Hyperbaric Medicine and the Modern Medical Practice

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Wound Care and Hyperbaric Medicine

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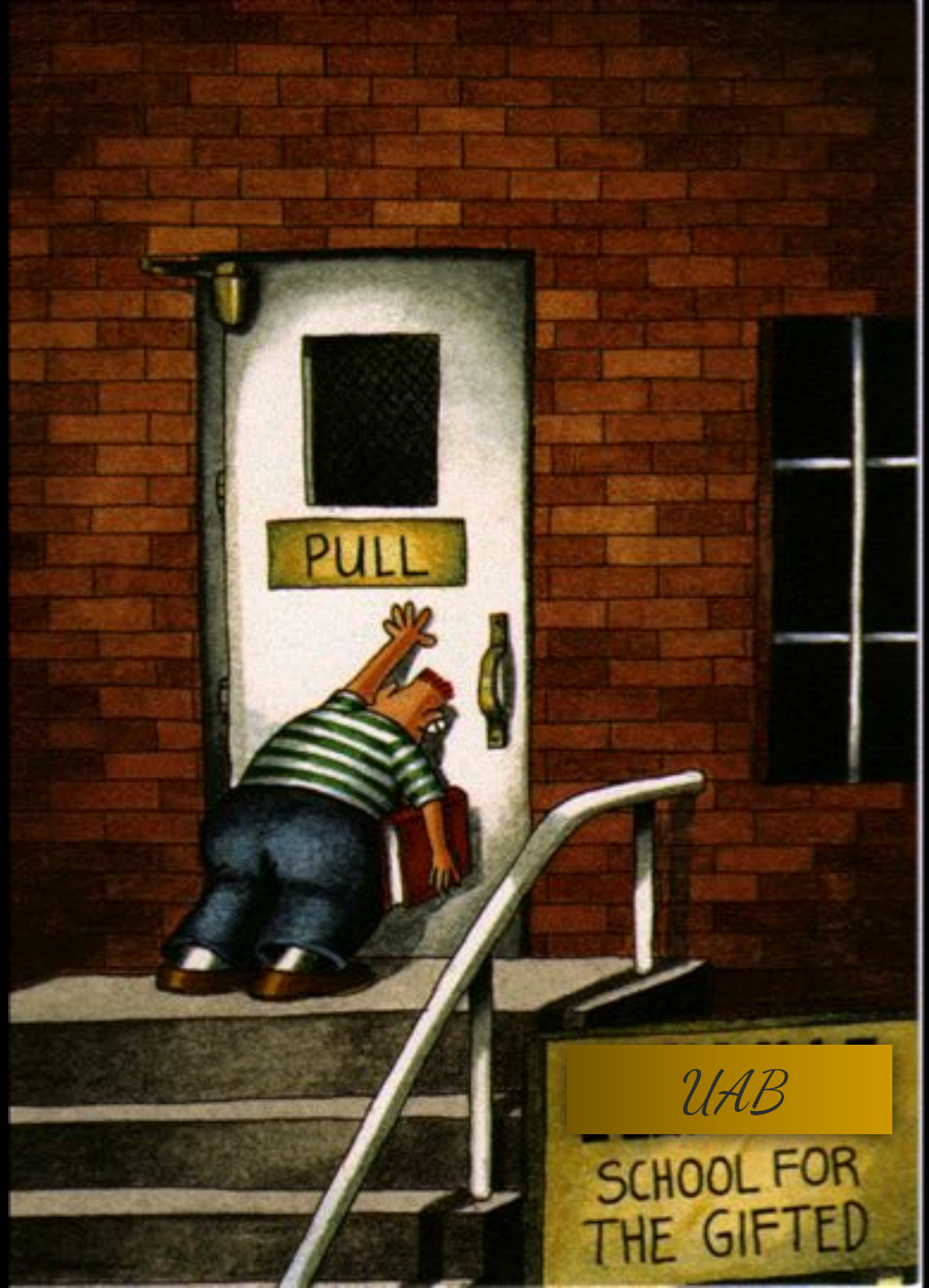
THE UNIVERSITY OF ALABAMA AT BIRMINGHAM

Disclosures:

- Sadly, none

Goals of this lecture:

- Briefly review hyperbaric medicine and how it works
- What diseases may benefit from hyperbaric oxygen therapy
- Why does HBO work for these conditions
- What new directions is HBO moving
- Cram all this in 60 mins?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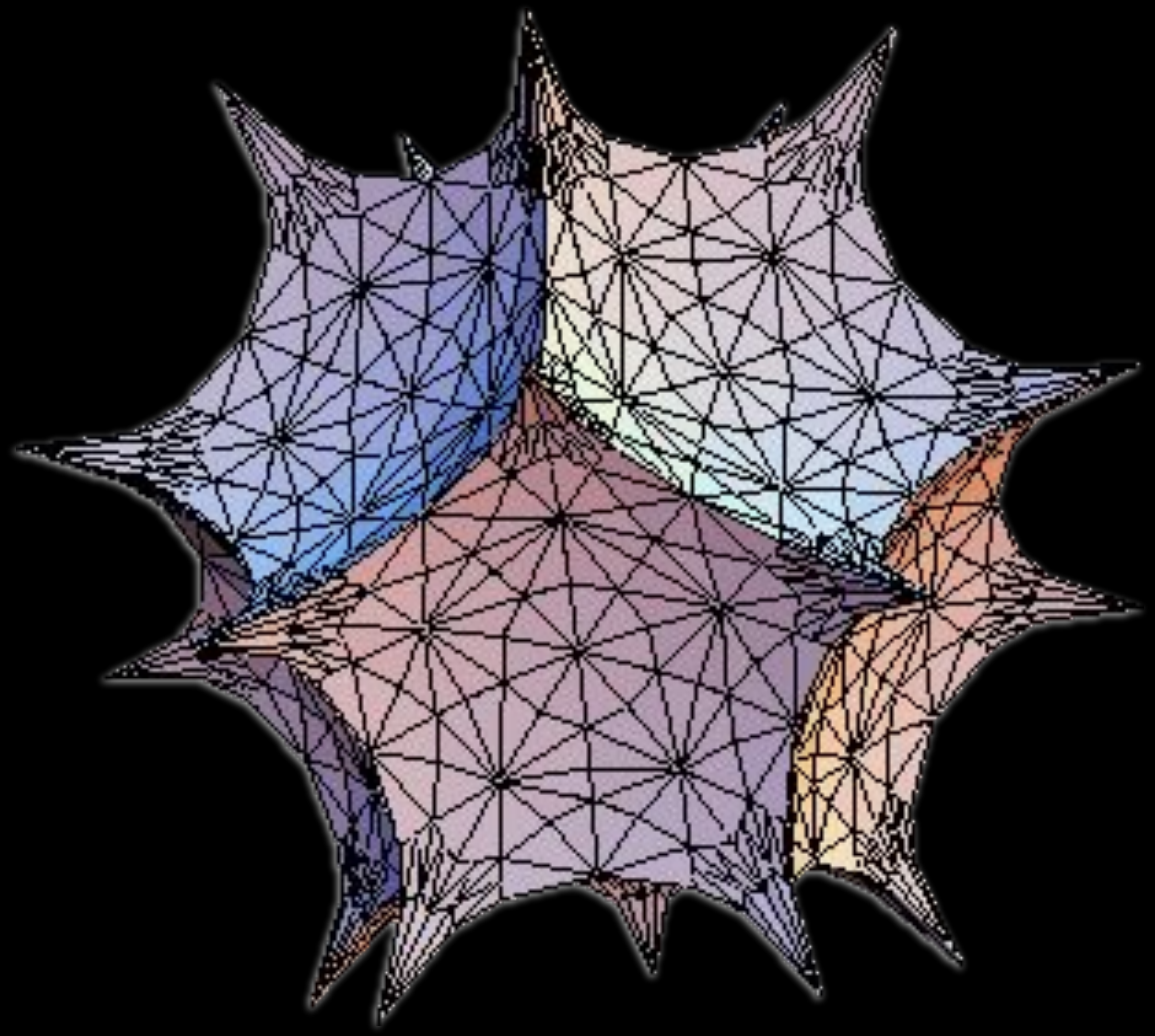
Hyperbolic Medicine



Bariatric Medicine

Hyperbarbaric Medicine

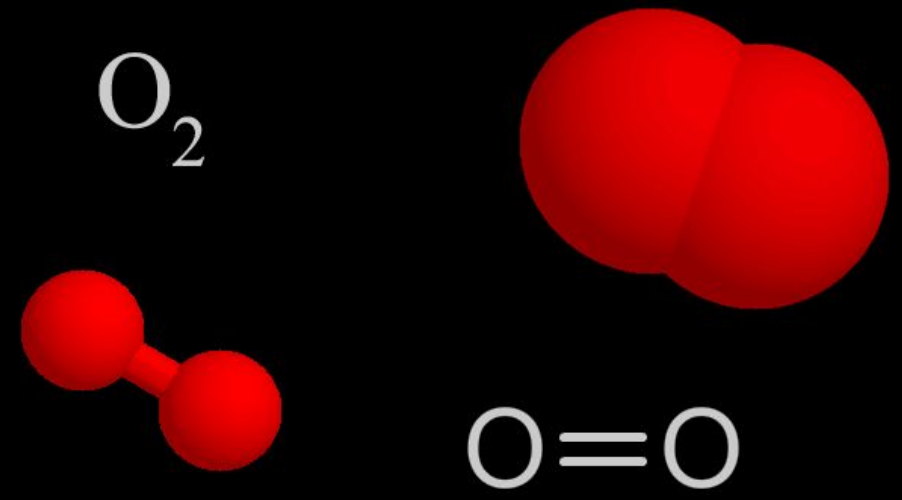

SECHRIST

Definition of HBO

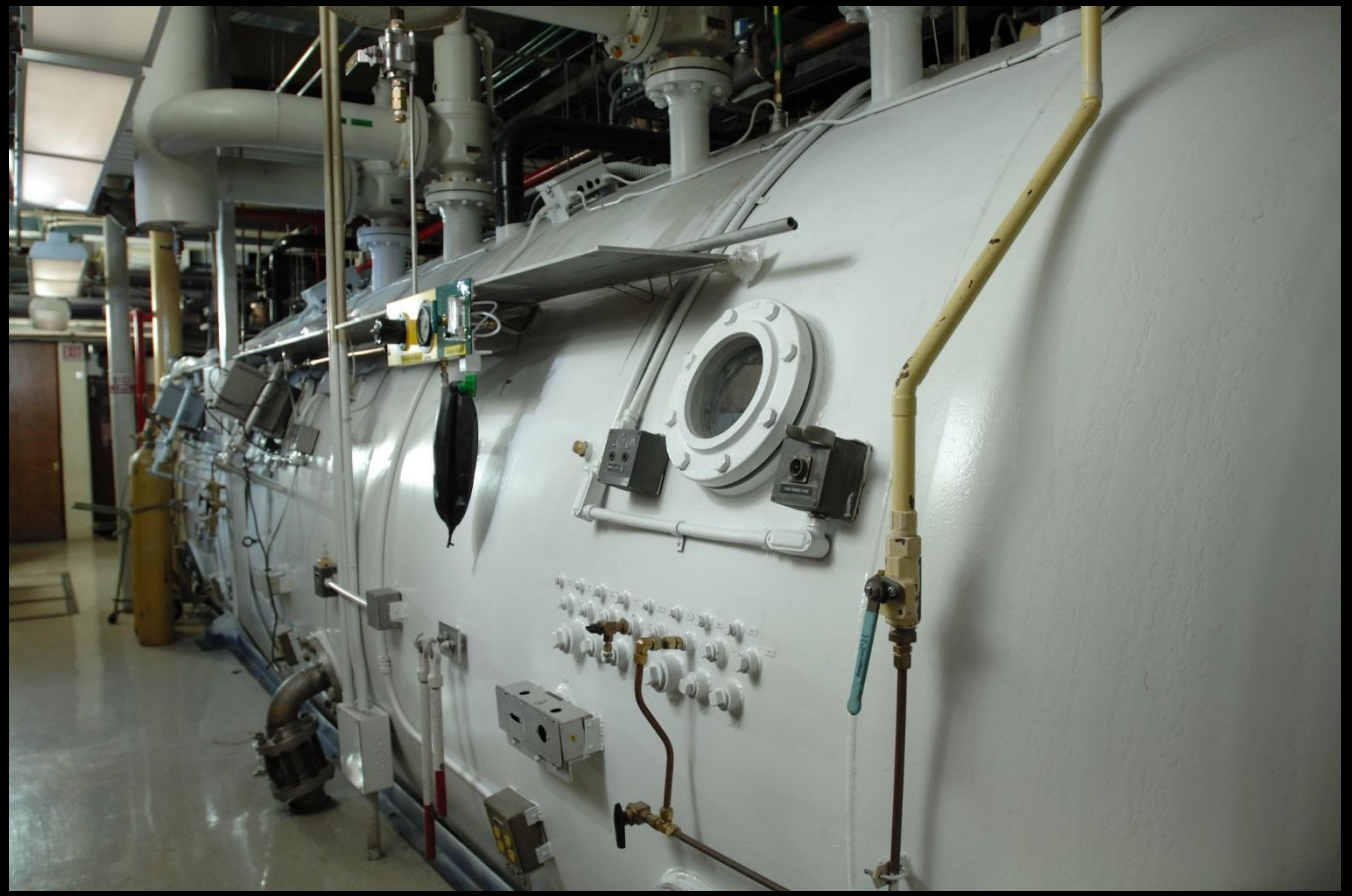
- A treatment in which a patient breaths 100% oxygen intermittently while inside a treatment chamber at a pressure greater than sea level *(Hyperbaric Oxygen Therapy Indications, 14th Edition)*
- Oxygen used as a drug

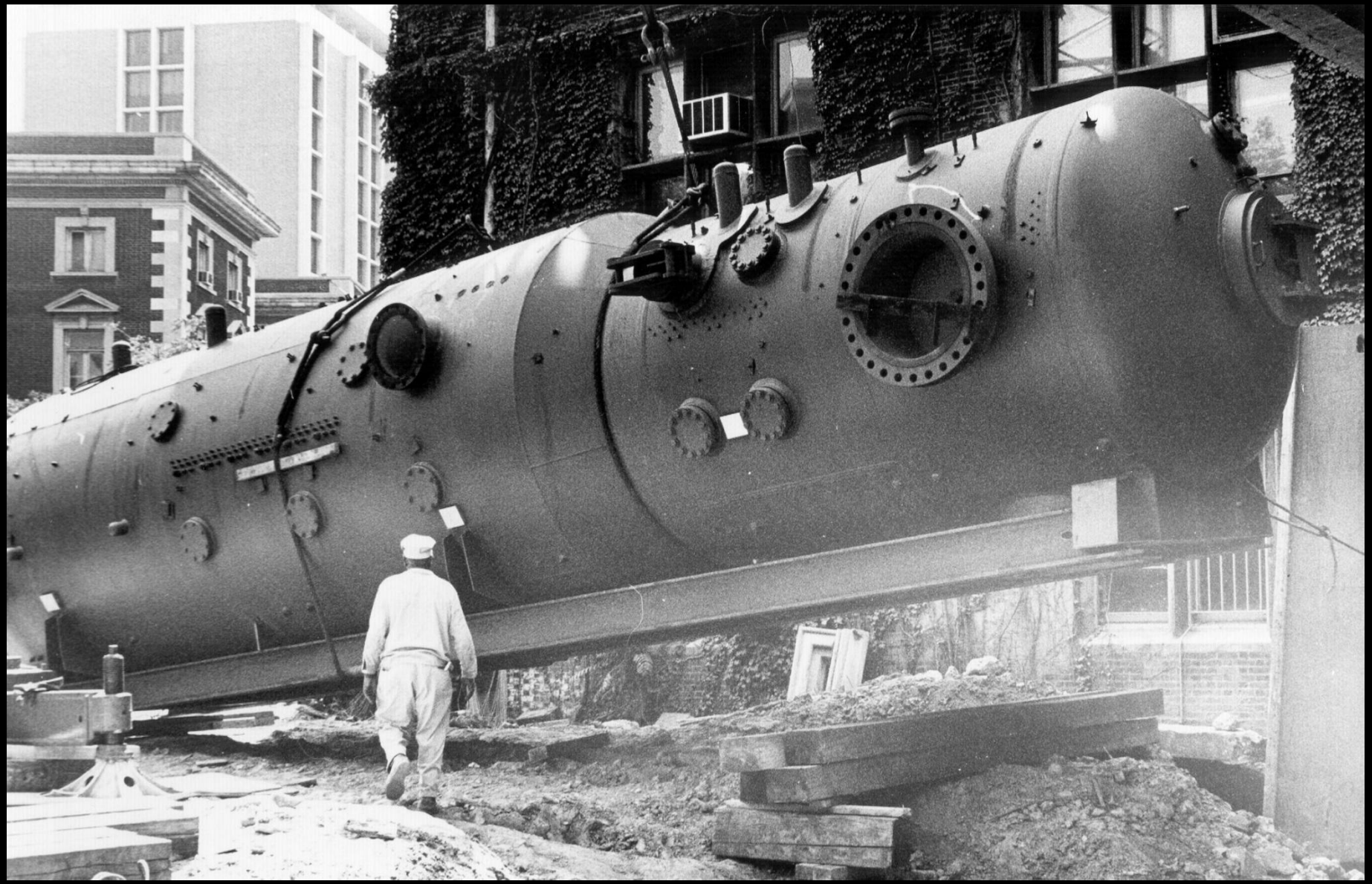
Oxygen

- Not Topically Absorbed
- Oxygen needs to be inhaled under pressure to have significant effect



