HYPERBARIC OXYGEN IN WOUND HEALING

Jose L. Albarran, CHT

Hyperbaric Oxygen Therapy:
A Working Definition

- Hyperbaric oxygen (HBO2) is a treatment, in which a patient breathes 100% oxygen intermittently while inside a treatment chamber at a pressure that is higher than sea-level pressure
- Must be 1.4 ATA or higher to qualify as HBO2
- At this time topical high pressure oxygen therapy (bags/boxes) not supported by science or recognized by CMS

Hyperbaric Oxygen Therapy Committee Report. UHMS 2008.

Pressure Equivalents

1 ATA = 760 mmHg = 14.7 psi = 0 FSW

2 ATA = 1520 mmHg = 29.4 psi = 33 FSW

3 ATA = 2280 mmHg = 44.1 psi = 66 FSW

ATA – Atmosphere Absolute　　mmHg – Millimeters of mercury　　FSW – Feet of sea water

Pressure Equivalents

pp02 @ sea level = .21 x 760 = 160 mmHg

pp02 @ 2 ATA = .21 x 1520 = 320 mmHg

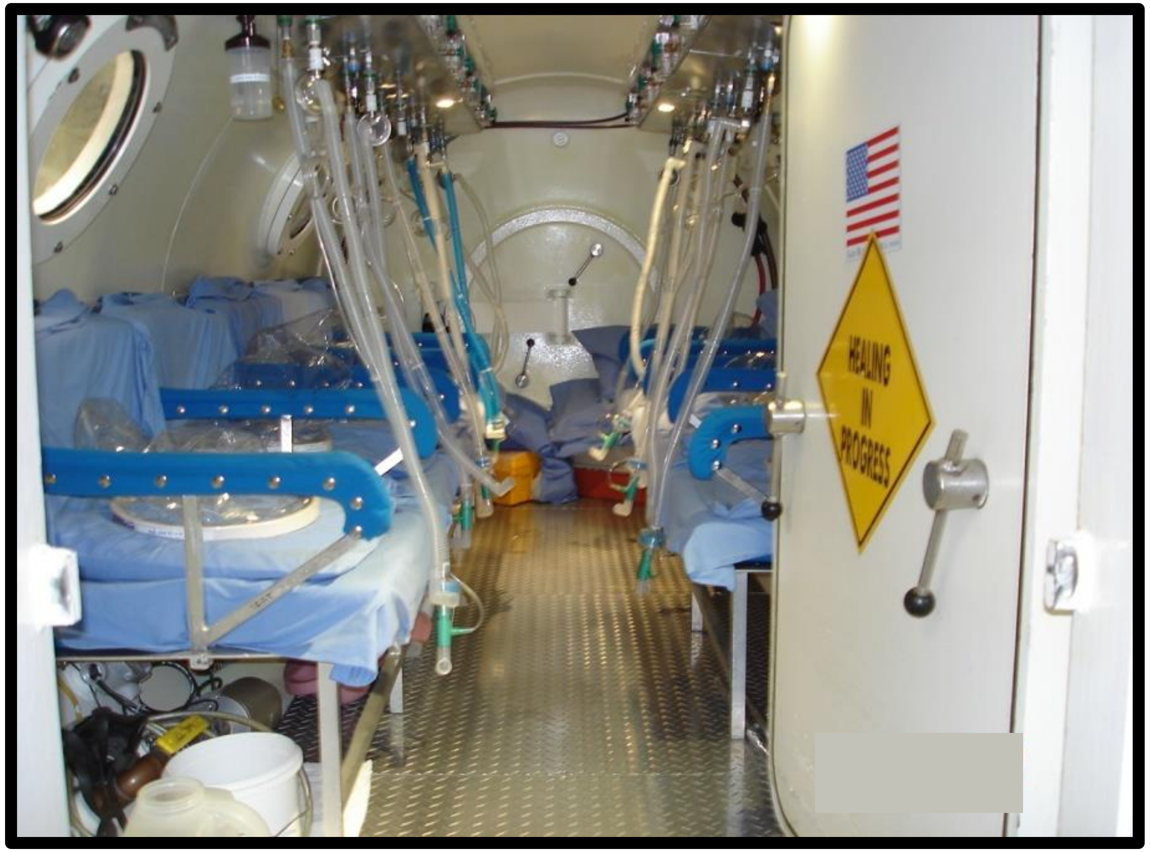
pp02 @ 3 ATA = .21 x 2280 = 480 mmHg

pp02 @ Fi02 of 1 @ 2 ATA: 1 x 1520 = 1520 mmHg

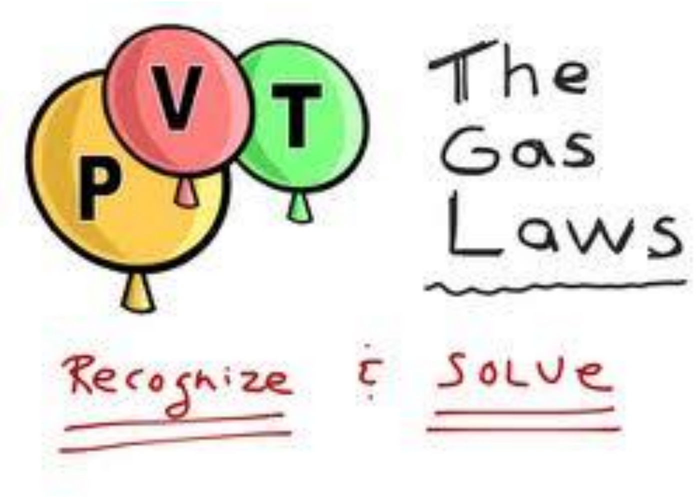
ATA – Atmosphere Absolute   mmHg – Millimeters of mercury FSW – Feet of sea water
pp02- partial pressure of oxygen   Fi01 – Fraction of inspired oxygen

