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IHMF: Definitions of Oxygen Saturation Technology, Hyperbaric Medicine, and Hyperbaric Oxygen Therapy

- **Oxygen Saturation Technology is increasing the oxygen saturation in the fluids of the body to a level greater than ambient pressure. No wound will heal without oxygen! [1]**
- **Hyperbaric Medicine is the medical administration of gasses at greater than ambient barometric pressure at a targeted dose of pressure/time to a patient in a pressure vessel for a specific medical condition, thereby increasing the saturation of bodily fluids.**
- **Hyperbaric Oxygen Therapy is the administration of USP oxygen at a partial pressure and barometric pressure greater than ambient in a pressure vessel, thereby increasing Oxygen Saturation of bodily fluids**

Although the same breathing gasses have been utilized in every breath inhaled since the first human walked the Earth, both diving and hyperbaric medicine take advantage of the physics and physiological chemistries of changing the partial pressure and barometric pressure of breathing gasses over time to effectuate desired outcomes. The purpose and desired outcomes are very different for diving vs hyperbaric medicine.

Hyperbaric Medicine uses specific breathing gasses, either mixed gasses or a purified single gas, using specific partial pressures of each gas and delivered at specific barometric pressures over time at a specific dose to a patient in a pressure vessel to treat a specific medical condition in order to effectuate a desired outcome. [2-10]

Recreational diving and technical diving use the same gasses in precise blends, utilizing specific partial pressures of each gas at specific barometric pressures over time delivered to the diver, either in the water or in a pressure vessel, to provide for the safety and performance of the diver at depth. Although the gasses are used and delivered in a

The TOR Institute
1315 Hwy 182 E
Morgan City, LA 70380
(985) 397-4692

IHMF Research Center
212 Stacks Rd, Suite A
Ennis TX 75119
(703) 505-7530

ANDI International
74 Woodcleft Ave
Freeport NY 11520
(516) 546-5137

similar fashion, the purposes are quite different. Diving is not medical treatment, though diving has led to medical recoveries.

Three highly pertinent cases that illustrate medical recovery from recreational and commercial diving come to mind:

1) A medical school student with cerebral palsy had a massive recovery from diving frequently while at St. Eustatius Medical School in the Caribbean.
2) Over a 180 day period of time, six commercial oilfield divers working in the Gulf of Mexico made a full recovery from HIV/AIDS. They had been diving on compressed air @ 160' seawater, after which all six divers tested negative to HIV, to everyone's shock and amazement. This case was studied extensively at Duke University. The recovery was attributed to excess nitrogen, potentially leading to a cure for HIV/AIDS.
3) The prison program in California with the lowest recidivism rate in their system is the commercial diving training program at Chico State Prison.

Each of the above referenced and well researched cases involves known mechanisms of action for hyperbaric medicine crossing over from sports diving. [11]

All aircraft flying above certain altitudes are required to carry supplemental oxygen, and all jet aircraft are required to maintain both a minimum cabin pressure as well as supplementing the cabin air with oxygen in order to maintain a minimum O^2 level, but these are neither Hyperbaric Medicine nor Hyperbaric Oxygen Therapy, nor are all the body fluids saturated at a greater rate than at sea level. Therefore, aerospace applications of compressed atmospheric air and supplemental oxygen are not a component of Hyperbaric Medicine, in and of themselves, but Aerospace Medicine is. The US Air Force was placed in charge of Hyperbaric Medicine Research in 1983, while the US Navy was placed in charge of deployment in theatre.

Both Diving Medicine and Aerospace Medicine are branches of Hyperbaric Medicine used to treat an injured diver or aerospace passenger, respectively. The research in both fields is applicable to Hyperbaric Oxygen Therapy. [5]

Oxygen Saturation Technology: Mechanism of Action

Oxygen Physiology

Air Force physiology research shows oxygen is used in more than 5,769 cellular processes. No wound will heal without oxygen. Since no wound will heal without oxygen, there is much greater internal and external wound healing potential when Oxygen Saturation Technology (OST) is used in a pressure vessel with oxygen mixtures appropriate for the pressure and treatment times. The pressure and timed dosage drive these higher levels of oxygen into tissues that are more dense and are also driven past blockages in the body's circulatory systems. [12]

Oxygen Saturation Effects on the Krebs Cycle

ATP is the unit of energy produced by the human body by the mitochondria. As oxygen enters cells that have experienced oxygen debt, and which may not have restarted their aerobic (with oxygen) Krebs Cycle after a brain insult, the anaerobic (without oxygen) (Ketone) glycolysis cycle, which makes 2 molecules of ATP for every 1 molecule of glucose input, ceases and the mitochondria begin making the normal 36 ATP per molecule of glucose input. The sudden burst of energy restarts normal cellular metabolic processes. This accounts for the fact that we see a 50% increase in brain blood flow and metabolism at 40 hyperbaric treatments, using imaging with contrast that is able to measure metabolism. (SPECT and 3T Functional MRI, with contrast, are able to measure these changes). [13, 14]