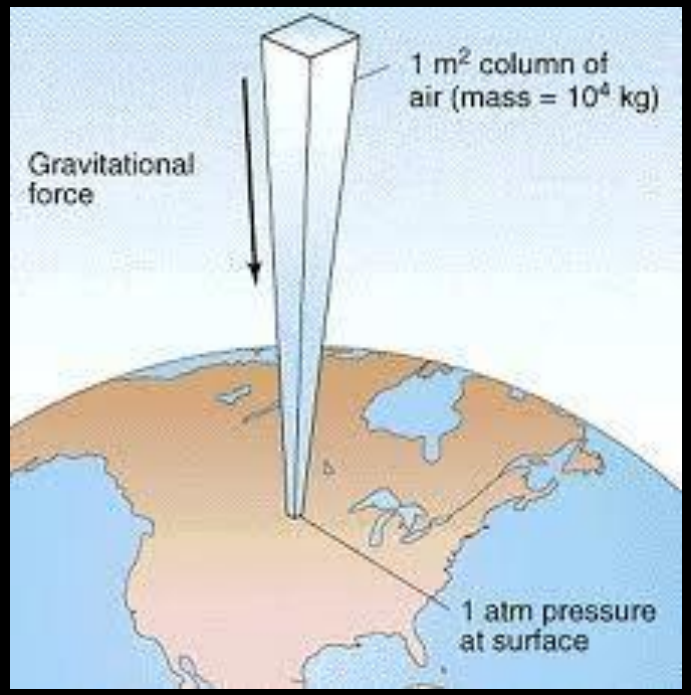

18 on LP Air
PNEUMATIC PRESSURE CONTROLS





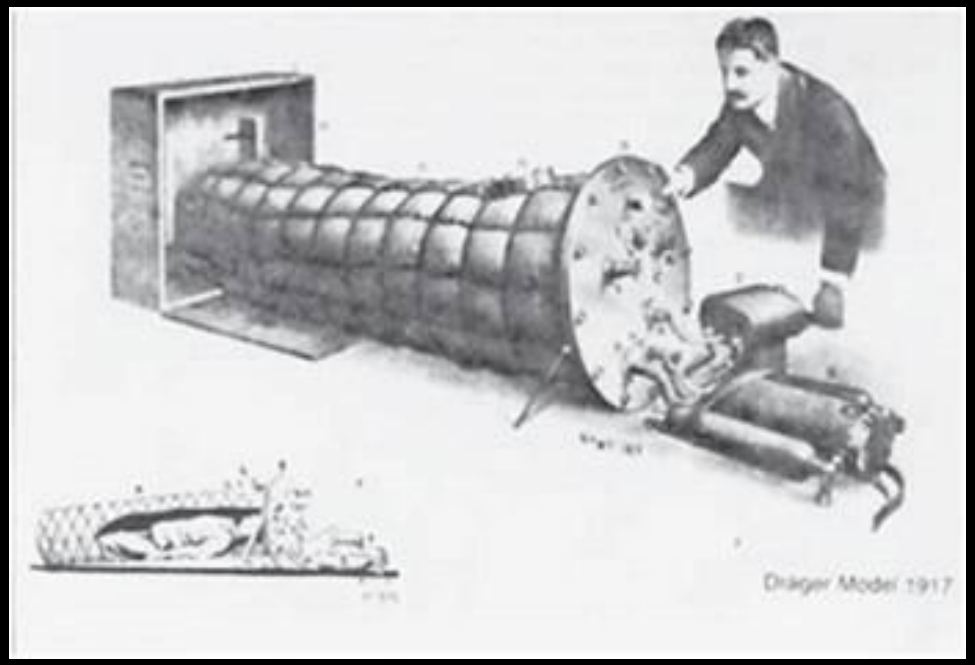
Baric = Pressure

- To understand Hyperbarics, need to understand pressure
- HBO uses the Atmosphere as a unit of pressure (ATM)
- 1 atm=14.7 psi = 33 fsw = 10 msw = 760mmHg = 101.3 kPa= 1 bar



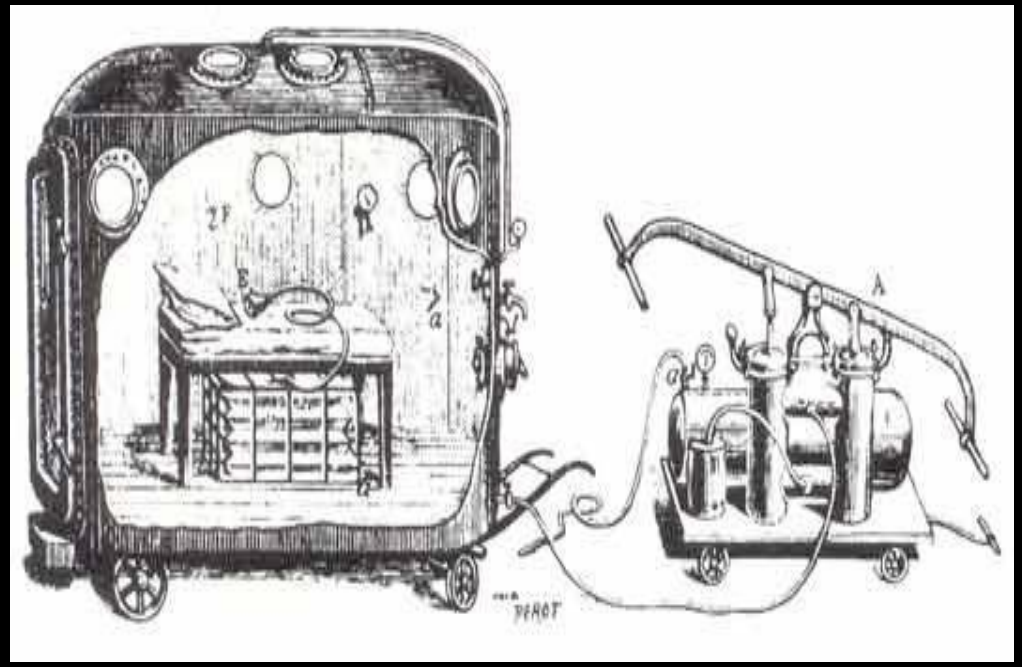
Brief History of HBO

- Henshaw (British Physician and Clergyman) in 1662 built high pressure “Domicillium”
- Reason: “Sounds like a good idea”
- Worked via organ bellows to place pressurized air into bag
- Used to treat acute diseases like pneumonia, TB, etc



Brief History of HBO

- 1879 French Surgeon Fontaine built a mobile operating room on wheels that could be pressurized
- Used Nitrous oxide as anesthetic. Hernias reduced more easily, and patients weren't cyanotic coming out of anesthesia



North American HBO

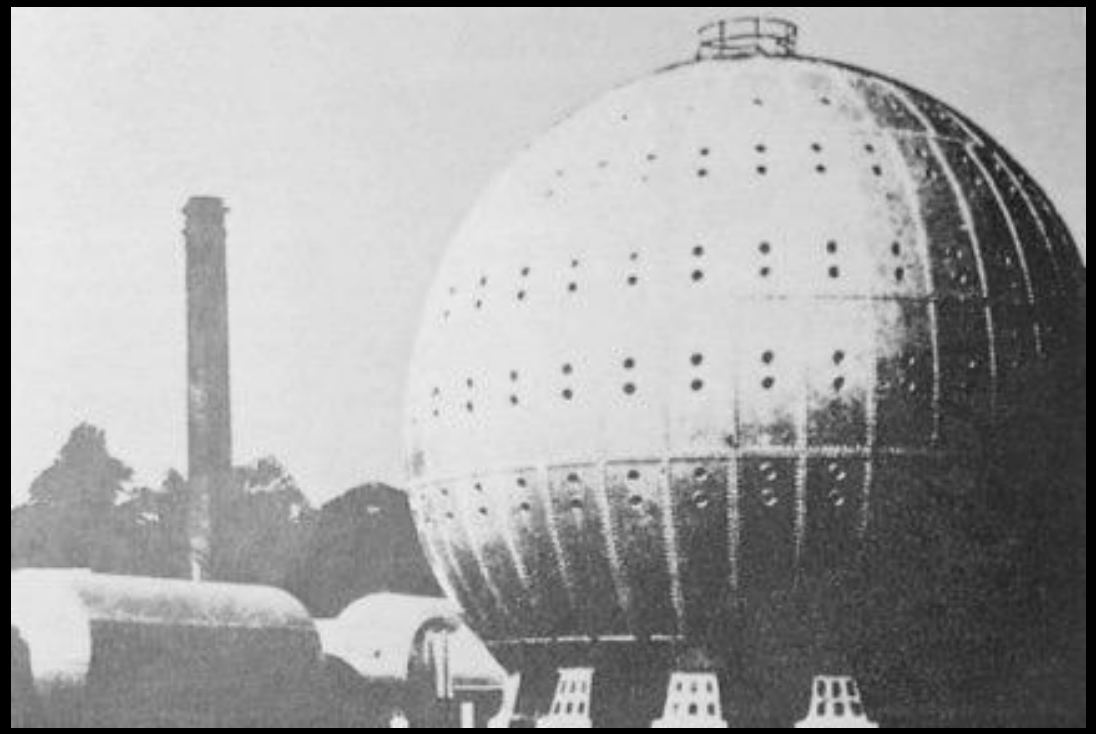
- First HBO chamber on North American continent constructed in 1860 in Ontario, Canada
- First chamber in US built by Corning a year later in New York to treat ‘nervous and related disorders’
- Caisson workers treated with hyperbaric air to prevent ”the Bends”
- The Chamber that received the most publicity, most used, was that of a Dr. Cunningham in Kansas City (1920’s)

Cunningham

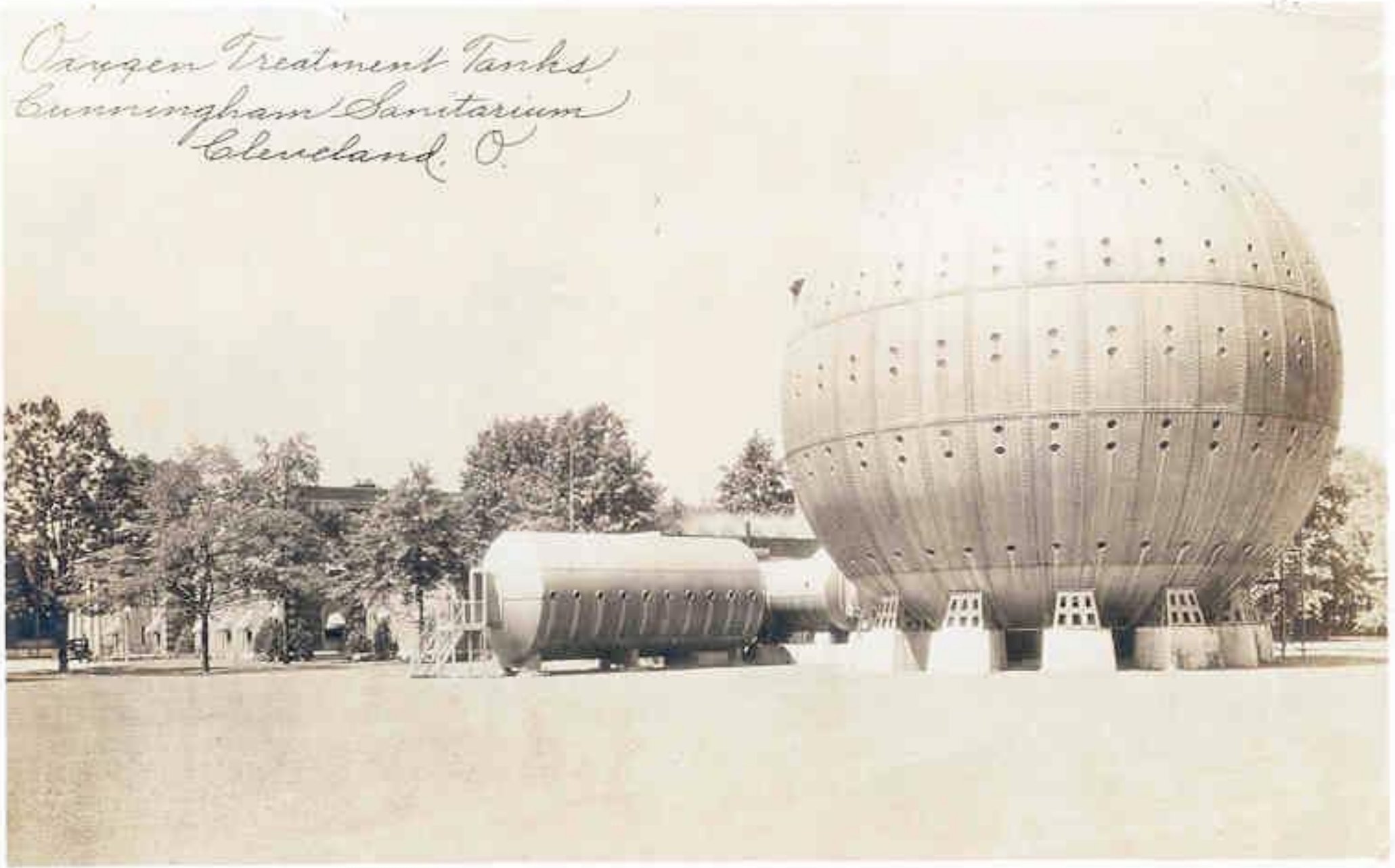
- Professor of anesthesia at U Of Kansas
- Noted patients with heart disease did worse at altitude, and improved at sea level
- In 1917 constructed an 88ft by 10 ft hyperbaric chamber to treat multiple illnesses
- During flu epidemic in 1918 treated a moribund medical resident with hyperbaric air, and saved him during the hypoxic crisis (ARDS)

Cunningham

- 1928: Timkin Rollerbearing CO built Dr. Cunningham the largest hyperbaric chamber ever constructed
- 6 stories high, 64 ft in diameter
- Reached a pressure of 3 ATA
- Closed in 1930 due to lack of scientific evidence
- Sold for scrap metal during WWII



Oxygen Treatment Tanks
Cunningham Sanitarium
Cleveland, O.



Grand Entrance


Recreation Room in Main Tank
Cunningham Sanitarium
Cleveland O
Smoking room!!!

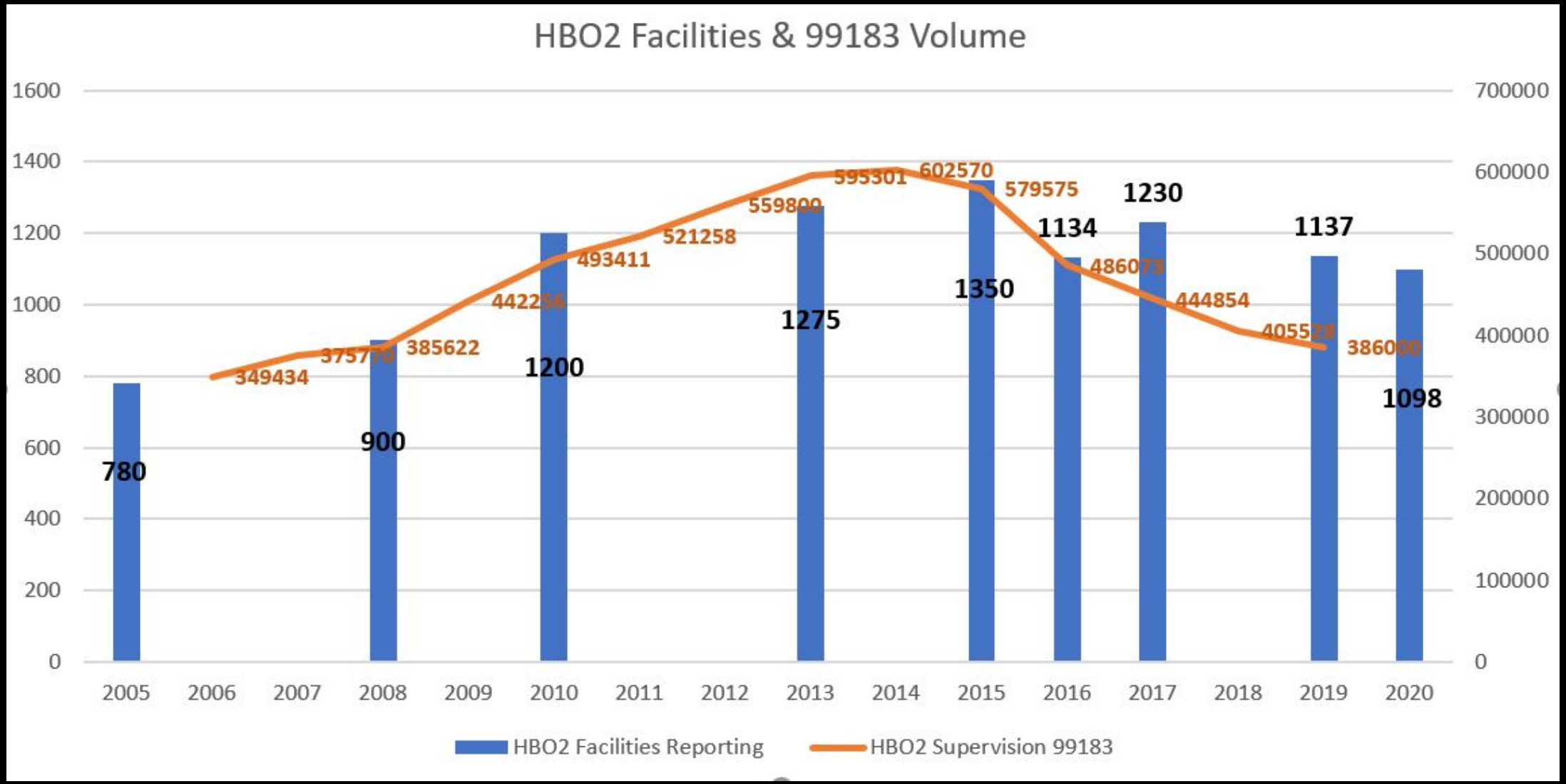

Bedroom
Cunningham Sanitarium
Cleveland, O.