Monoplace Chambers

Multiplace Chambers



The Gas Laws

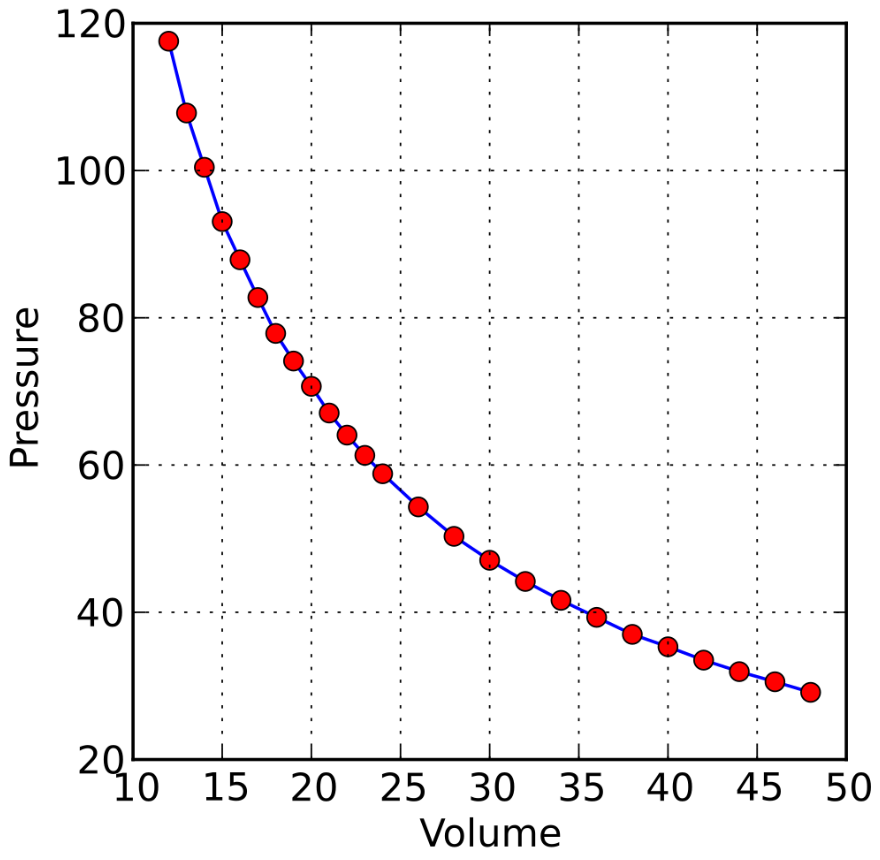


- Boyle's Law
- Charles' Law
- Henry's Law
- Dalton's Law

- Developed at the end of the 18th century to explain relationships of pressure, volume, and temperature of gases in a system

Boyle's Law

For a body of gas at constant temperature, the volume is inversely proportional to the pressure



Dalton's Law

The sum of the partial pressures of gases in a system = the total pressure in the system