Oxygen Saturation Therapy Pulse Dosing

Further, the pulsed dosing of the treatments creates an on and off cycle that stimulate tissue revascularization. The intermittent signals requesting oxygen as the oxygen dose diminishes in these injured tissues allows the body to know which tissues have achieved sufficient oxygen vs those which still lack an oxygen supply. These known metabolic and vascular changes demonstrate why all of the testing and evaluation instruments used to determine neurological function show improvement in virtually every measure, from memory processing speed to reaction speed to executive function. Ketone body metabolism uses fat as the fuel instead of oxygen. Brain death is determined by the fact that the body has stopped requesting oxygen. [15, 16]

Oxygen Mechanisms of Action

The result of ending oxygen debt and reestablishing normal oxygen availability to these cells is the activation of 8,101 genes, many of which are directly involved with inflammation, wound healing and revascularization. In addition, the patient's own stem cells are activated up to 8 times the normal rate, thus supplying fresh cells to fill gaps where cellular death can be reversed. Thus, these healing processes that have been recorded scientifically explain the results that have been seen in the clinical setting for as long as pressure vessels have been used to treat humans, which is about 300 years! It is time to deploy 300 years of scientific discoveries. In few therapies do we have as much understanding of the mechanism of action as we do with Oxygen Saturation using pressure vessels. [17-20]

One of the challenges of hyperbaric medicine is that we had to invent both molecular biology and biophysics and map the human genome before we could explain the mechanisms of action of Hyperbaric Oxygen. These scientific disciplines are now mature and the mechanisms of action of Oxygen Saturation are some of the most studied of any therapy.

Oxygen Plasma Saturation

With all of the different methods of measuring pressure (ata, psig and mmhg), it is helpful to look at a single standard. Oxygen saturation does not significantly increase red blood cell function. Once fully saturated, the red blood cells cannot accept more oxygen. Instead, with Oxygen Saturation, the oxygen bypasses the red blood cells, as shown in the 1959 Dutch study by Boerema, “Life without Blood.” The pigs used in the study survived after all of their red blood cells had been removed, living purely on the oxygen saturated in their plasma and other body fluids. Bypassing the red blood cell respiration process and saturating the plasma with oxygen with increased pressure forces oxygen into many areas of the body that are normally deficient in oxygen. Thus, the clinical reports on spinal cord injury recovery, both acutely and after some time has passed, make sense. Sufficient oxygen prevents scar tissue formation (which is why this treatment is also used extensively by plastic surgeons.) The plasma, and all of the liquids in the body, even those which have a distinctly different circulation system, such as the lymphatic system and the cerebrospinal fluid, become saturated with oxygen in similar percentages as the plasma. [21]

So, what difference does the pressure make? Starting at sea level, by adding pressure and oxygen purity, the oxygen saturation into the plasma is:

Medical Oxygen at 1 ata (0 psig) inhaled through a mask or cannula results in about 5% dissolved oxygen on blood plasma. Oxygen at room pressure does have a therapeutic effect, but not nearly as great as hyperbaric oxygen therapy.

- HBAT 1.3ata: Hyperbaric Air Therapy is FDA-approved for mountain sickness, resulting in about 50% increase in plasma oxygen. Consider that the US military and NIH and private research went to great lengths to find treatments that would increase oxygen by just 25% in wounded individuals, the 50% increase already available to military medicine, but not utilized, demonstrates a loss of recovery with equipment already in use. Military medicine encouraged the development of a fluorocarbon IV solution, which fortunately carried 25% more oxygen than human plasma, but when used, destroyed red blood cells in human patients. Hyperbaric oxygen therapy would have mitigated this unfortunate side effect, and potentially would have made the IV solution more viable.