Laboratory
Cunningham Sanitarium
Cleveland O.


Dining Room in Main Tank
Cunningham Sanitarium
Cleveland O.

Development of the Specialty

- First half of 20th century hyperbaric facilities used air, second half converted to oxygen
- Early uses for HBO included CO, cardiac surgery, radiation enhancement, wounds
- “Over zealous and inappropriate use” lead to formation of UHMS in 1972 then committee in 1976 to self regulate the use of HBO to proven “indications”
- 1992 MD exam for Diving Medicine through ABPM
- Multiple HBO fellowships starting in 1990s for training
- Significant growth in field, especially with wound care centers


HBO2 Facilities & 99183 Volume
1600
1400
1200
1000
800
600
400
200
0
700000
600000
500000
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300000
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100000
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2005
2006
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349434
375770
385622
442256
493411
521258
559800
595301
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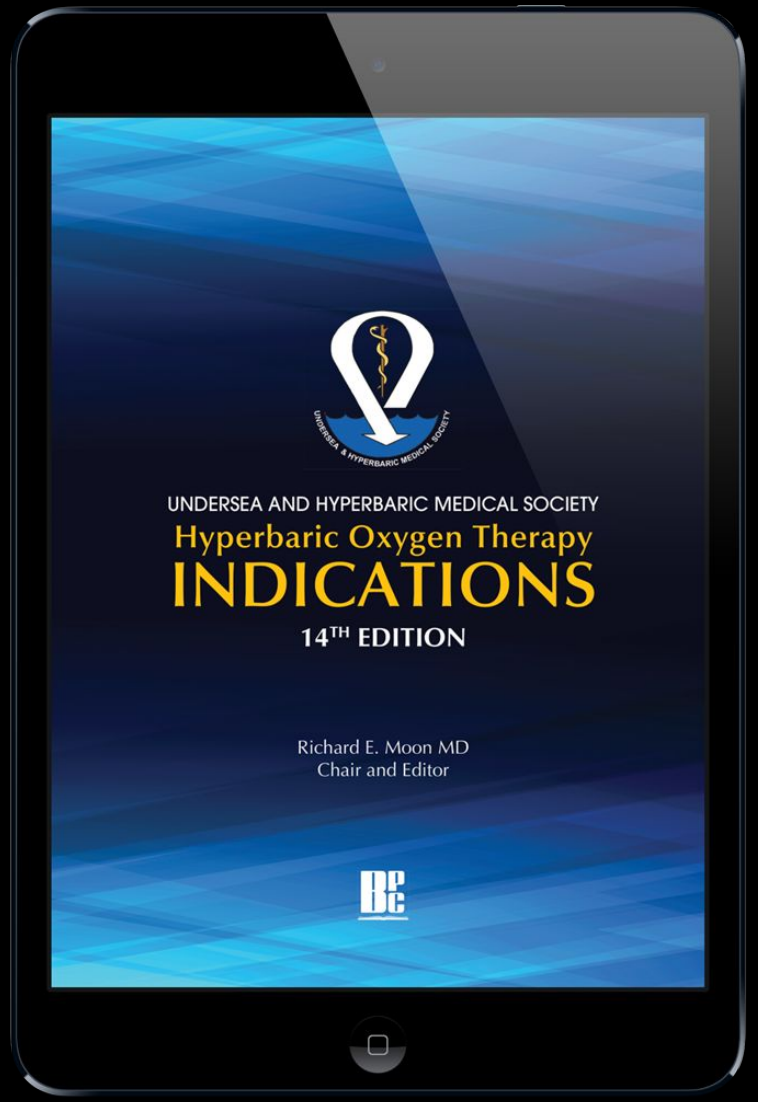
405528
386000
HBO2 Facilities Reporting
HBO2 Supervision 99183

What do we use Hyperbarics for?



Indications: 2019 UHMS Recommendations

- AGE
- Decompression Illness
- CO/CN
- Gas Gangrene
- Necrotizing Fasciitis
- Crush injury/Compartment Syndrome
- Thermal Burns
- Severe Anemia
- Arterial Insufficiencies (CRAO)

- Enhancement of healing in selected problem wounds
- Intracranial abscess
- CROM
- Delayed Radiation Injury
- Compromised Skin Flap and Grafts
- Diabetic Foot wounds
- Acute Idiopathic Sudden Sensironeural Hearing Loss

Acute/Emergency Conditions

- AGE
- Decompression Illness
- CO/CN
- Gas Gangrene
- Necrotizing Fasciitis
- Crush injury/Compartment Syndrome
- Thermal Burns
- Severe Anemia
- Arterial Insufficiencies/CRAO/Reimplantation
- Compromised Skin flap and/or graft

Chronic Conditions

- Enhancement of healing in selected problem wounds
- Intracranial abscess
- CROM
- Delayed Radiation Injury
- Compromised Skin Flap and Grafts (Acute or chronic)
- Diabetic Foot wounds
- Acute Idiopathic Sudden Sensironeural Hearing Loss
- Majority of Patients treated

Investigational

- Sepsis
- Placental insuff
- Neonatal hypoxia
- CP
- Stroke
- Head injury
- Nerve repair
- Post-rescusitation
- Sports Medicine
- Cerebral edema
- Osteonecrosis
- Spine cord injury
- IBD
- NEC
- SBO
- Liver regeneration
- Organ Transplantation
- Ischemia-reperfusion injury
- Fibromyalgia
- MS
- Migraine
- AVN
- Post MI/CABG

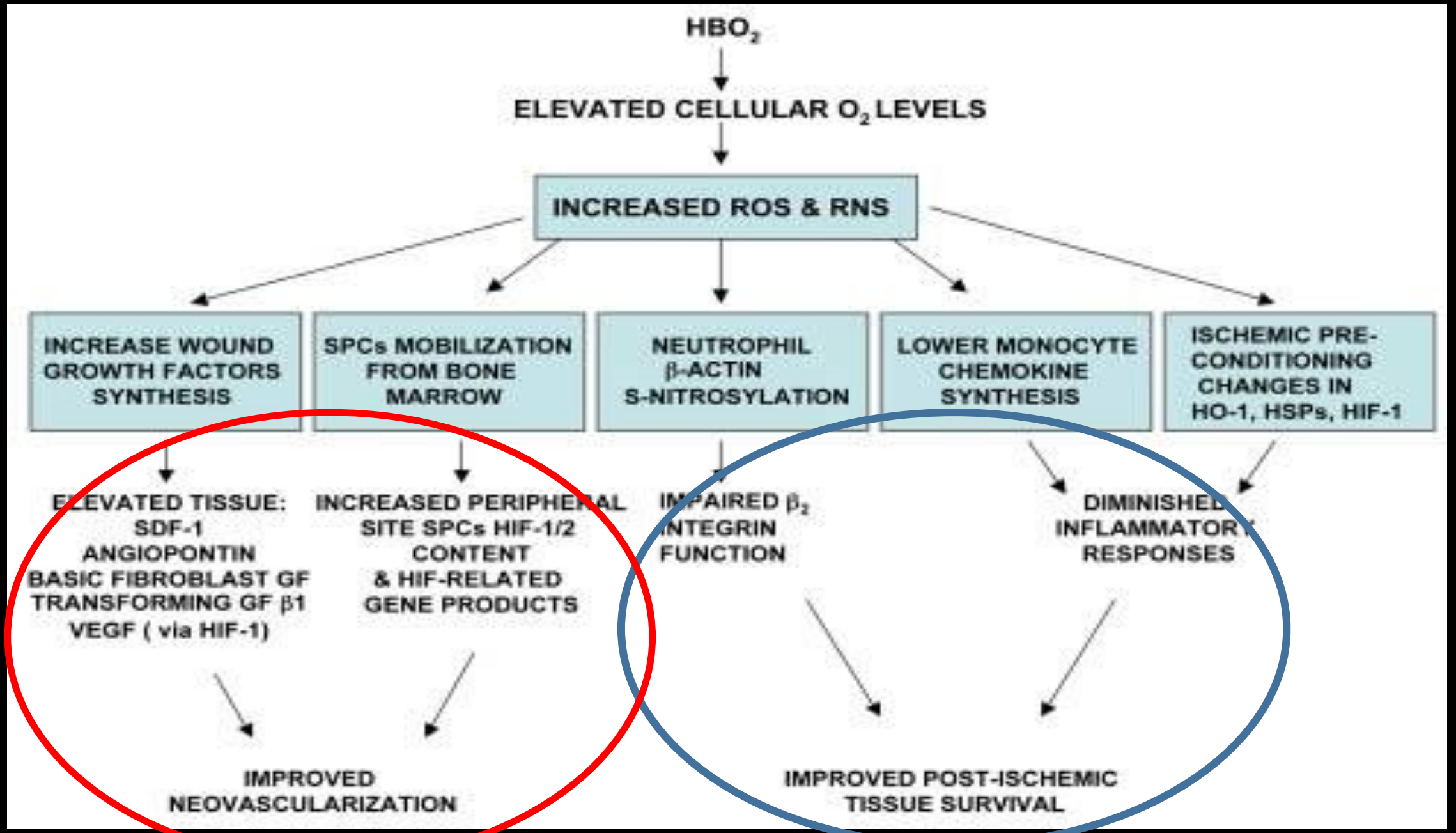
Physiologic Effects of HBO

- Hyperoxygenation
- Vasoconstriction
- Attenuate ischemia and rescue penumbra
- Reduce ischemia-reperfusion injury/Inflammation via WBC inhibition
- Role in infectious disease
- Neovascularization
  - DNA signaling (Via HiF, HO, HSP, SDF, others)
  - Stem cell mobilization
  - Growth factor synthesis
  - Oxygen free radical production (ROS, RNS)

What about ROS?

- I thought ROS are bad?
- ROS produced briefly during HBOT
  - Hydroxyl, hydrogen peroxide, superoxide, hypochlorous acid all produced
- However, scavenging antioxidants combat the ROS
  - SOD, catalase, glutathione, thioredoxin, paraoxanase
- HiF, HO, Heat Shock Proteins induced
- The response to ROS more robust and longer acting than the ROS stress
- ROS□ ↓ NF-kB, IkBa*

J Appl Physiol 2009;106(3):988-95
Compr Physiol 2016;7(1):213-34
**Biomolecules.* 2021 Aug 14;11(8):1210

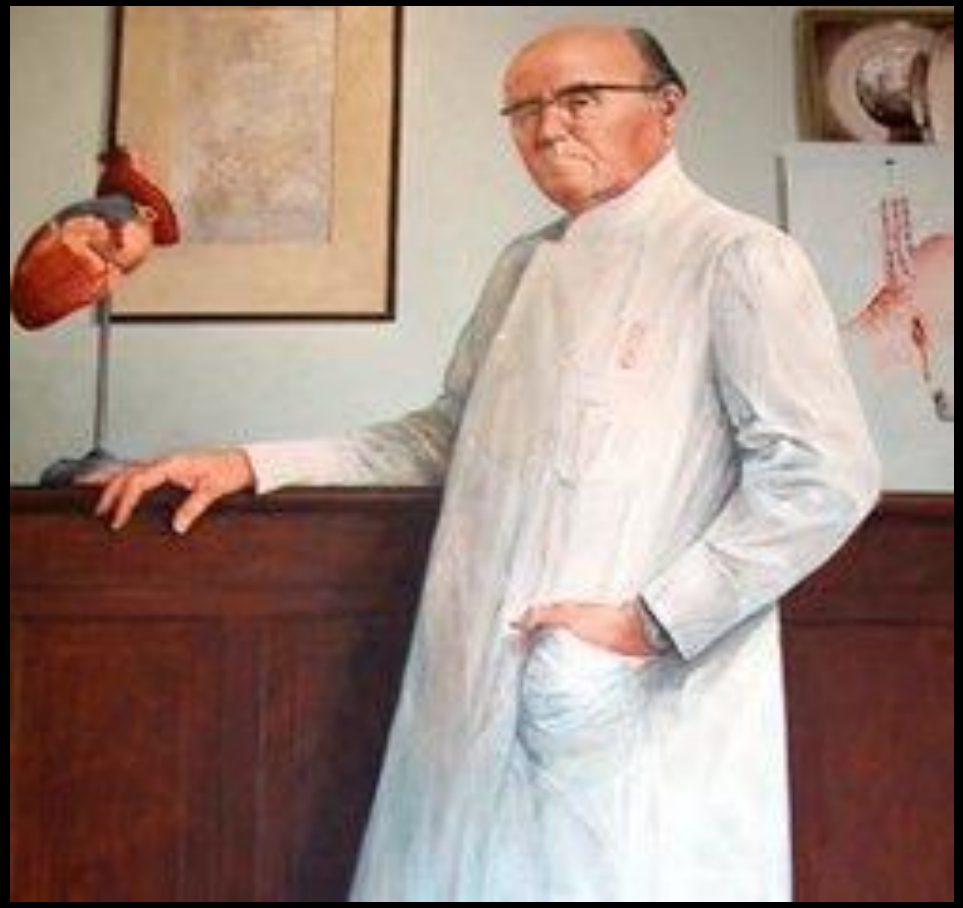


Plast Recon Surg 2011:127 (Suppl 1);S131-141)

Hyperoxygenation

- O_2 Content = (Hgb x 1.36 x SaO_2) + ***($0.003 \times PaO_2$)***
- On room air, Hgb ~ 97% saturated = 19.5 vol%
- 5.8 vol% extracted by tissues
- O_2 dissolved in plasma is 0.32 vol%
- ↑ O_2 has minimal effect on total Hgb O_2 content unless you increase pressure (PaO2)
  - 100% O_2 @ 1ATA=2.09 vol%
  - 100% O_2 @ 3ATA=6.8 vol%
- The tissue requirements for O_2 can be met by dissolved O_2 in plasma at 3ATA

