBI – Virginia Commonwealth (post-deployed military) NCT01220713
- HBOT for mild/moderate TBI – San Antonio (post-deployed military) NCT00810615
- Multicenter HBOT trial – USAMRMC NCT01306968
- HBOT in Chronic TBI or PTSD – ongoing, not recruiting (Consortium HBOT Centers) NCT01105962

# Take home Messages

- HBOT is do-able for acute TBI
  - But few hospitals are equipped
  - AND the research evidence does not yet support doing this on a routine basis
    - May be fewer deaths
    - No evidence that people do better in long run
    - Good preliminary evidence in animals and a little good evidence in people
- HBOT is pretty safe for acute TBI
  - Ear pressure problem, rare seizure
  - Claustrophobia

# Take home Messages

- Not much evidence on how effective HBOT really is for chronic TBI
  - Ongoing studies may help in illuminating this





Thank you!