> "The Gamow Bag was field tested on Mount Everest during the 1988 Wyoming Centennial Everest Expedition (WCEE). We report six cases of acute mountain sickness which were managed in part with the Gamow Bag. All of the patients presented with dyspnea, weakness, and headache…After treatment, three of the patients had complete resolution of their symptoms and later ascended to or above the altitude where they first became ill. The other three patients were able to continue descent without incident." [22]

- HBOT 1.3 ata was reported by RAND Corporation. The SOCOM teams at high altitude in Afghanistan all had 1.3 ata capable chambers. SOCOM did NOT have air compressors at high altitude, but they had unlimited supplies of oxygen. The service members used Oxygen cylinders, taking appropriate precautions, to inflate their 1.3 ata chambers. The result was their mountain sickness was immediately resolved, and they were able to continue the mission instead of following the normal air protocol, which required them to recuperate at lower altitudes for a week.
- HBOT 1.5 or 1.55 ata: 700% or 7x more oxygen in plasma at sea level
- HBOT 2.4: 1200% or 12x more oxygen than normal. The brain negatively responds to these higher pressures, and vasoconstriction prevents this much oxygen getting to the brain.

The Holbach-Wasserman research in the 1970's demonstrated the following results related to the amount of oxygen saturating the brain:

- HBOT 1.5: maximum oxygen saturation in the brain. Maximized glucose metabolism
- HBOT 2.0. Same amount of oxygen as at normobaric pressure, glucose metabolism not at maximum rate
- HBOT 2.4. Less oxygen in the brain, less glucose metabolism than the other two methods. This lowered oxygen level is what makes patients prone to induced seizures. Seizures are now known to be caused by decreased oxygen in a section of the brain which causes it to, "short out."

Idling Neurons

One of the more recent findings in medicine is that cells become dormant before they die. This turns out to be true in virtually every organ system. Idling heart cells, lung cells, liver cells, and kidney cells have all been found to exist. The concept of "Idling Neurons" by Neubauer was published by The Lancet in 1990, followed by "Enhancing Idling Neurons," also published in The Lancet. These cells that are idling have been stunned as the result of oxygen deprivation or toxic overload. These cells can remain stunned for decades. Hyperbaric oxygen therapy almost instantly resolves the oxygen debt issues and causes those cells to recover and begin to function normally. [23-26]

Reperfusion Injury

The reperfusion injury cascade is caused when an area is deprived of oxygen, developing Oxygen Debt, and then oxygen is permitted to go back into those tissues. This swelling process occurs 100% of the time in these tissues when there is a hypoxic event, and explains the phenomenon of pump head, which is highly significant, occurring in about 40% of all heart interventions where the heart-lung machine is used. This reperfusion reaction is suppressed on a 24-hour exponential curve. Thus, pretreating surgery patients with HBOT results in much less swelling and scarring, including bruising caused by patient position manipulation during surgery. HBOT pretreatment is also effective for SOCOM personnel, athletes, MMA fighters, and for other first responders who can be expected to experience bruising in upcoming events. An HBOT pretreatment before the known event is shown to improve both outcomes, critical performance, and decision making. [27]

Oxygen Debt

Oxygen Debt is altered cellular processes and potential damage that occurs as a result of a lack of oxygen in given tissues. The Van Meter research on resuscitation demonstrates that Oxygen Debt relief occurs on a known time table:

> "The study, published in the August issue of Resuscitation, tested the theory that high-dose hyperbaric oxygen therapy would increase the window of survival and improve the return of sustained spontaneous circulation in test subjects, compared with normobaric oxygen or standard-dose hyperbaric oxygen following cardiopulmonary arrest. Previous studies showed no evidence that porcine or human subjects could be resuscitated beyond a 15-min window following cardiac arrest. The researchers found however that they were able to successfully resuscitate a group of laboratory swine using high doses of hyperbaric oxygen, 25 min after cardiac arrest. Current statistics of the American Heart Association, however, show that a patient's heart must be restarted within 16 min or a patient will die without any exception.
>
> Lead author of the study, Keith Van Meter stated that, "To resuscitate any living organism after 25 min of heart stoppage at room temperature has never been reported and suggests that the time to successful resuscitation in humans may be extended beyond the stubborn figure of 16 min that has stood for 50 years."

> The study involved 18 male laboratory pigs, in whom researchers induced cardiac arrest, sustaining them in normothermic conditions for 25 mins without any form of cardiac intervention such as resuscitation, artificial breathing support or drug therapy. The subjects were then randomly separated into three groups, each comprising six animals: One group receiving normobaric oxygen, the second group standard-dose hyperbaric oxygen and the third group receiving high-dose hyperbaric oxygen. All animals were then subsequently placed on an advanced cardiac life support (ACLS) system for 2 h periods in an attempt to resuscitate them. The results were highly significant: none of the animals from the first two groups survived, however four out of six subjects in the high-dose hyperbaric oxygen group were successfully resuscitated.
>
> “The present study shows that short-term high-dose hyperbaric oxygen is an effective resuscitation tool and is safe in a small multiplace hyperbaric chamber,” states Van Meter. “A rehearsed team can easily load a patient in cardiopulmonary arrest into a small multiplace chamber in the prehospital or hospital setting without interrupting CPR or advanced cardiac life support. Successful resuscitation at 25 mins suggests that if high-dose hyperbaric oxygen is used at the current ACLS limit of 16 mins, a greater survival may be achieved in humans and allow application of more definitive treatment, such as clot-dissolving drugs.”
>
> This study thus offers the possibility of developing a hyperbaric resuscitation system that could potentially be used in a widespread clinical setting. [9]