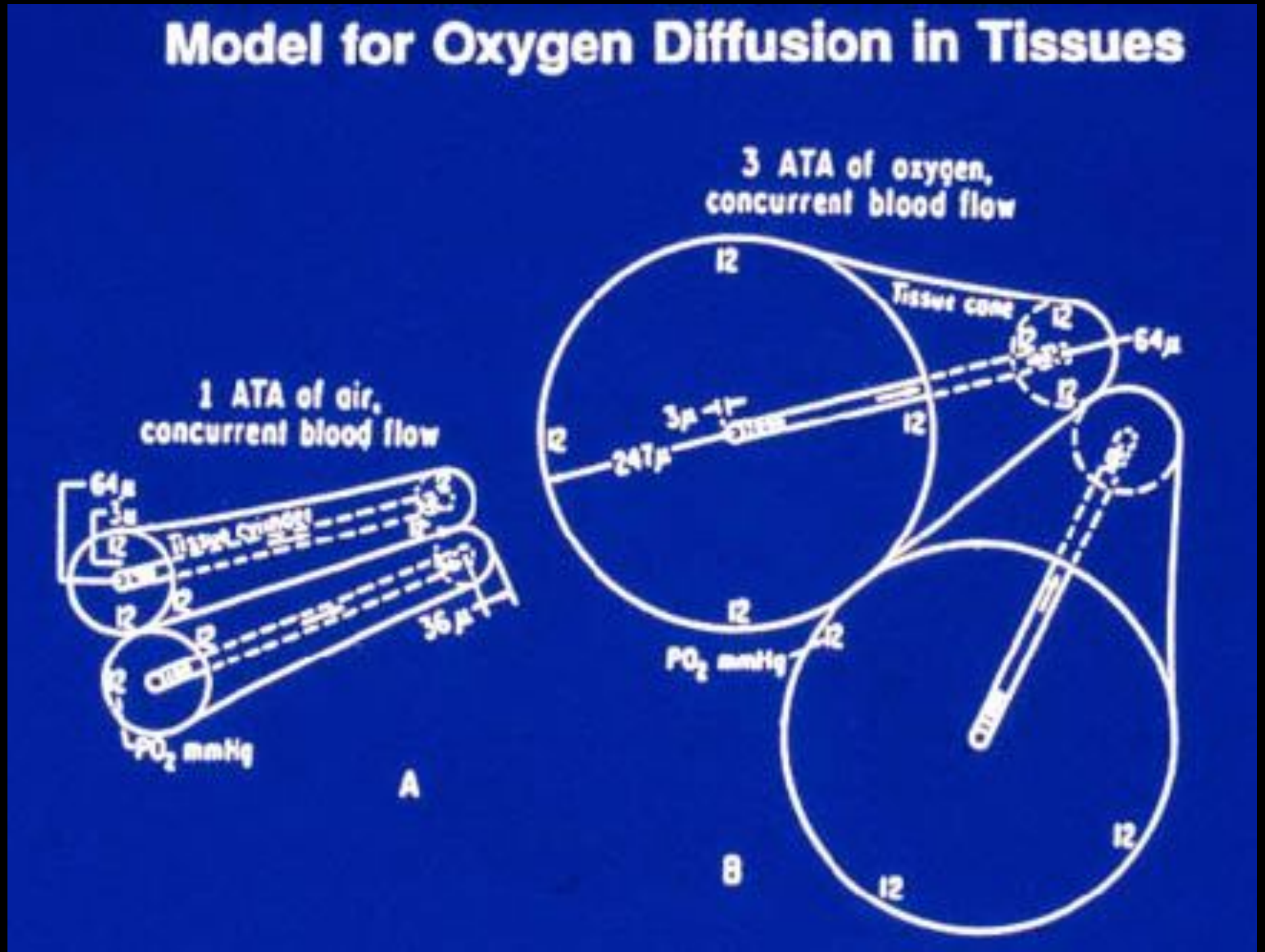
“Life without blood”
Boerema: J Card Surg. 1960;1:133-046



Comparison of Oxygen Tissue Diffusion

ATA	PO2	O2 DIFFUSION DISTANCE
1	100 mmHg	64um
3	2193 mmHg	250um

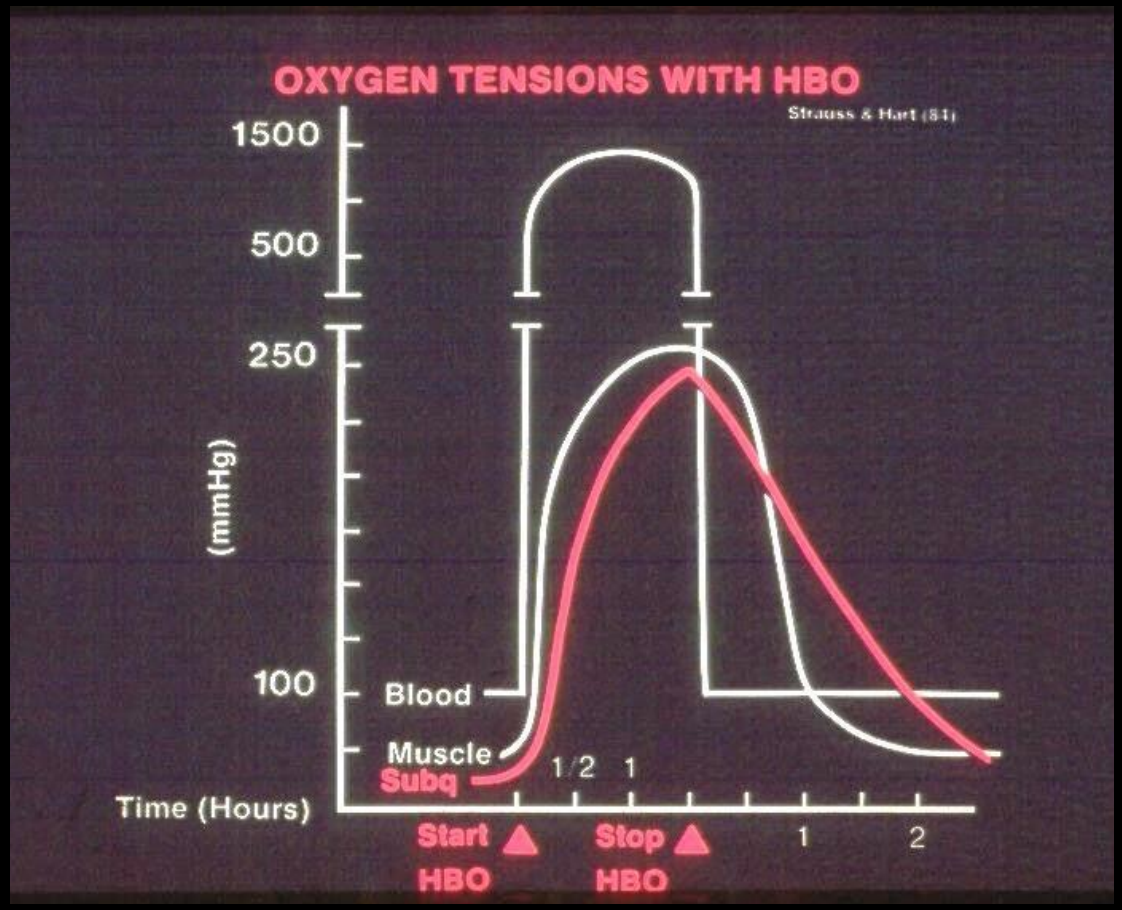
Model for Oxygen Diffusion in Tissues



That’s fine…..How Long does tissue stay saturated with oxygen?

Tissues Hyperoxygenation

- Tissue levels lag behind due to vasoconstriction
- Remain elevated for hours after removal from chamber



Plas Recon Surg; 99:148-55, 1997

- Ischemic Wound Model
  - Rabbit ear wound
  - 2.0 ATA compression
  - PO_2 of 250 to 350mmHg attained
  - PO_2 returned to baseline in 4 hours

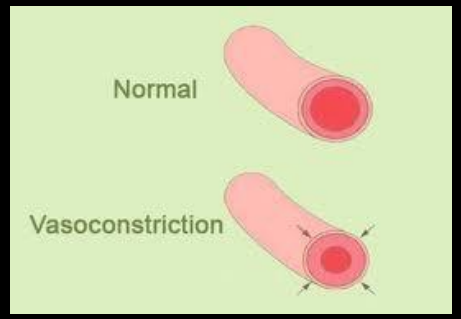
- Normal Wound Model
  - The PO2 returns to normal in <1 Hour
  - As ischemic wound heals, time to PO2 to return to baseline normalizes

Clinical Applications of Hyperoxygenation

- Acute traumatic ischemia/Crush injury/compartment syndrome
- Carbon monoxide/CN toxicity
- Gas embolism
- Decompression sickness
- Compromised skin flaps/grafts
- Thermal burns
- Severe anemia
- Acute arterial insuff (post re-implantation, CRAO)

Vasoconstriction

- Elevated O_2 levels cause arteriolar smooth muscle vasoconstriction, decreasing inflow ≈20%*
- Slight decrease in cardiac output with relative bradycardia and unchanged BP
- Despite vasoconstriction, there is large gain in delivered O_2
- Net result is decrease in tissue edema with increase in tissue oxygenation



*Plast Reconstr Surg 76;596-603, 1985

Clinical applications of vasoconstriction

- Crush injury/Compartment syndrome/Re-implantation
- Thermal Burns
- Cerebral edema/Head Injury
- Compromised grafts and flaps

Ischemia/Reperfusion injury

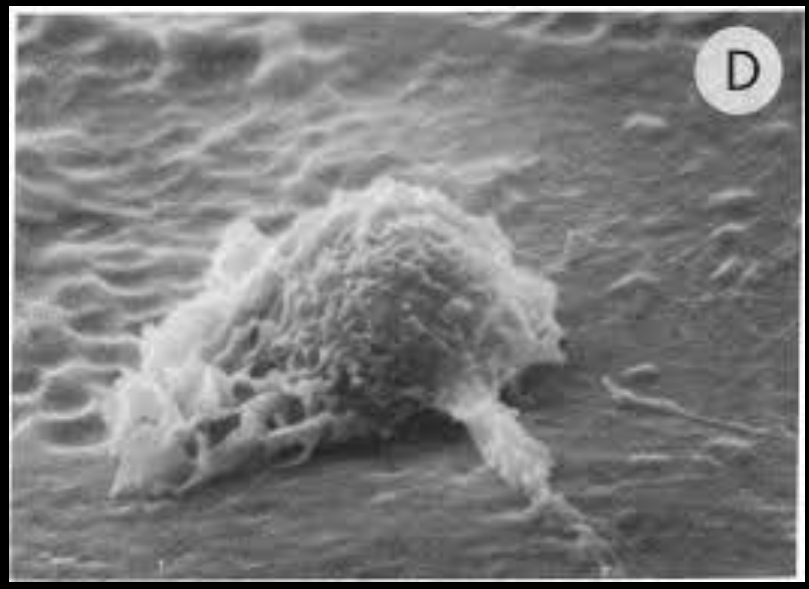
- Defined as “acute interruption in blood flow with subsequent restoration of perfusion creating further tissue damage beyond that observed during the initial ischemic event”
- See microvascular dysfunction:
  - Arteriolar vasoconstriction
  - Capillary leakage with tissue edema
  - ROS production
  - Leukocyte adhesion/activation
  - Reduced energy production

Effect of HBO on IR injury

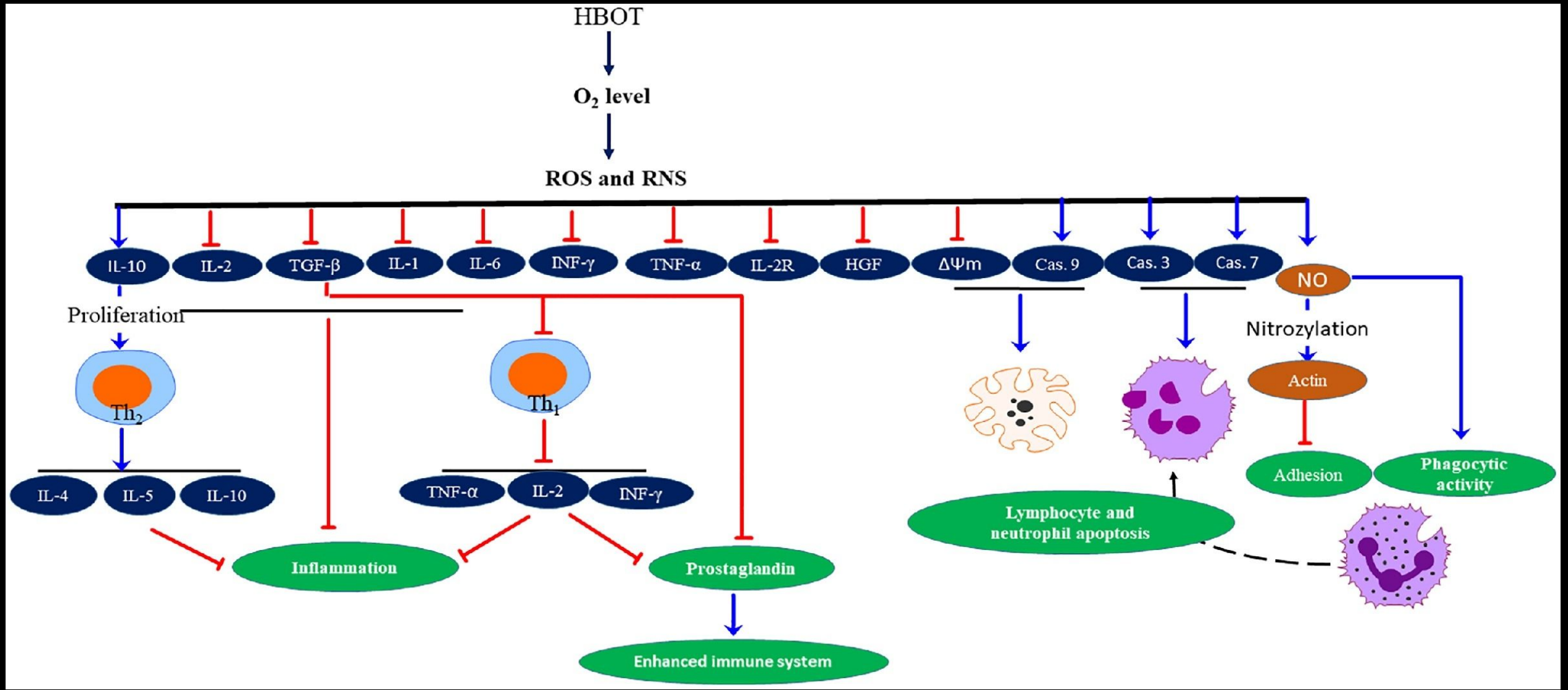
- Common sense would say HBO would increase tissue damage
- Opposite proved true in multiple studies with postischemic tissues*
  - See reduction in lipid peroxidation
  - Dose dependent as >4 ATA ***does*** increase lipid peroxidation

IR Injury: Plast Reconstr Surg 2011;127 (Suppl):131S-141S

- HBO at 2.8ATA to 3.0 ATA inhibits neutrophil B-2 integrin adhesion
- Does not inhibit antibacterial function
- HBO enhances Heme-Oxygenase-1, HSP 70
- Alters HiF-1 production
- Lowers monocyte chemokine synthesis



Inflammation/IR injury



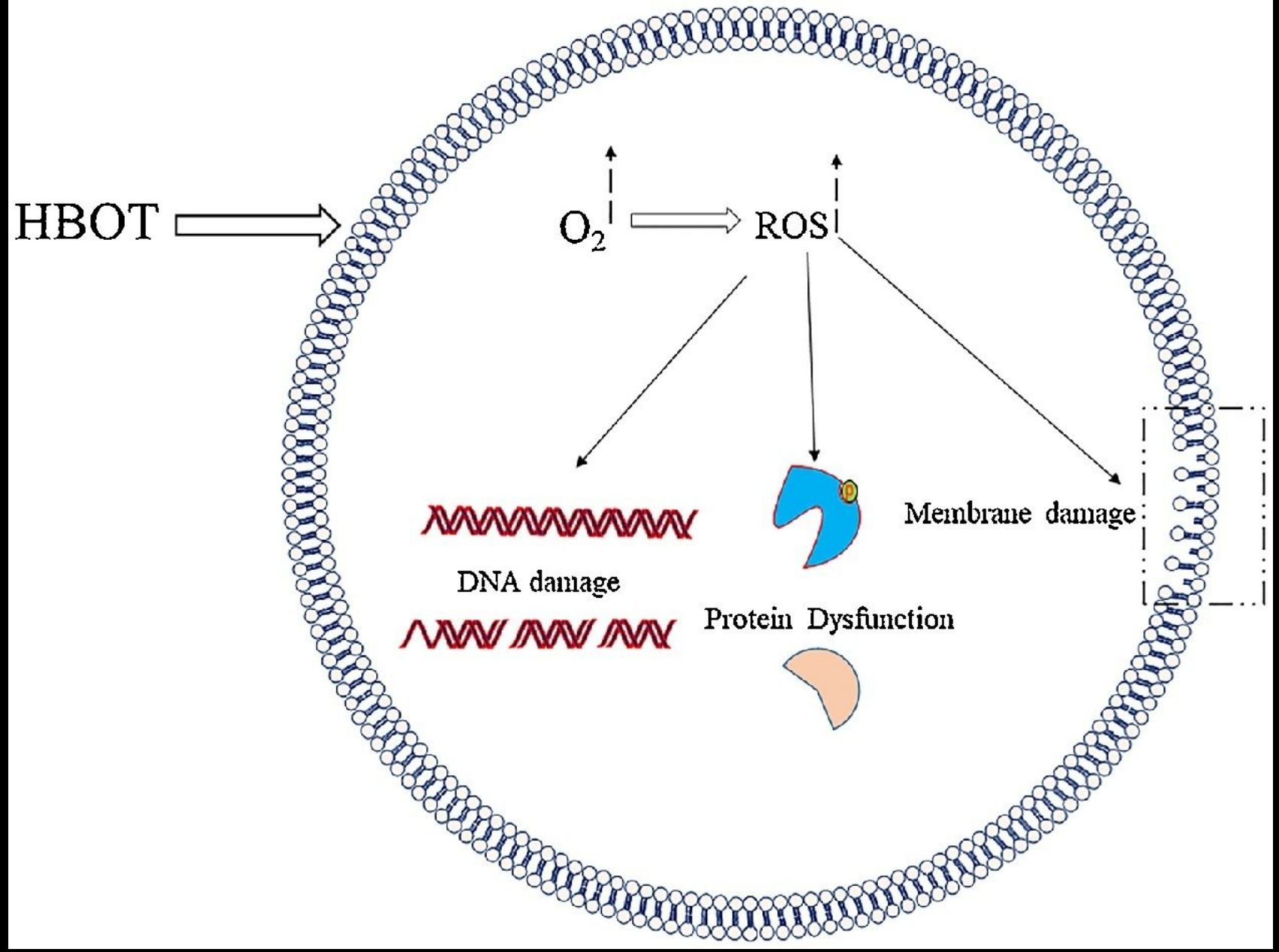
Clinical applications of IR injury

- Acute Traumatic Ischemia
- Re-implantation
- CO/CN
- Gas embolism
- CHI
- Thermal burns
- DCI
- Compromised skin flaps/grafts