$$P_{Total} = P_1 + P_2 + P_3$$

Air: Oxygen (21% = 160 mmHg) + Nitrogen (79% = 600 mmHg) = 760 mmHg

Physiology of HBOT

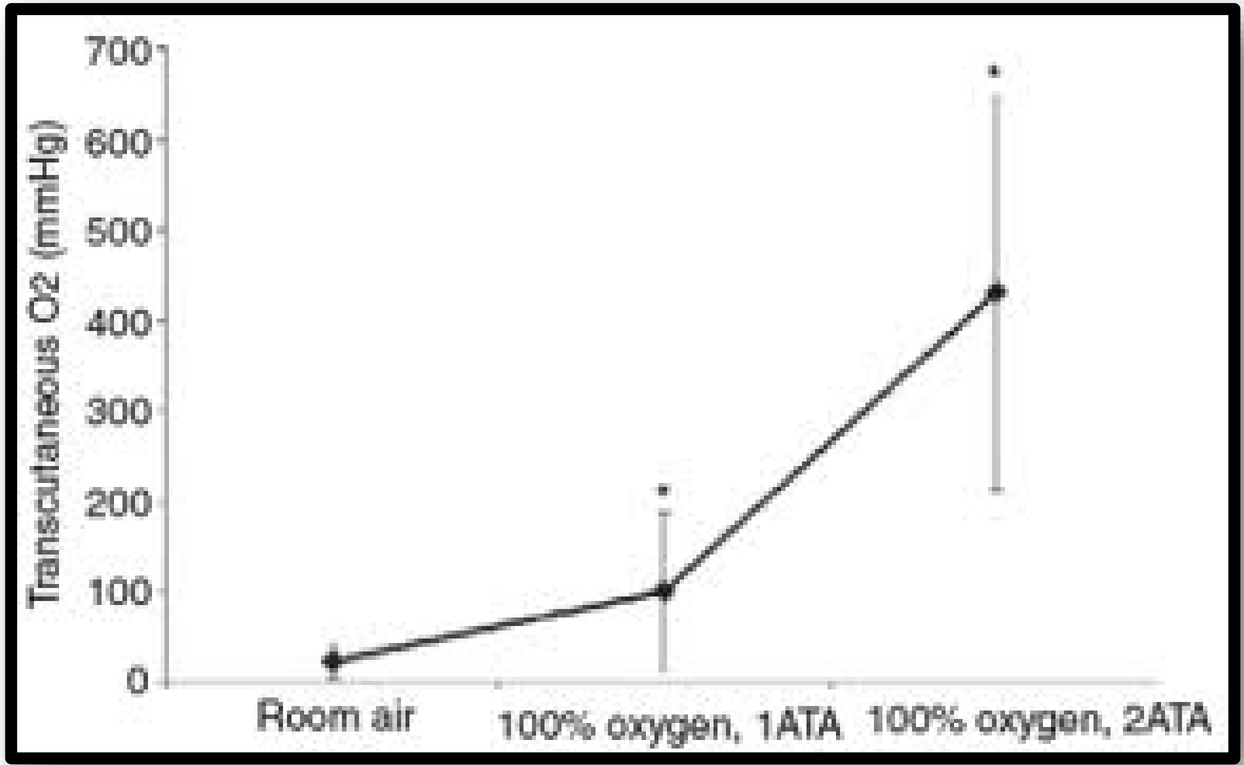
- Mechanical Effect
  - Boyle’s Law – reduction of bubble size
    - Decompression sickness
    - Carbon Monoxide poisoning
    - Iatrogenic gas emboli
- Effects of increased partial pressures of O_2
  - Oxygen behaves like a drug at pressures greater than atmospheric pressures
  - Need for “script” for HBOT, ie pressure, frequency and duration of tx.
    - Essentially all other indications fall into this category

Reduction of Bubble Size

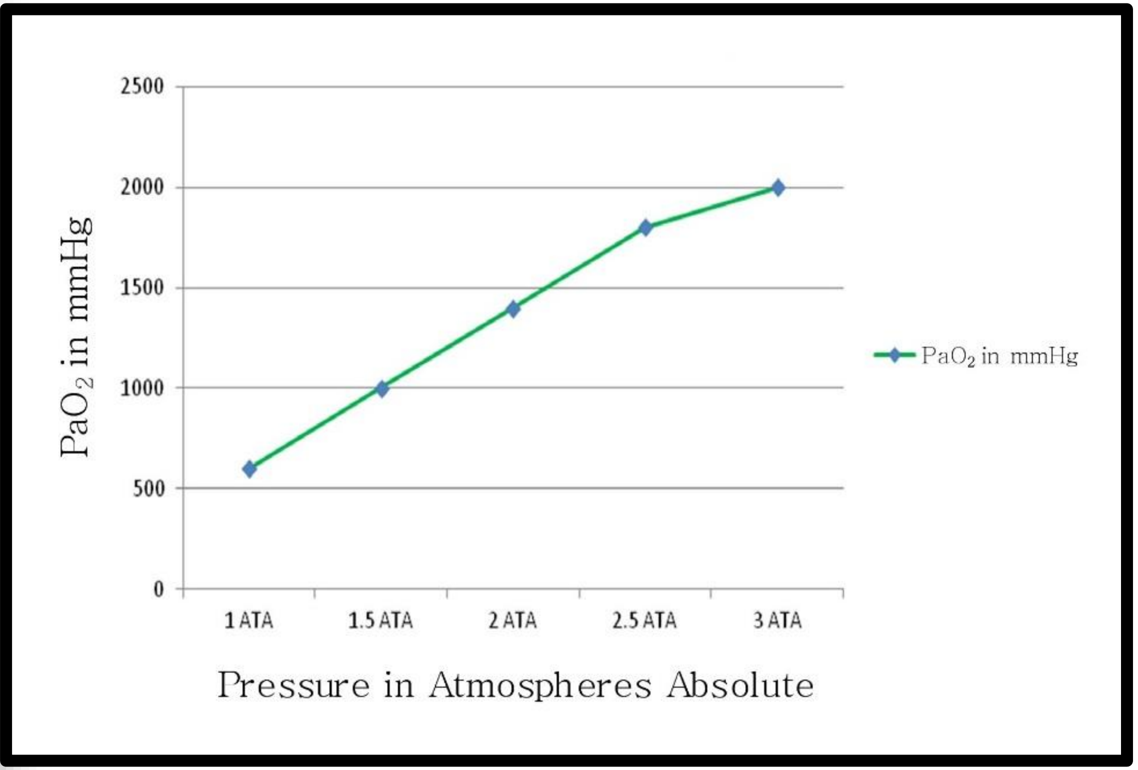
PRESSURE IN ATMOSPHERES	RELATIVE VOLUME	RELATIVE SURFACE AREA
1	100%	100%
6	17%	30%

Effect of Increased PPO2

Transcutaneous PO_2 (mmHg)