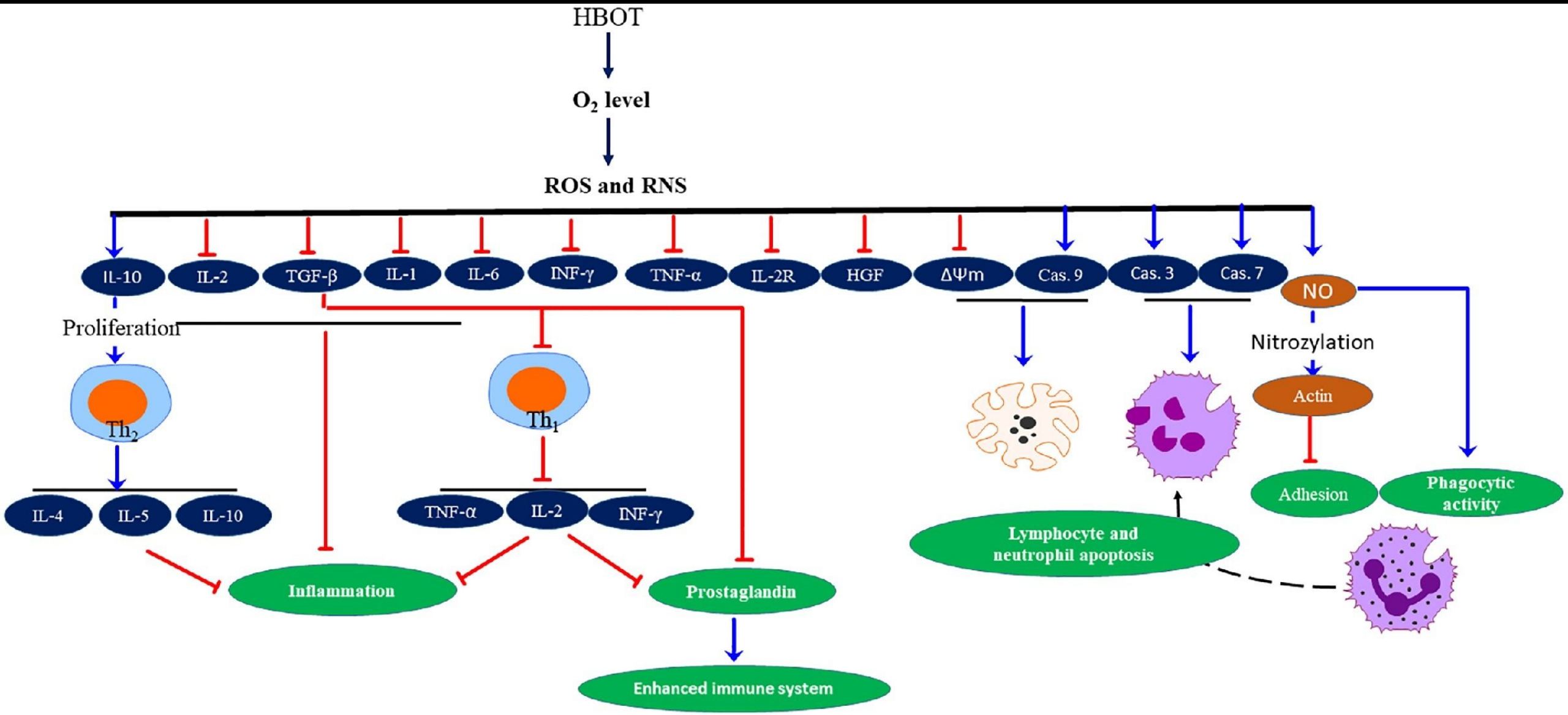
Figure 2. The lateral calf wound post-HBOT shows improvement in the edema and evidence of tissue viability.

HBO & ID

- Modest direct antimicrobial effects from HBO
- Neutrophils require O2 for microbial killing. Oxygen burst (NOX) requires 10-15 fold increased O2 consumption
- HBO can enhance antibiotic penetration into bacteria in Aminoglycosides, Cephalosporins *(UHM* 1999;26(3):169-74)
  - *AG transport across bacterial cell wall O2 dependent*
- Alpha toxin production by C perfringens stopped with O2> 250mmHg



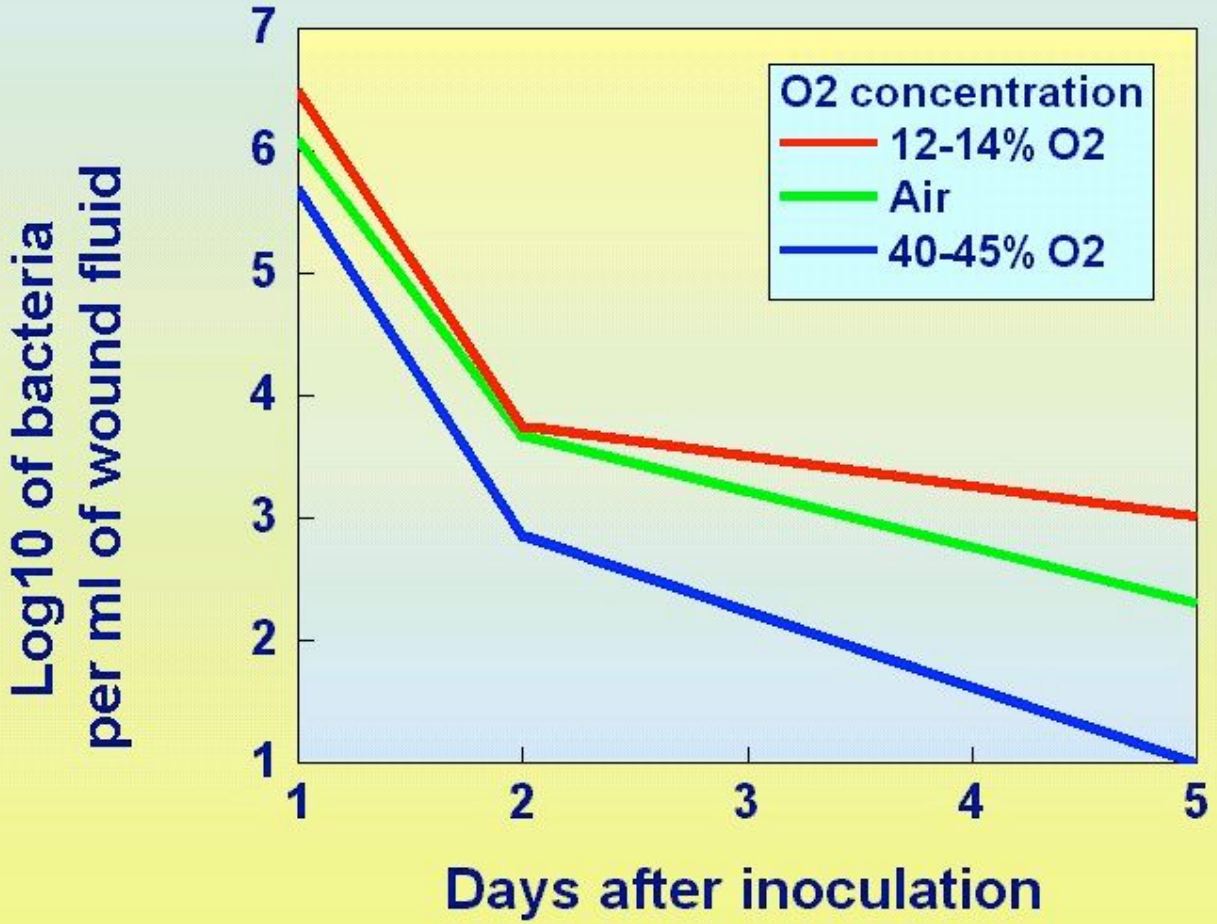
Biomedicine & Pharmacotherapy. 2019;109:440-447



Biomedicine & Pharmacotherapy. 2019;109:440-447

Knighton, DR, Halliday, B, Hunt, TK Arch Surg 119: 199-204, 1984

Effect of Increasing Oxygen Concentration on Bacterial Clearance from Wounds



adapted from Rabkin, JM, Hunt, TK. Infection and Oxygen. in Problem Wounds, The Role fo Oxygen. Norwalk, CT: Appleton & Lange, 1988.

HBO and Infectious Diseases

- DFU
- CROM
- Clostridial gas gangrene
- Intracranial abscess
- Necrotizing soft tissue infections
- Others
  - Fungal
  - Biofilm
  - COVID???

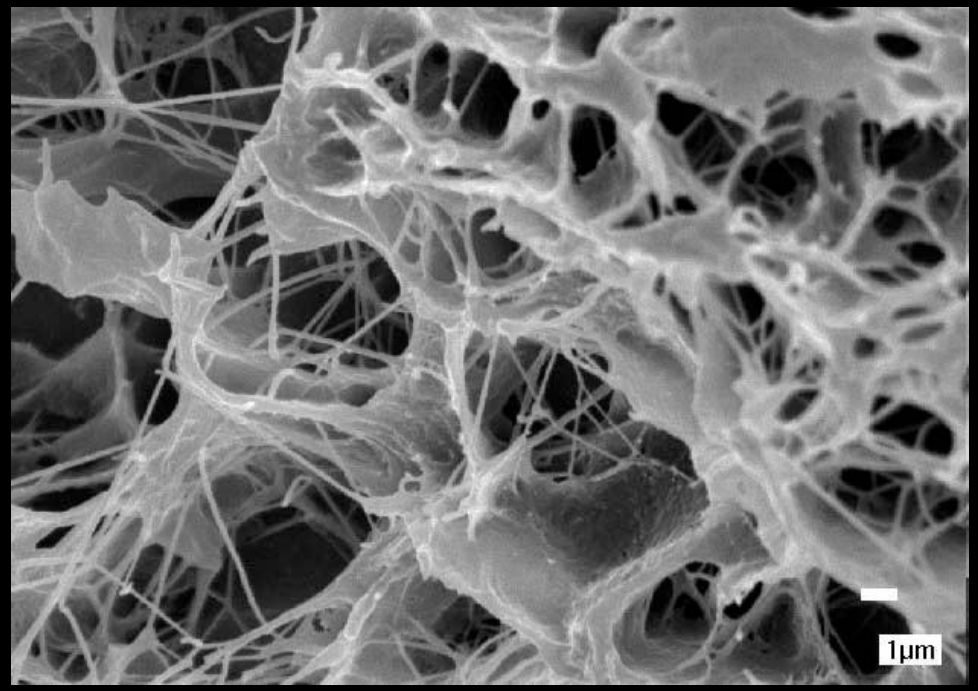
Neovascularization

- ***Neovascularization***: Blood vessel formation by de novo production of endothelial cells
- ***Angiogenesis***: New vessels arising from pre-existing ones
- Adequate oxygen tension a prerequisite for the formation of collagen matrix by fibroblasts
- Collagen matrix provides framework on which neovascularization takes place
- Maximal with high lactate, low pH, ***+ Oxygen***
- HBO directly ↑ VEGF, ↑HIF-1,↑ PDGF, ↑TGF-B, ↑ SDF

Plast Reconstruc Surg. 2011;127:131S-141S

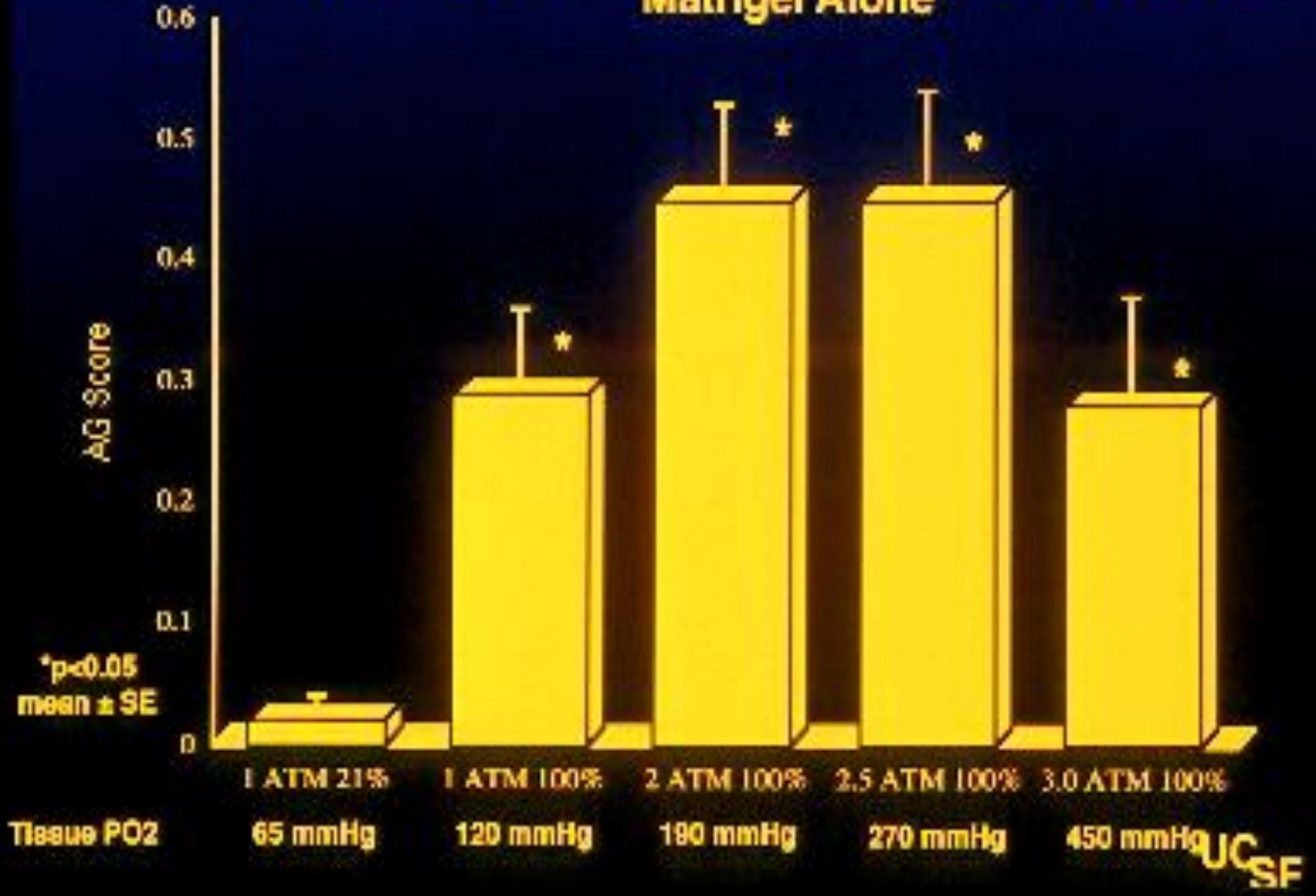
Oxygen dependent enzymes involved with Collagen Synthesis

- Prolyl-Hydroxylase
- Lysyl-Hydroxylase
- Lysyl-Oxidase



Oxygen Tension and Angiogenesis

Matrigel Alone

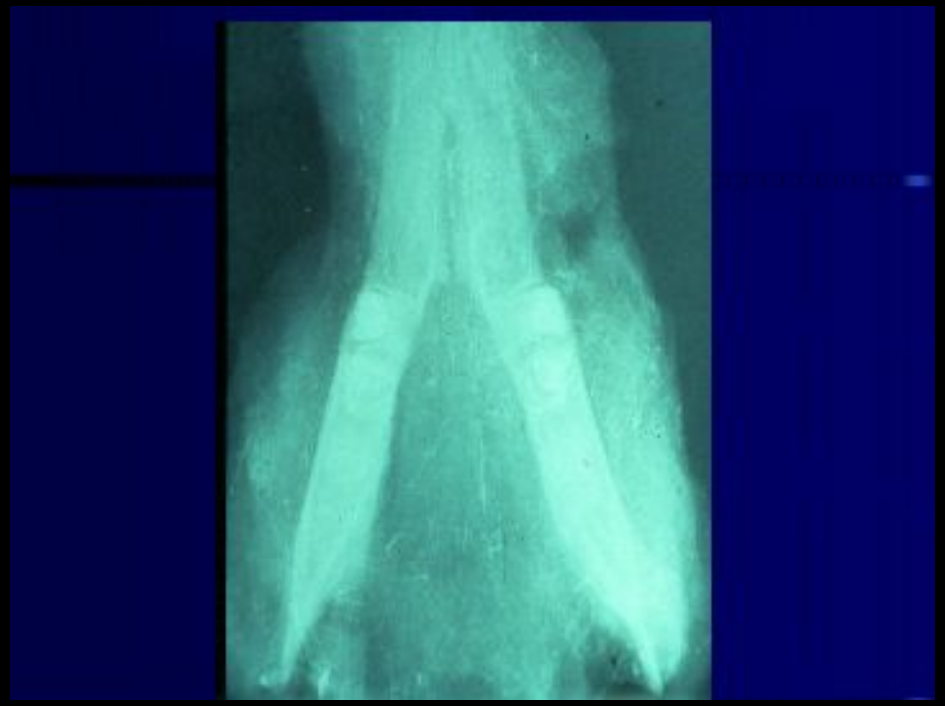


UCSF

Fig 1—Histologic sections of Matrigel after H&E staining at 100×. (A) Example of score on angiogenesis scale of 0. (B) Example of score on angiogenesis scale of 1.

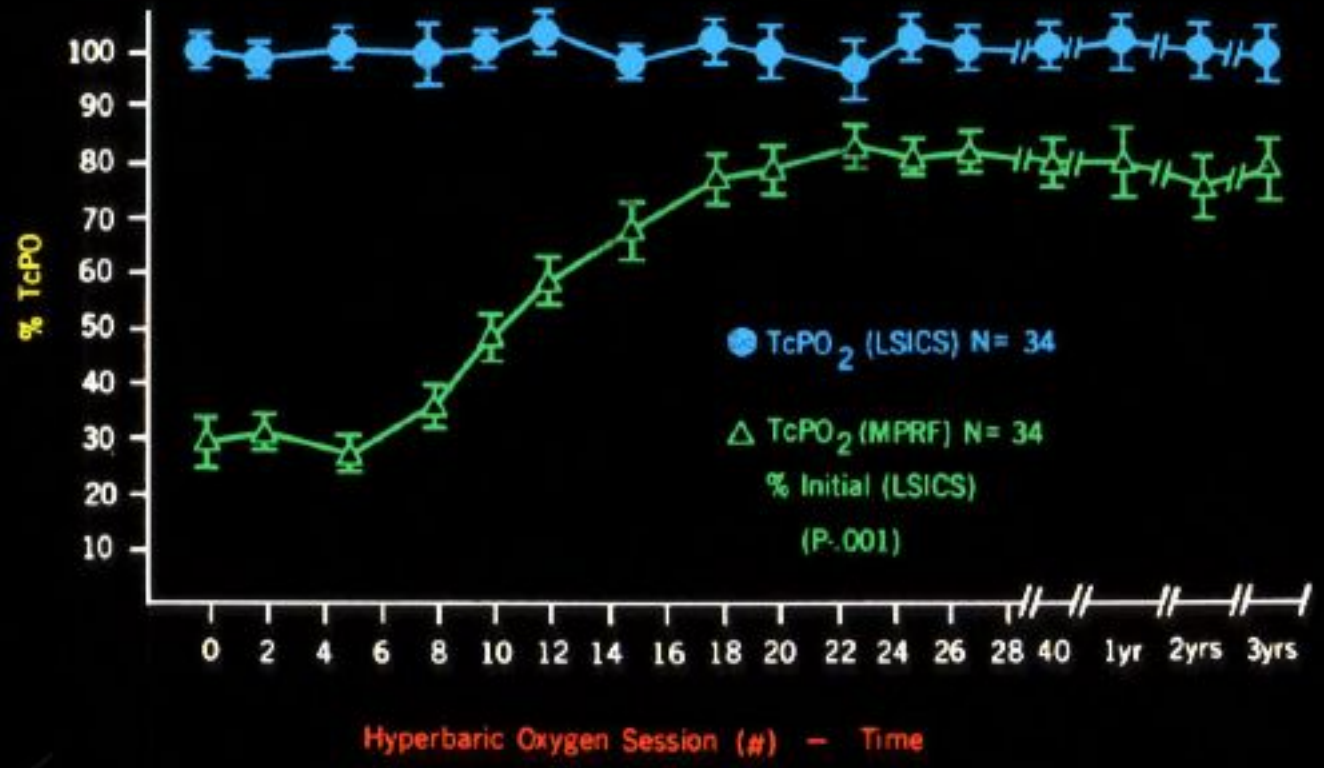
HBO and neovascularization

S/P Radiation and 100% oxygen



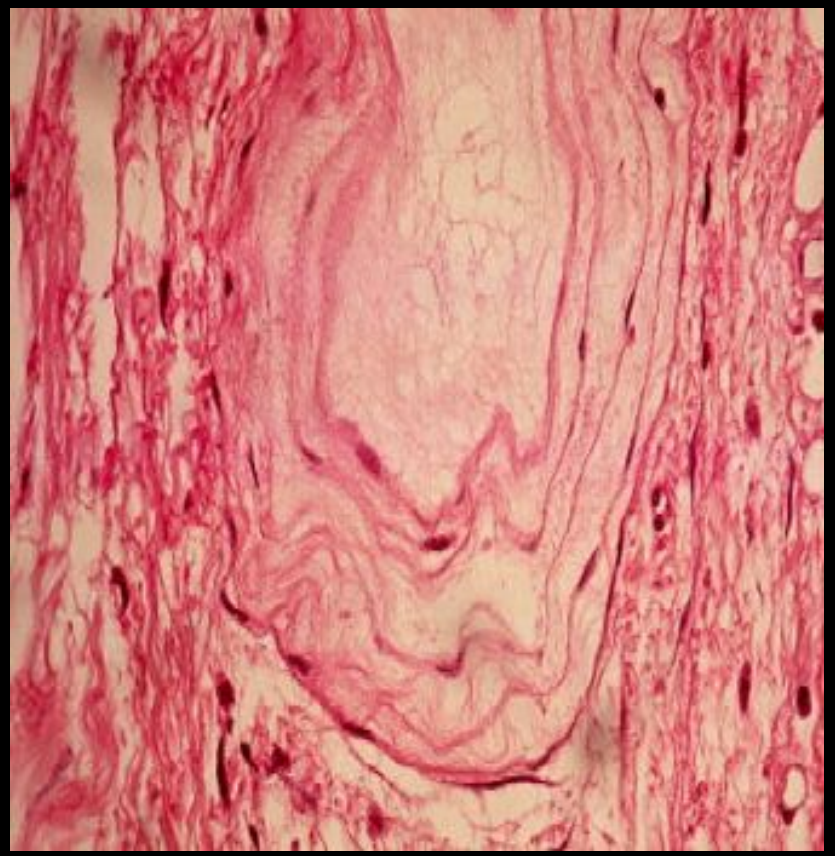
S/P Radiation and HBO

Neovascularization

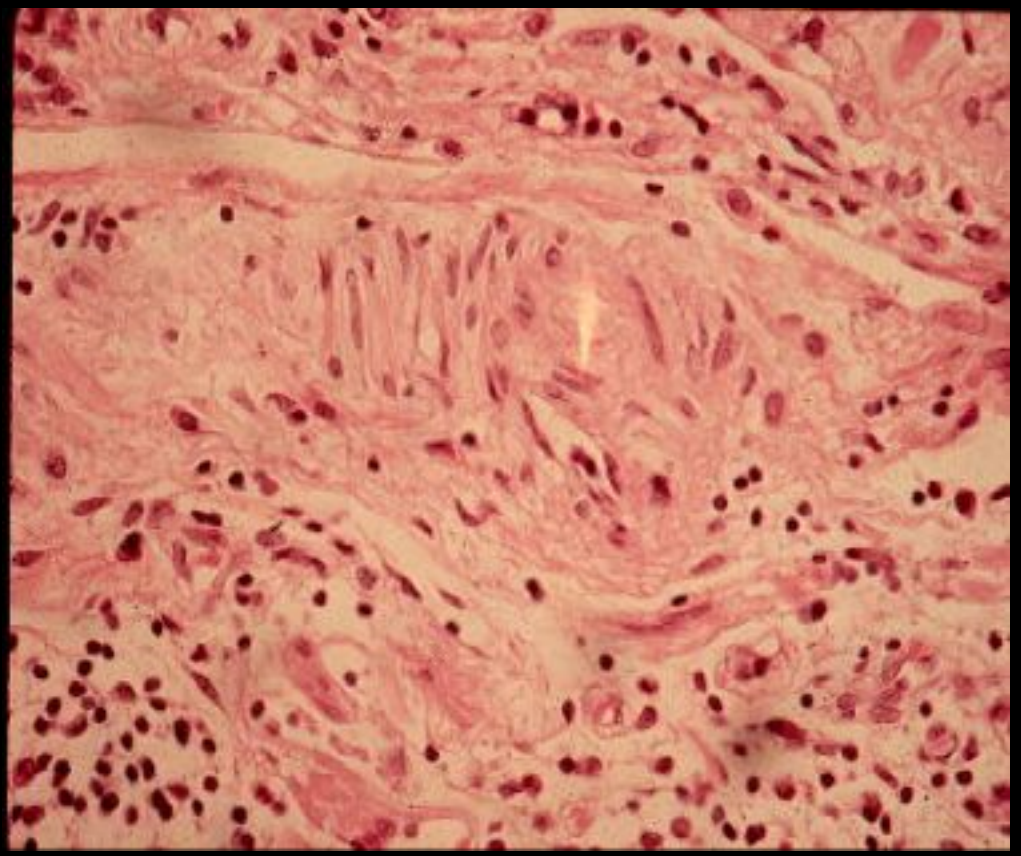


Neovascularization

Pre-HBO



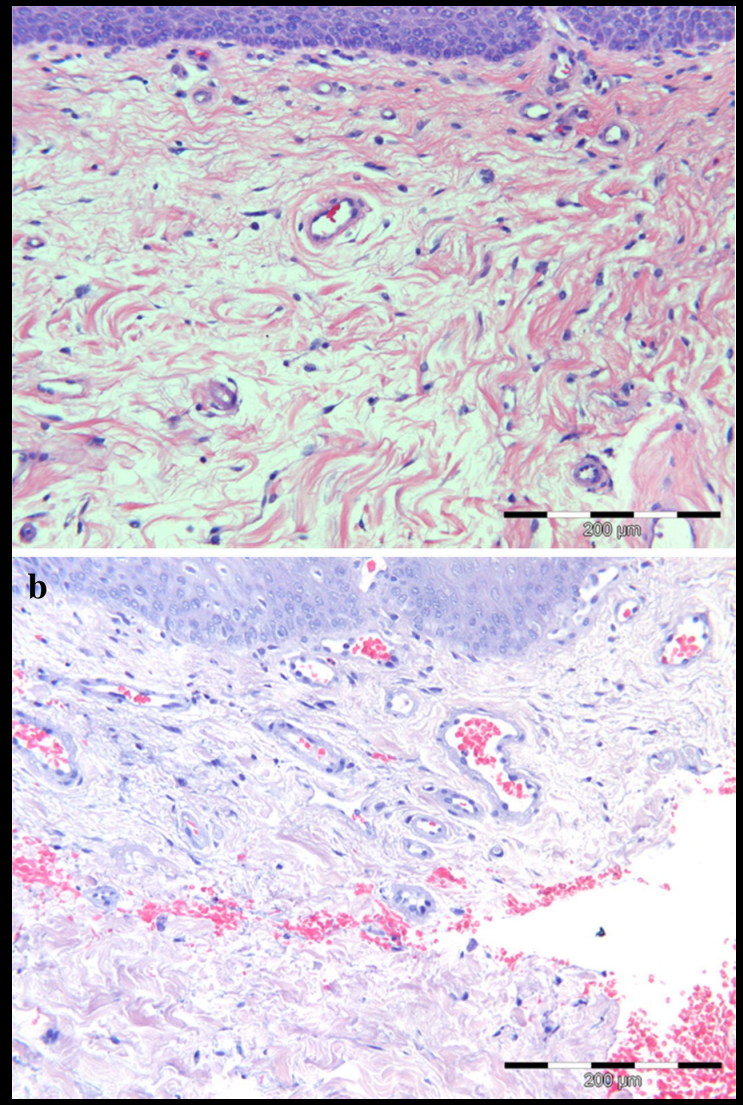
Post- HBO



Int J Oral Maxillofac Surg. 2015;44(3):301-7

Pre-HBO

Post-HBO

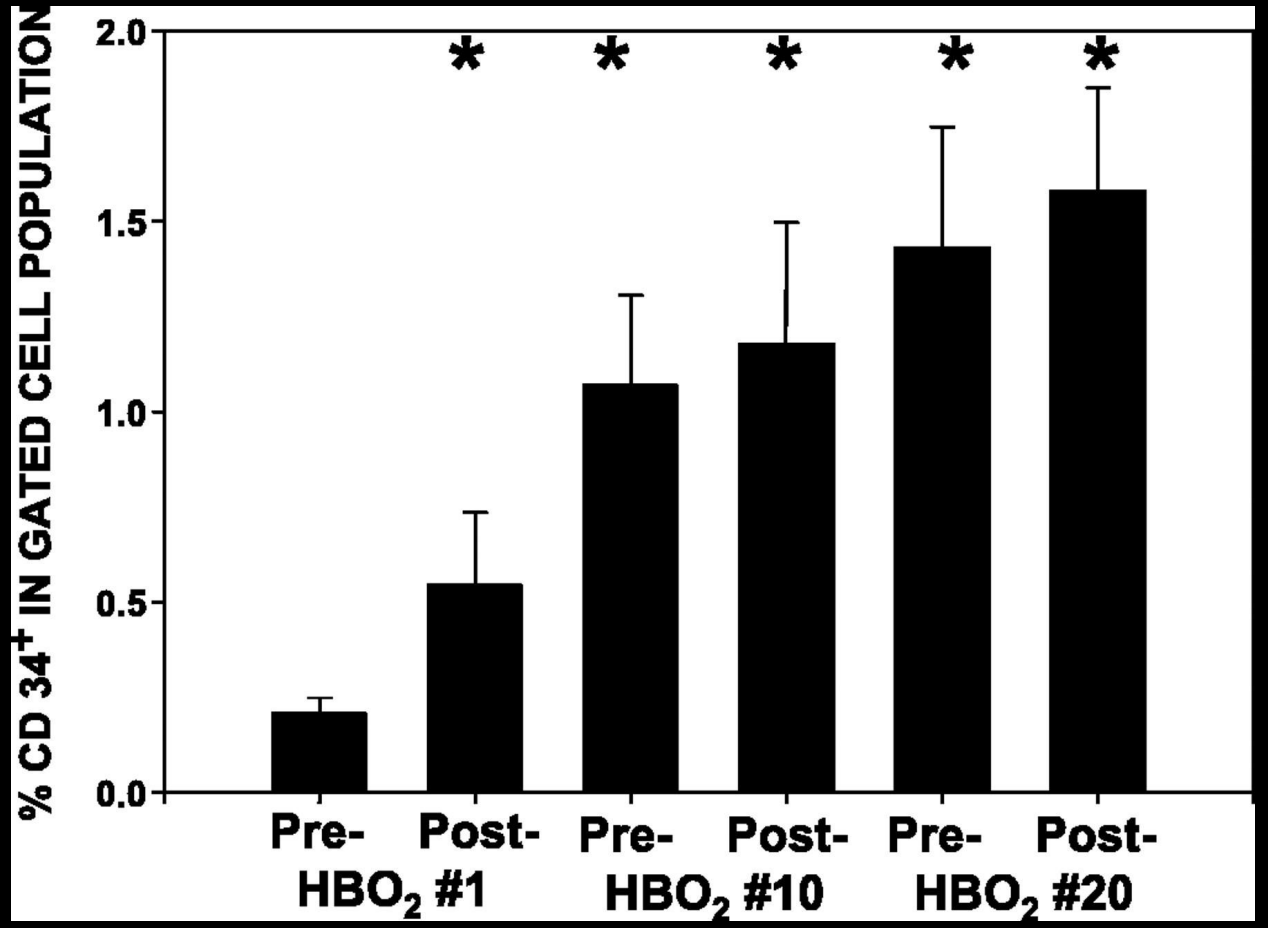


Stem Cell Mobilization by HBO

- Hypothesis is exposure to HBO would mobilize human stem/progenitor cells (CD34) from bone marrow via NO-dependant mechanism
- Pts undergoing HBO for tooth extraction in previously irradiated field (no open wounds/lesions) had blood levels drawn day 0, 10^{th}, and 20^{th} treatments