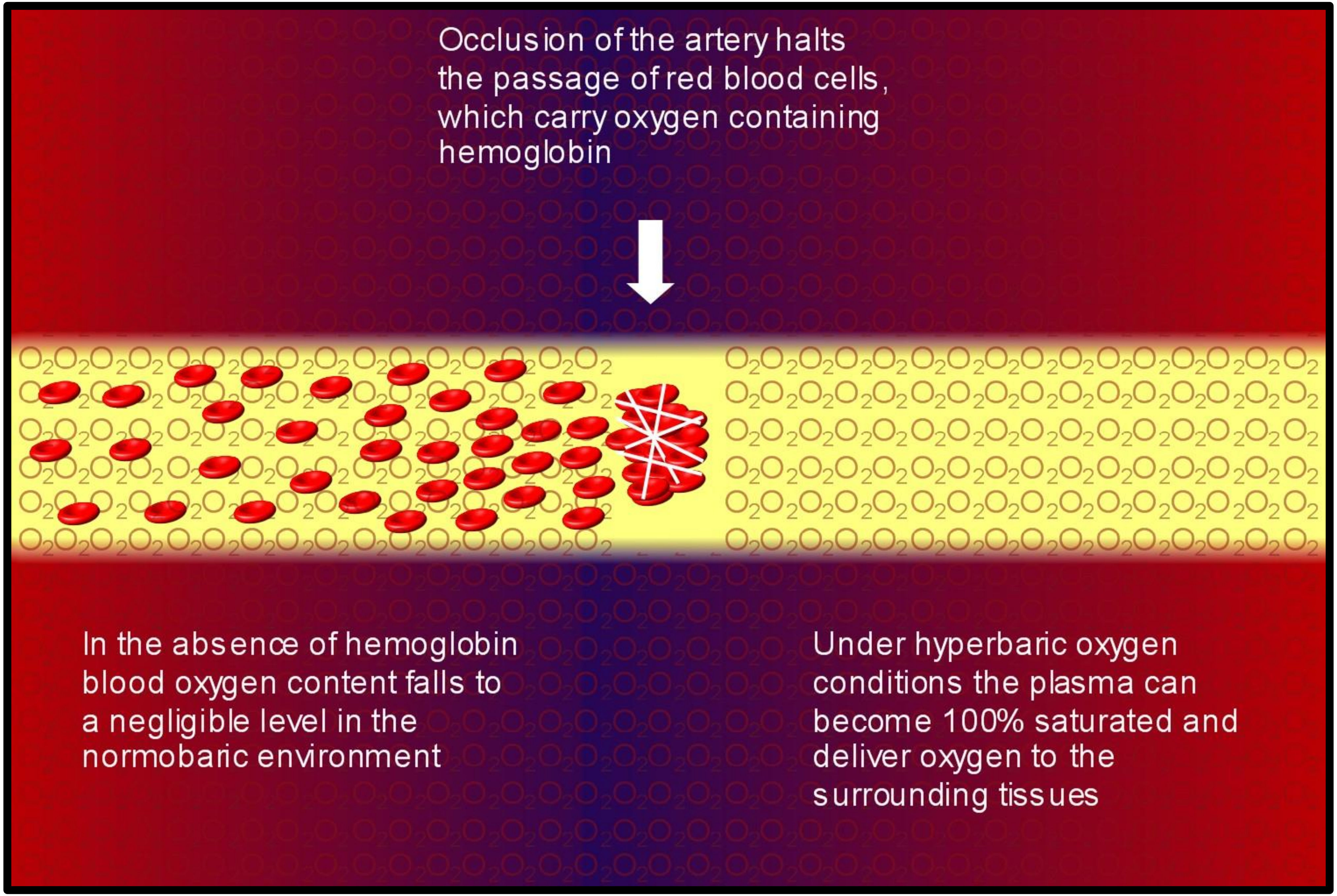
PaO_2



As pressure increases in 100% 0_2 environment, there are concomitant linear increases in inspired 02 and transcutaneous oxygen levels

Physiology of HBOT

- Large body of evidence supports intermittent hyperoxygenation of hypoperfused tissue beds
- Process only achievable by exposure to HBO2
- Physiologically, produces directly proportional increase in plasma O2 that is available for cellular metabolism
- Establishes adequate O2 availability within vascularized tissue compartment surrounding wound
- Can we super-saturate hemoglobin?


Occlusion of the artery halts the passage of red blood cells, which carry oxygen containing hemoglobin
In the absence of hemoglobin blood oxygen content falls to a negligible level in the normobaric environment
Under hyperbaric oxygen conditions the plasma can become 100% saturated and deliver oxygen to the surrounding tissues

Physiology (cont.)

- Neutrophils, fibroblasts, macrophages, and osteoclasts all dependent on adequately oxygenated environment to carry out their functions
- Fibroblasts cannot synthesize collagen without O2
- Proper oxygenation of vascularized tissue compartment crucial to initiation of wound repair process and becomes a rate-limiting factor for cellular functions associated with wound healing

Side Effects of HBOT

- Middle ear barotrauma
- Sinus squeeze
- Claustrophobia
- Progressive myopia
- Progression of cataracts
- CNS oxygen toxicity seizure
- Pulmonary oxygen toxicity
- Transient increase in BP and decrease in HR
- Pulmonary barotrauma

CNS = central nervous system.

Middle Ear Barotrauma

- Trauma to eardrum due to pressure changes
- Incidence approximately 2%-4%
- Eustachian tube dysfunction most common cause
- Rupture of TM or round window rare but possible
- Insertion of tympanostomy tubes is appropriate intervention if pain with pressurization or any evidence of trauma or hemorrhage to TM

TM = tympanic membrane.

Ocular Effects

- Myopia
  - Progressive development of myopia in 20%-40% of patients exposed to HBOT
  - Typically returns to baseline within 6 weeks but can in rare cases be permanent
  - Thought to be lenticular in etiology
- Nuclear cataracts
  - Growth of pre-existing cataracts seen with prolonged HBOT
  - Not reversible

CNS Oxygen Toxicity

- HBOT lowers CNS seizure threshold
- Prolonged exposure to O2 under pressure can trigger “epileptic-like” seizure
- Spontaneous resolution with reduction of FiO2 and pressure
- Preventable with mid-treatment air break
- Not a contraindication to future HBOT
- Risk factors: hypoglycemia, corticosteroids, narcotics

FiO_2 = inspired oxygen concentration.

Problem Wounds

- Fail to progress through orderly healing sequence, usually as a result of one or more of the following factors
  - Persistent infection
  - Malperfusion and hypoxia
  - Cellular failure
  - Edema
  - Unrelieved pressure or recurrent trauma
  - Improperly managed drainage/exudate

Wound-Related Effects of HBO2

- Improved leukocyte bacterial killing
- Suppression of synthesis of bacterial toxins
- Blunting of systemic inflammatory response
- Prevention of leukocyte activation and adhesion following ischemic reperfusion
- Stimulation of vascular endothelial growth factor and platelet-derived growth factor leading to angiogenesis
- Increase in wound fluid nitric oxide content

Hunt TK. *Ann Emerg Med.* 1988;17(12):1265-1273.

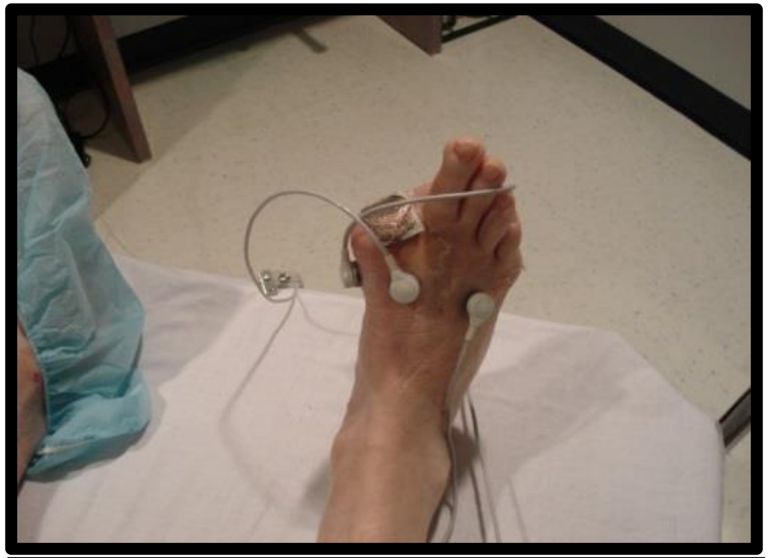
Net Effect of HBO2 – Summary Statement

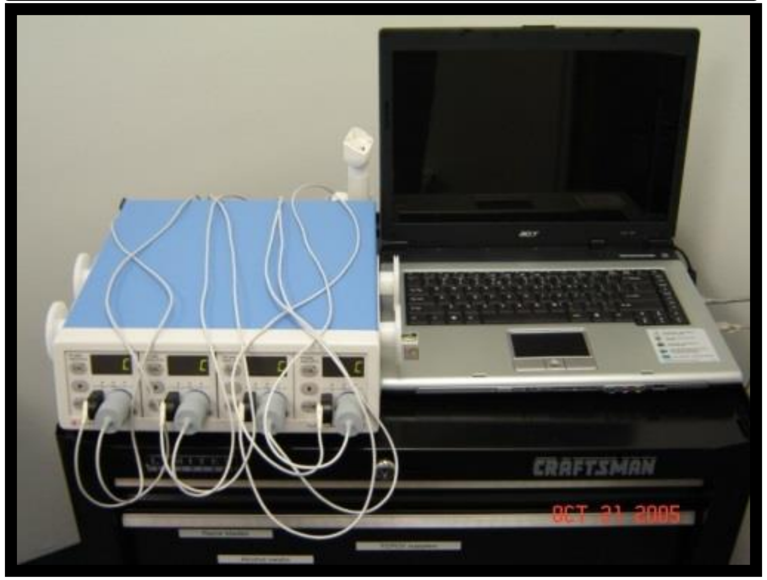
- Serial HBO2 exposures lead to improved local host immune response, clearance of infection, enhanced tissue growth, and angiogenesis, leading to progressive improvement in local tissue oxygenation and healing of hypoxic wounds

Gesell L, ed. UHMS. *Hyperbaric Oxygen therapy Indications*. 12th edition. 2008:7-196.