Am J Physiol Heart Circ Physiol 2006;290:1378-86,

Stem Cell Mobilization by HBO



Conclusions

- Hyperoxia increases bone marrow NO. NO is part of signaling platform to induce certain cellular functions
- Via elevated NO, HBO mobilizes stem cells
- Stem cell levels remain elevated for the course of 20 HBO treatments
- Mobilized cells have potential to differentiate into at least several different cell lines (VEGF-R)
- Additional studies show similar findings, dose dependent*

**Stem Cell Res. 2014;12(3):638-45*

Neovascularization

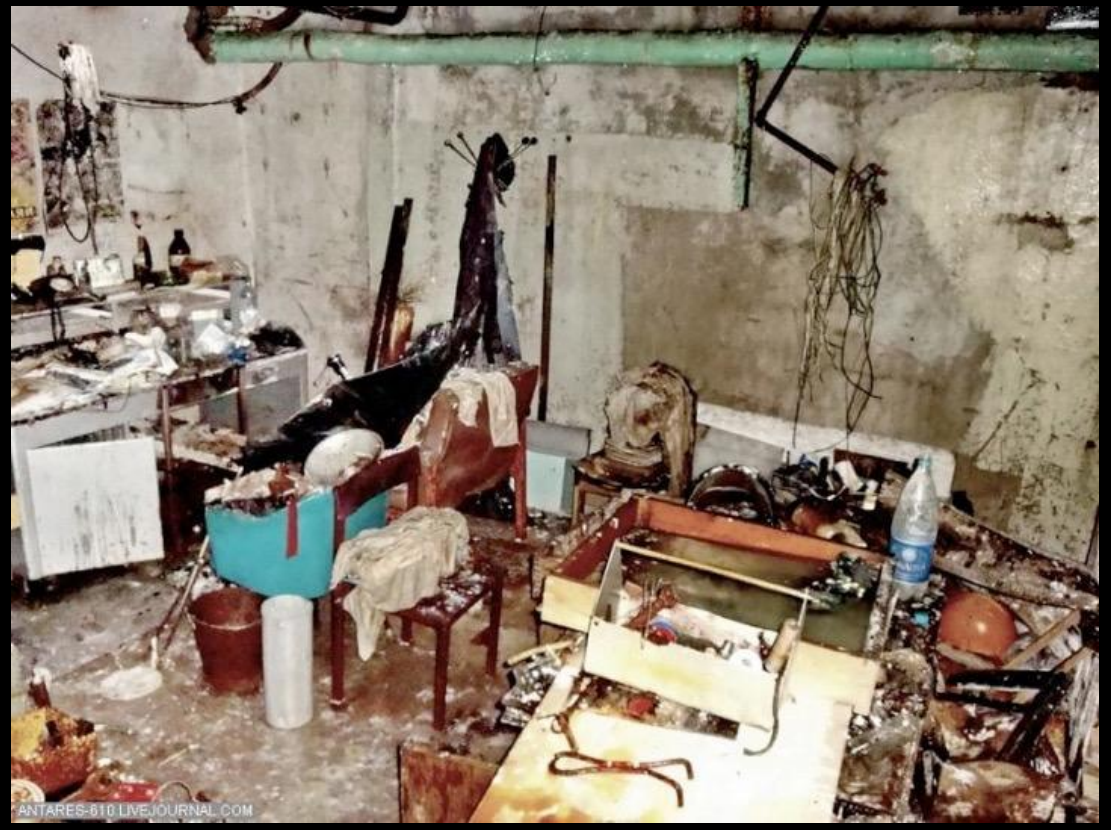
- Evidence that ROS exert roles in transduction cascades of growth factors that regulate cell proliferation and differentiation *(J Appl Physiol* 2009;106: 988-995*)*
- HBO affects lactate levels, Thioredoxin, and HIF-1 (*Sci Rep*. 2020 ;10(1):274)
- HBO also increases Stromal Derived Growth Factor-1(SDF-1) *(Mol Med Rep* 2013;8(4):1118-24)
- HBO increases Placental Growth Factor (PIGF) which can affect angiogenesis *(Life Sciences* 2008. 83 (65-73)

Clinical Applications of Neovascularization

- Wound healing in areas of impaired circulation
  - Radiation damaged areas
  - Diabetic/Ischemic wounds
  - Connective tissue disease
  - Non-operative peripheral vascular disease
  - Osteomyelitis
  - Avascular Necrosis (AVN)

Side Effects of HBO

- Claustrophobia
- Barotrauma
- Seizure
- CHF exacerbation
- Pneumothorax
- Eye Complications
- Boredom, 2 hrs daily
- Fire



“Though other medical modalities have grown faster on less data, hyperbaric oxygen has drawn a dramatic line between those who do not have a hyperbaric chamber and are skeptics, and those who do have one and believe…”

T.K. Hunt 1994

Changing gears

New Horizons for HBO

HBO and CABG

- Pretreatment with hyperbaric oxygen and its effect on neuropsychometric dysfunction and systemic inflammatory response after cardiopulmonary bypass: A prospective randomized double-blind trial
- *Journal of Thoracic and Cardiovascular surgery,* 2005;130:1623-30
  - Blinded study, looked at neuropsychometric testing, as well as inflammatory mediators
  - 3 treatments 24, 12, and 4 hours before bypass, Group A at 1.5 ATA air, Group B at 2.4 ATA O2

Results

- Inflammatory mediators:
  - Group A ↑ soluble E-selectin, CD-18, compared to group B
  - ↑ IL-6, IL-8, ICAM-1, and TNF-α were significant in both groups
- Neuropsychometric impairment
  - Significantly more pts in group A (air group) had neuropsychometric impairment compared with group B ($p<.05$). Testing done 48 hrs before, 4 mons after
  - 16/32 in group A, 9/32 group B with abnormalities
  - No single variable a predictor (age, IQ, bypass time, LV function, ischemia time)

Conclusions

- Pretreatment with HBO reduces neuropsychometric dysfunction
- Modulates inflammatory response after bypass. Does not inhibit effect.
- Subsequent Study (*Cardiovasc Revasc Med* 2010;11(1):8-19)
  - Improves LVSV,
  - Reduced myocardial injury
  - Decreased blood loss
  - Decreased LOS
  - Decreased post op complications
  - Saved Money

New Study with PCI (*Cardiovasc Revasc Med* 2020;30:14-19)

- Compared SPECT findings in PCI patients for STEMI with HBO vs control at 6 weeks
- Pilot study, 24 pts. 13 HBO (Start Day 3, for 15 txs) and 11 Control
- Similar characteristics both groups
- Affected SPECT segments in HBO group at baseline and 6 weeks
  - 47.1 +/- 14.6 % vs 33.7 +/- 16.2%
- Affected SPECT segments in control group
  - 55.5 +/- 19.5% vs 45.9 +/-17.9%
- EF in HBO improved from 44□ 57.2 vs 45.9□55
- HBOT in STEMI associated with improved perfusion, slight increase in EF. Needs more study

Radiation treatment and HBO

- HBO used for pre-radiation in certain cancers (head and neck, GBM)
- Thought to create more oxidative stress in cancer cells while protecting normal cells
- Hypoxic cancer cells radio-resistant
- The biological effect of ionizing radiation about 3-Xs higher if delivered in well-oxygenated tissues
- May lessen radiation damage to normal cells, lessen radiation effects

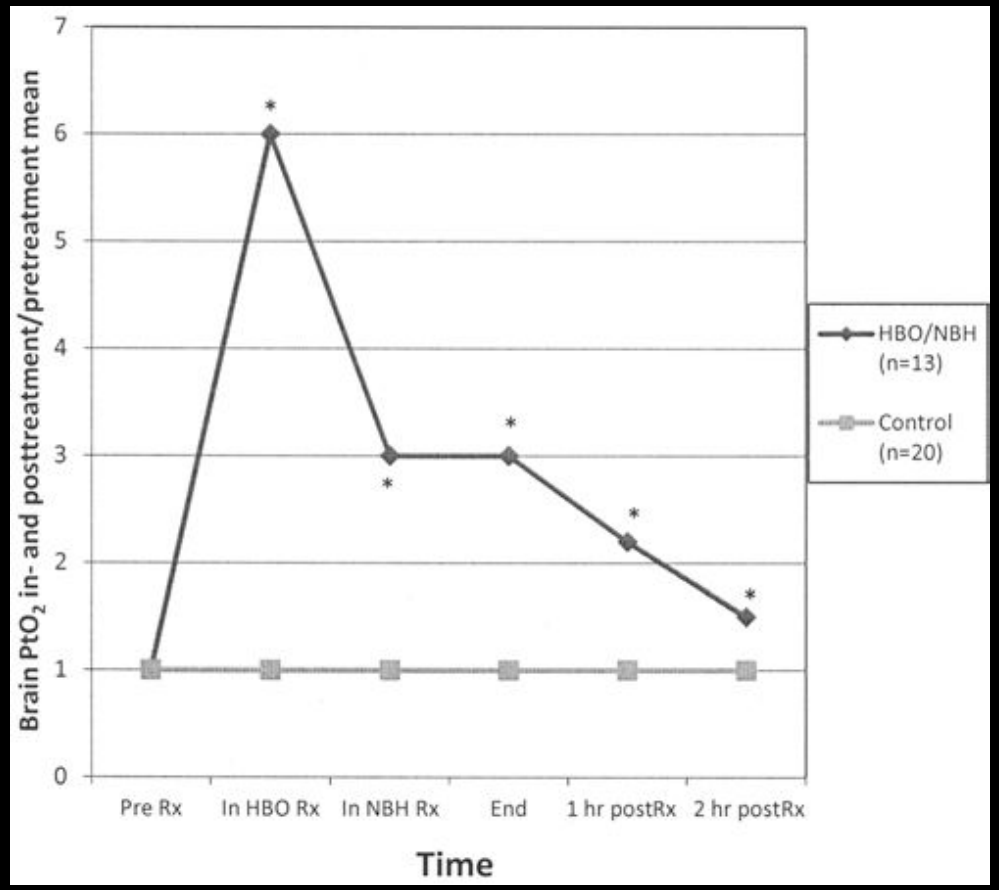
Studies

- *Curr Med Res Opin* 2015;21(11):1977-84
  - Total 203 pts, all grade III/IV gliomas
  - HBO had improved outcomes (survival rate, progression free survival, time to progression, response rate)
  - No complications
- *Front Oncol* 2021;11:643469
  - Looked at recurrent High-Grade Glioma
  - 11.6 months after previous radiation
  - 9 patients
  - 3 month survival 66.5%, 6 month 27.7%
  - Median survival was 10 months

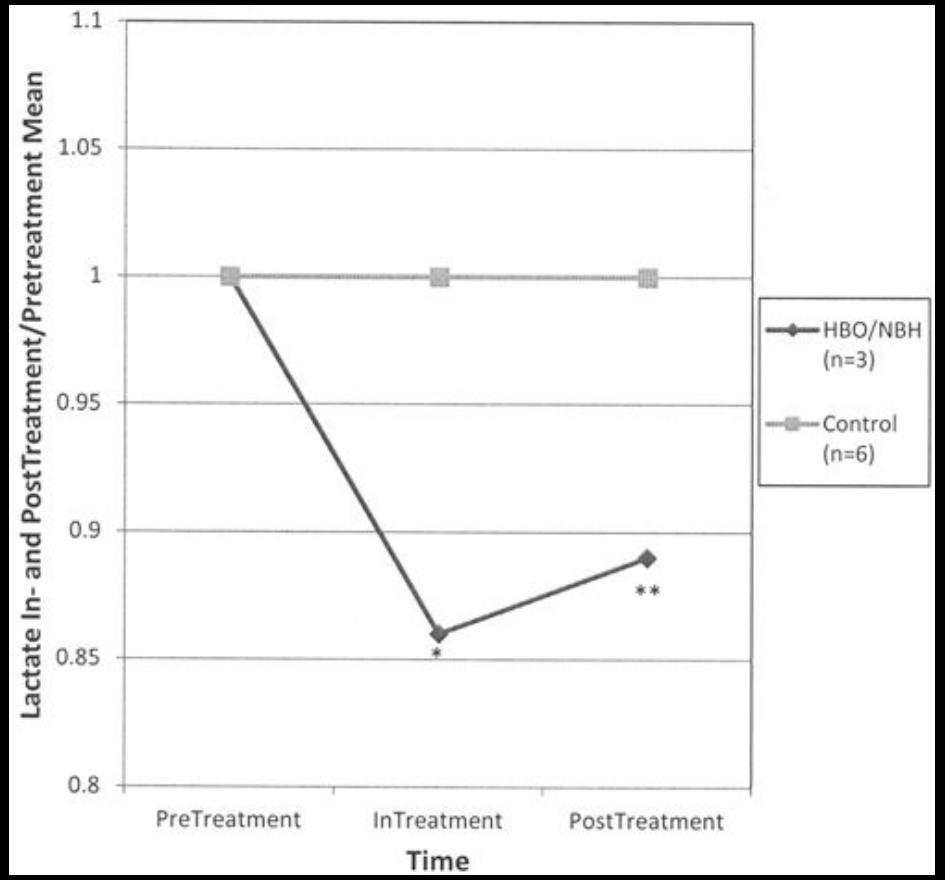
HBO and Severe, Acute Head Injury

- *J Neurosurg*. 2013 Mar 19;118:1317-28
  - 42 pts with severe acute TBI GCS<8
  - Prospective, randomized trial
  - Had HBO/NBO (60 mins at 1.5 ATA then 3 h of 100% Oxygen at 1 ATA for 3 days) or controlled standard care
  - Evaluated ICP, Oxygen toxicity, cerebral metabolism, and clinical outcome