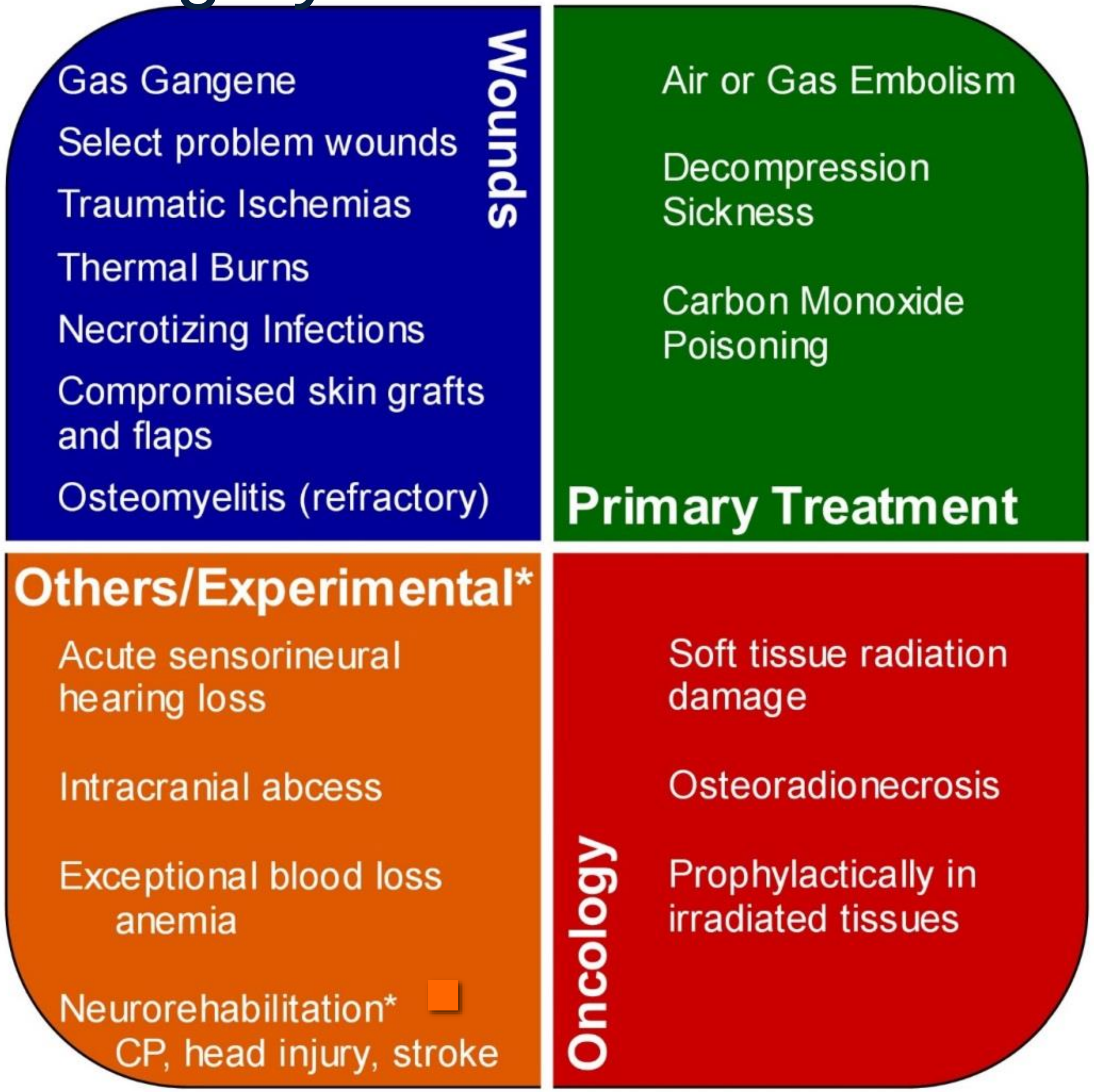
Measurement of Wound Hypoxia

- Transcutaneous oxygen tension (PtcO2) measurements provide direct, quantitative assessment of O2 availability to periwound skin
- Clark polarographic electrode generates a current that can be measured and converted to mmHg
- TcpO2 generally considered to be most useful in predicting failure of a wound to heal without intervention, failure to heal planned amputation, and failure to respond to HBO2
- Normal > 40 mm Hg
- Abnormal < 20 mm Hg
- Precise values remain controversial





Indications by Category

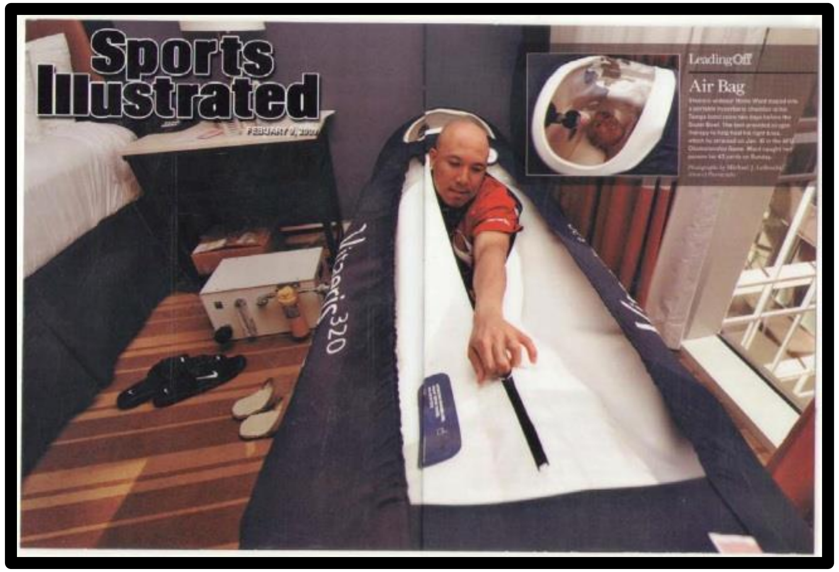


Contraindications

- Absolute
  - Current untreated pneumothorax
- Relative
  - Ongoing or recent treatment with bleomycin or adriamycin (pulmonary toxicity)
  - Ongoing chemotherapy (counters effects)
  - Severe COPD with bullous emphysema
  - Acute bronchospasm
  - Acute viral or allergic rhinitis
  - CHF with low Ejection Fraction or aortic stenosis
  - Implanted devices not rated to treatment pressures

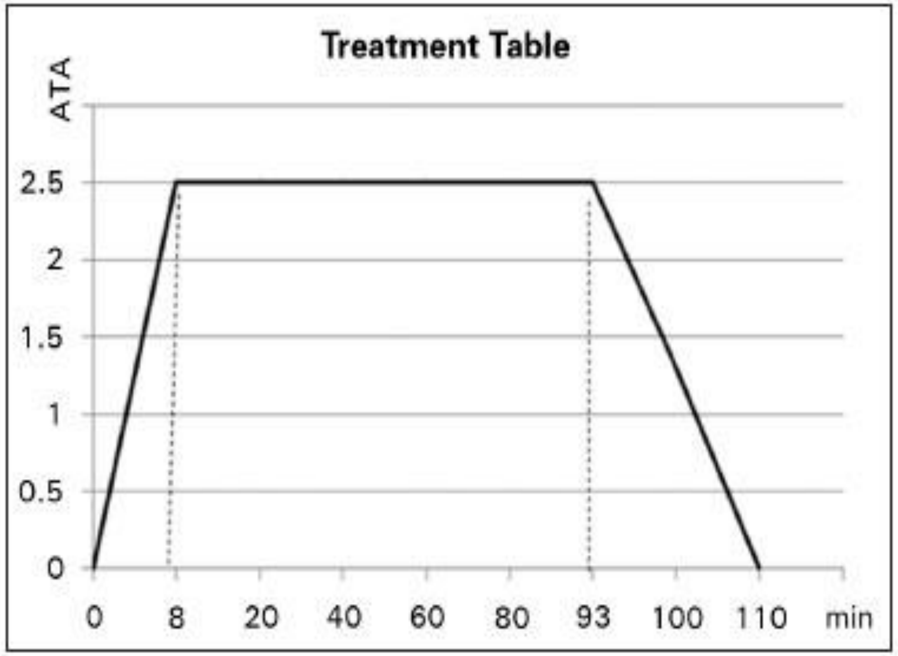
Common Off-label/Unapproved Uses of HBO2

- Autism
- Cerebral palsy
- Lyme disease
- Multiple sclerosis
- Athletic injuries
- Rock stars