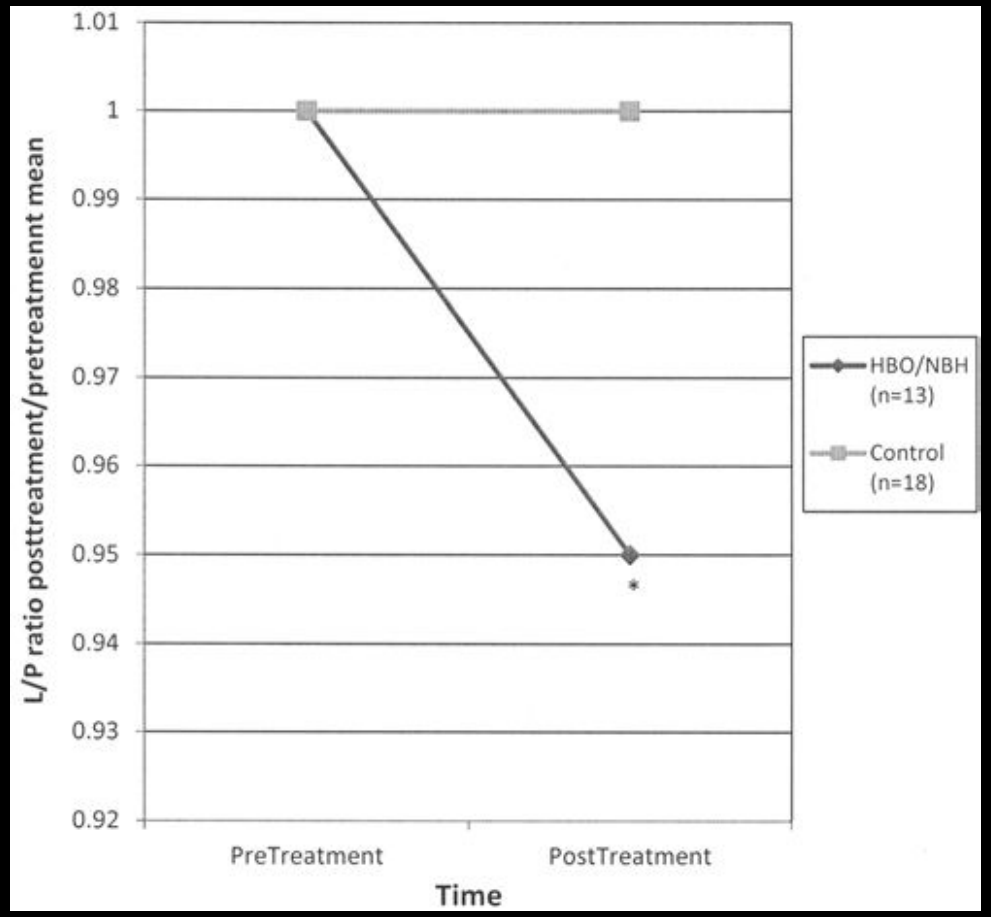
Brain PtO2



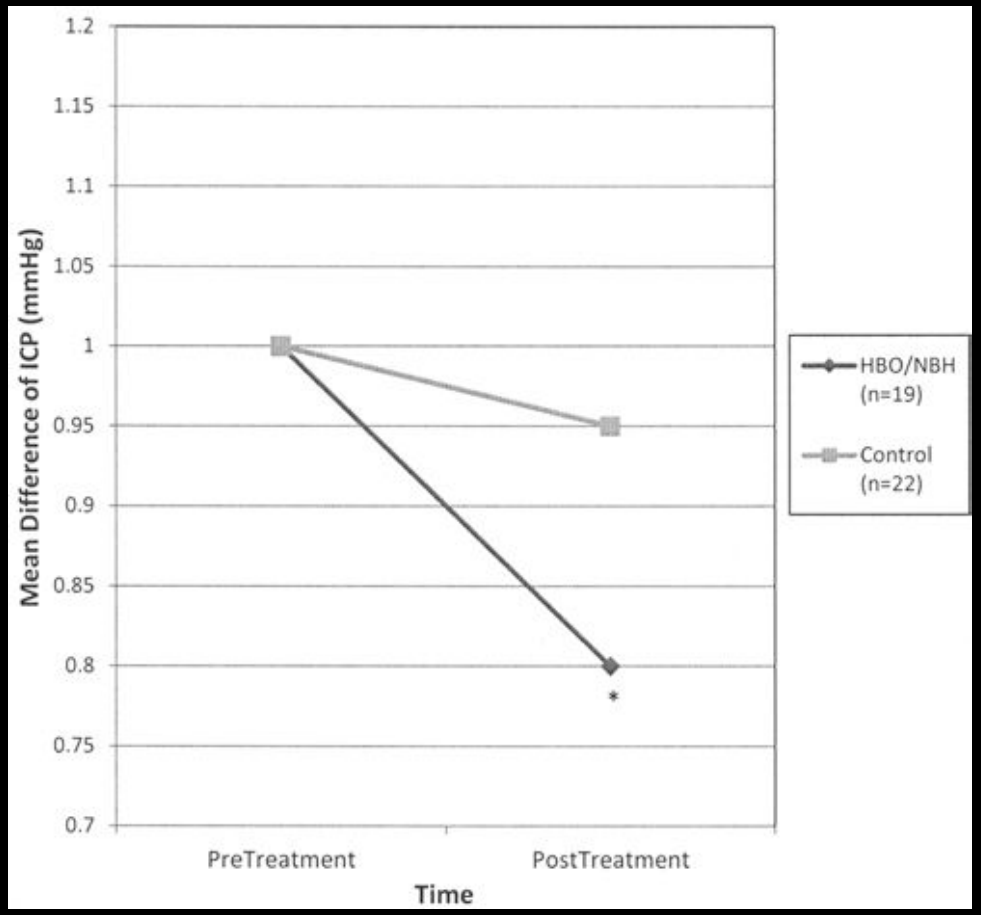
CNS Lactate levels



Lactate/Pyruvate Ratio



ΔICP



Conclusions

- HBO and NBO significantly improved markers of oxidative metabolism in uninjured and injured brain
- ↓ Intracranial hypertension and ICP
- ↓ markers of cerebral toxicity
- Significant reduction in mortality and improved favorable outcome as measured by GOS
- Improvement better than past clinical outcomes observed with either treatment used separately
- No complications
- Large multi center trial under way (HOBIT)

HBO and CVA

- *PloS One.* 2013;8(1):e53716
  - Prospective randomized, controlled crossover trial
  - 74 people with CVA in previous 6-36 mons with >1 motor dysfunction
  - 40 HBOT treatments vs control (2.0 ATA)
  - NIHSS, ADLs, and SPECT were primary endpoints

HBO and CVA

	Treatment group				Cross group				
	Baseline	Post HBOT	P_1	P_2	Baseline	Control period	Post HBOT	P_1	P_3
NIHSS	8.53±3.62	5.52±3.59	<0.0001	0.004	8.71±4.11	8.34±4.25	5.85±3.44	0.43	<0.0001
ADL	16.1±6.52	12.77±7.26	<0.0001	0.02	17.38±9.49	17.45±9.53	13.82±8.75	0.42	<0.0001
EQ- 5D	9.3±1.36	7.67±1.33	<0.0001	0.009	8.78±1.55	8.64±1.69	7.57±1.51	0.122	<0.0001
EQ- VAS	4.93±1.62	6.45±1.50	<0.0001	0.016	5.14±2.25	5.34±2.27	6.79±1.85	0.053	<0.0001

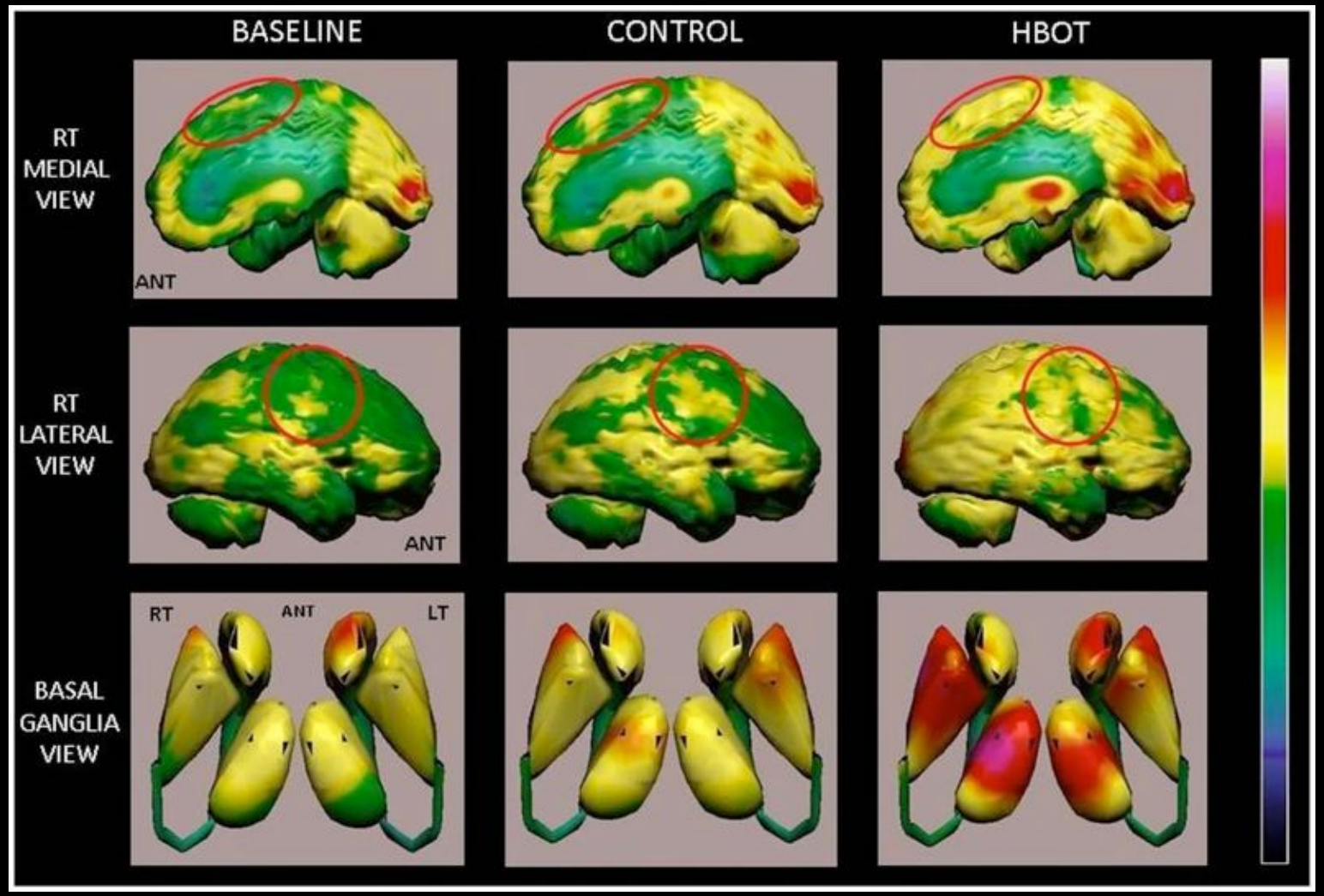
*Data presented as Mean ± standard deviation.

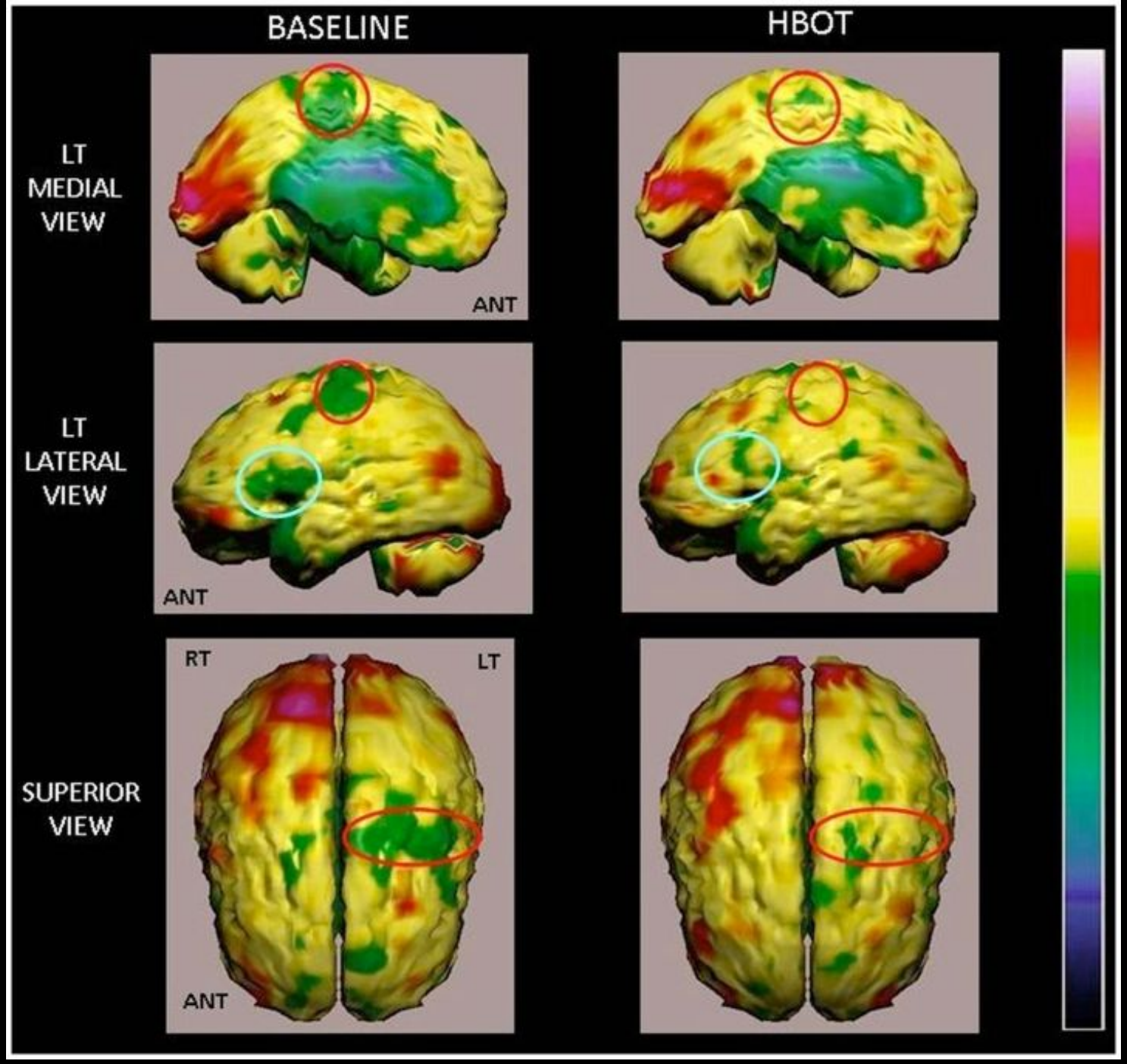
Abbreviations: NIHSS = National Institutes of Health Stroke Scale; ADL = activities of daily living; EQ = Evaluation of Quality of life evaluation by the EQ-5D descriptive system and the EQ visual analogue scale (EQ-VAS). HBOT = Hyperbaric Oxygen Therapy.

P_1 = p value compared to baseline in the same group. P_2 = p value compared to the cross group after the control period. P_3 = p valus compared to the 2nd evaluation at the end of the control period.

doi:10.1371/journal.pone.0053716.t002

Patient 1 year after CVA




BASELINE
HBOT
LT MEDIAL VIEW
LT LATERAL VIEW
SUPERIOR VIEW
ANT
ANT
RT
LT
ANT

Conclusions

- HBO can lead to significant neurological improvements
- Neuroplasticity can be activated even long after damage
  - HBO delivers more O2
  - Initiates cellular & vascular repair
  - ↑ Cerebral blood flow
  - Improves mitochondrial function, cellular metabolism
  - Alleviates oxidative stress, ↓ apoptosis
  - Promotes neurogenesis by ↑ neural stem cells, glial and astrocytes
- Functional improvements mirror findings on SPECT
- Needs more research

HBO and Post-Concussive syndrome

JAMA Intern Med 2015;175(1):43-52

- Multi-center, double-blind, sham-controlled clinical trial of 72 soldiers
- Routine PCS care provided in specialized clinics.
- Participants were randomized 1:1:1 to 40 HBO sessions administered at 1.5 atmospheres absolute (ATA), 40 sham sessions consisting of room air at 1.2 ATA
- The Rivermead Post-Concussion Symptoms Questionnaire (RPQ) served as the primary outcome measure.

Table 2. Changes From Baseline in Postconcussion Symptom Scores Using the Rivermead Post-Concussion Symptoms Questionnaire and Subscales Among the Intent-to-Treat and Per-Protocol Populations[a]

	Intent-to-Treat Population				Per-Protocol Population		
Intervention	Baseline, Mean (SD)	After Intervention, Mean (SD)	Change Score (95% CI)	*P* Value[b]	Baseline, Mean (SD)	After Intervention, Mean (SD)	Change Score (95% CI)
Rivermead Post-Concussion Symptoms Questionnaire 3 Subscale							
Standard care	5.4 (2.7)	5.1 (2.8)	0.0 (−1.0 to 1.0) (n = 20)	.97	5.4 (2.7)	5.1 (2.8)	0.0 (−1.0 to 1.0) (n = 20)
HBO	5.5 (3.3)	4.2 (3.0)	1.2 (0.0-2.4) (n = 23)	.04	4.7 (3.2)	3.1 (2.2)	1.6 (−0.1 to 3.3) (n = 11)
Sham	4.7 (3.1)	3.5 (3.3)	1.5 (0.1 to 2.9) (n = 21)	.03	4.8 (3.7)	2.7 (2.8)	2.2 (0.7 to 3.6) (n = 13)
Rivermead Post-Concussion Symptoms Questionnaire 13 Subscale							
Standard care	27.1 (12.2)	25.5 (13.9)	0.5 (−4.0 to 5.0)	.87	27.1 (12.2)	25.5 (13.9)	0.5 (−4.0 to 5.0)
HBO	27.5 (13.1)	22.5 (12.4)	4.2 (−0.8 to 9.1)	.02	25.0 (13.4)	15.6 (10.9)	9.4 (2.9 to 15.9)
Sham	25.5 (11.6)	20.7 (12.8)	5.5 (0.7 to 10.3)	.04	25.9 (14.0)	17.4 (13.3)	8.5 (2.8 to 14.2)
Total Rivermead Post-Concussion Symptoms Questionnaire							
Standard care	32.5 (14.4)	30.6 (16.1)	0.5 (−4.8 to 5.8)	.91	32.5 (14.4)	30.6 (16.1)	0.5 (−4.8 to 5.8)
HBO	33.0 (15.8)	26.7 (14.8)	5.4 (−0.5 to 11.3)	.008	29.7 (16.3)	18.7 (13.0)	11.0 (3.2 to 18.8)
Sham	30.2 (14.2)	24.2 (15.4)	7.0 (1.0 to 12.9)	.02	30.8 (17.6)	20.1 (15.7)	10.7 (3.9 to 17.5)

Abbreviation: HBO, hyperbaric oxygen.

[a] The 95% CIs were calculated using 95% binomial exact CIs.

[b] Wilcoxon signed rank test.

Conclusions

- Among service members with persistent PCS, HBO showed no benefits over sham compressions
- Both intervention groups demonstrated improved outcomes compared with PCS care alone.
- This finding suggests that the observed improvements were not oxygen mediated but may reflect nonspecific improvements related to placebo effects.
- BIMA Study

Why are we not doing more of this?

- Need to educate
- Patient selection key
- Need aggressive surgery for most indications
- Most locations don’t do emergencies/critical care
- Sick patients difficult to treat
- Changing practice patterns can be very, very, very, very difficult despite lots or research
- Not enough physician experience with HBO
- Physicians not familiar with data
- Can be seen as side show/not main stream medicine
- And, of course, more data and studies

Thank you, please wake person next to you

QUESTIONS???