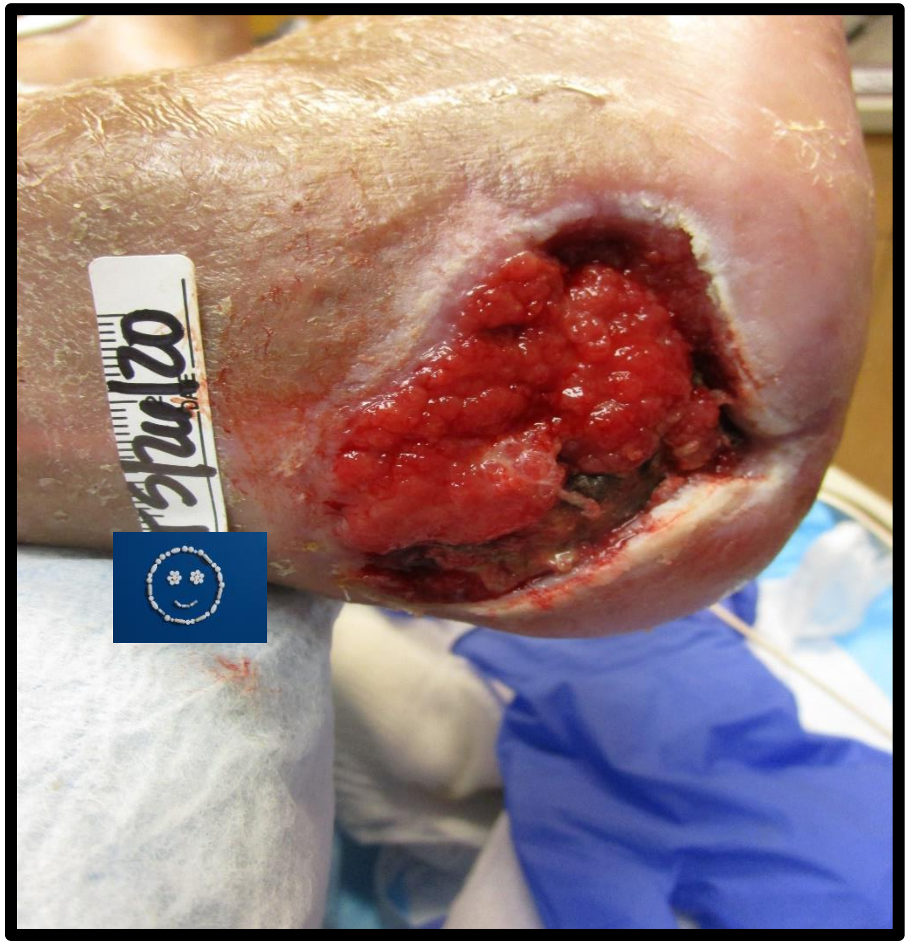
HBO2 Treatment Protocols

- Standard Wound Protocol – 2.0 ATA: 90 minutes at treatment pressure plus time for descent and ascent; approximately 107 minutes total time
- Radiation Injury Protocol – 2.4 ATA: 90 minutes at treatment pressure plus time for descent, two 5 minutes air –124 minutes total time
- Carbon Monoxide Protocol – 3 dive series beginning at 3.0 ATA (Weaver Protocol)



ATA = atmospheres absolute.

- Male
- 45 Years old
- Type one Diabetic
- Osteomyelitis

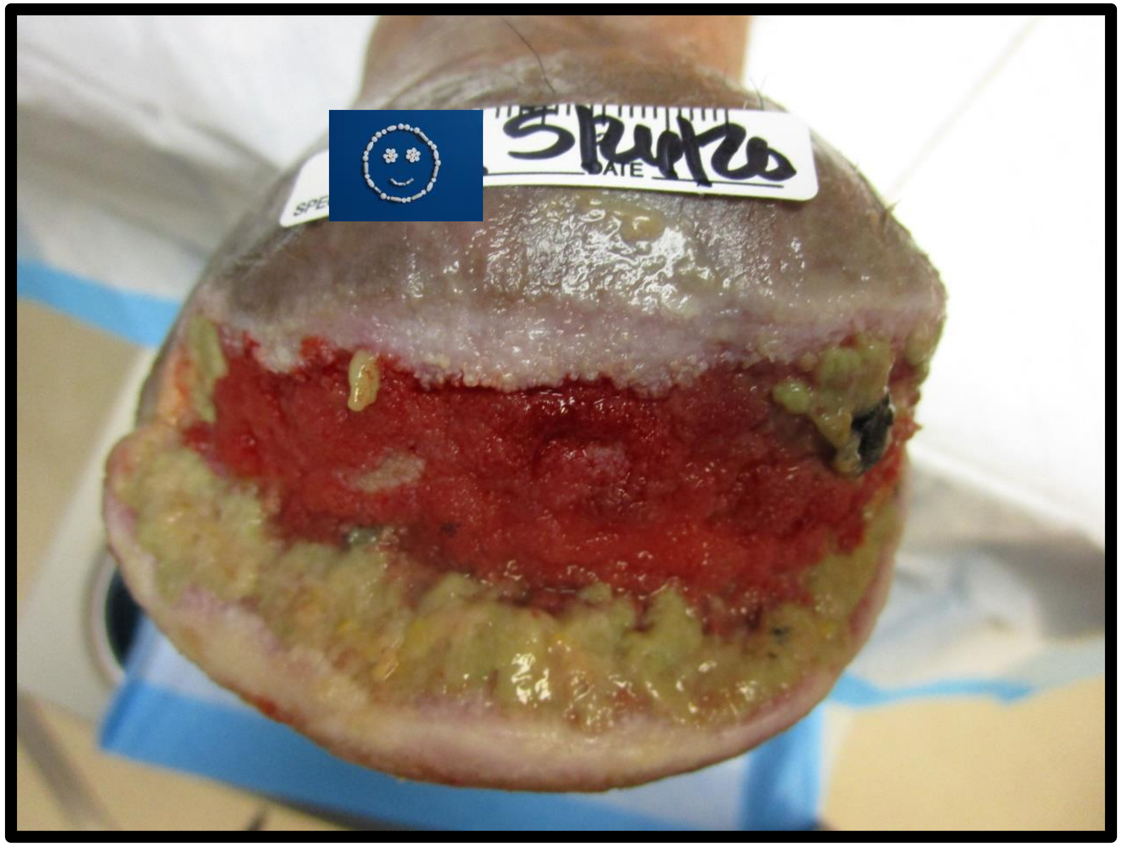



CM
SPEC.
7.27.20
DATE

Patient finally healed!

- ➢HBOT
- ➢Antibiotics
- ➢Offloading
- ➢Proper wound care
- ➢Wound Care Specialist

Patients First visit, NPWT



- 43 Year old Male
- Type 2 Diabetes
- Acquired Absence of Right Foot
- Non- Pressure Chronic Ulcer with Necrosis of the bone
- Osteomyelitis

A week after HBOT start

Week 3 HBO

Almost party time!!!

Healed!!!

PT went back to work and so did we…

I like to walk

Finally

References

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