Normobaric (room level and room pressure) oxygen takes 71.3 minutes to resolve Oxygen Debt (when circulation or other processes like reperfusion injury or the glutamate cascade does not interfere in oxygen debt resolution). Standard HBOT pressures (1.5 to 2.4 ata) resolve Oxygen Debt in 12.8 minutes and High Dose HBOT (4.0 ata) resolves Oxygen Debt in 5.2 minutes. Keep in mind the study subjects in the Van Meter research had experienced cardiac arrest for 20 minutes, so the normal blood brain barrier restrictions were not functioning.

The longer periods of oxygen debt can result in cellular death or idling cells in numerous organs in the body, including idling neuron. [28] [29]

The Gas Laws

It is important to acknowledge that Hyperbaric Medicine and Aerospace Medicine are governed by the laws of physics. Unfortunately, only a few medical professionals employ physics as part of their medical practice. Anesthesiologists and Radiologists are classic examples. They readily understand hyperbaric medicine, but they do not have, as a rule, individual patients. So, what we have been discussing is grounded in physics.

The following is from: https://byjus.com/jee/gas-laws/ [Yes, it is British English.]

The gas laws are a group of laws that govern the behaviour of gases by providing relationships between the following:

- The volume occupied by a gas.
- The pressure exerted by a gas on the walls of its container.
- The absolute temperature of the gas.
- The amount of gaseous substance (or) the number of moles of gas.

The gas laws were developed towards the end of the 18th century by numerous scientists (after whom, the individual laws are named). The five gas laws are:

- Boyle's Law, which provides a relationship between the pressure and the volume of a gas.
- Charles's Law, which provides a relationship between the volume occupied by a gas and the absolute temperature.
- Gay-Lussac's Law, which provides a relationship between the pressure exerted by a gas on the walls of its container and the absolute temperature associated with the gas.
- Avogadro's Law, which provides a relationship between the volume occupied by a gas and the amount of gaseous substance.
- The Combined Gas Law (or the Ideal Gas Law), which can be obtained by combining the four laws listed above.

Under standard conditions, all gasses exhibit similar behaviour. The variations in their behaviours arise when the physical parameters associated with the gas (such as temperature, pressure, and volume) are altered. The gas laws basically describe the behaviour of gases and have been named after the scientists who discovered them. [30]

Bibliography:

1. Kot, J., Z. Sicko, and T. Doboszynski, *The Extended Oxygen Window Concept for Programming Saturation Decompressions Using Air and Nitrox*. PLoS One, 2015. **10**(6): p. e0130835.
2. Boussi-Gross, R., et al., *Hyperbaric oxygen therapy can improve post concussion syndrome years after mild traumatic brain injury - randomized prospective trial*. PLoS One, 2013. **8**(11): p. e79995.

3. Harch, P.G., *Medicine that overlooks the evidence.* Arch Phys Med Rehabil, 2006. **87**(4): p. 592-3; author reply 593.
4. Harch, P.G., *Paul G. Harch, MD: the genetically modulated healing effects of hyperbaric oxygen therapy.* Altern Ther Health Med, 2015. **21**(1): p. 46-55.
5. Harch, P.G., et al., *A phase I study of low-pressure hyperbaric oxygen therapy for blast-induced post-concussion syndrome and post-traumatic stress disorder.* J Neurotrauma, 2012. **29**(1): p. 168-85.
6. Harch, P.G., et al., *Hyperbaric oxygen therapy for mild traumatic brain injury persistent postconcussion syndrome: a randomized controlled trial.* Med Gas Res, 2020. **10**(1): p. 8-20.
7. Holbach, K.H., A. Caroli, and H. Wassmann, *Cerebral energy metabolism in patients with brain lesions of normo- and hyperbaric oxygen pressures.* J Neurol, 1977. **217**(1): p. 17-30.
8. Kraitsy, K., et al., *Repetitive long-term hyperbaric oxygen treatment (HBOT) administered after experimental traumatic brain injury in rats induces significant remyelination and a recovery of sensorimotor function.* PLoS One, 2014. **9**(5): p. e97750.
9. Van Meter, K., et al., *Hyperbaric oxygen improves rate of return of spontaneous circulation after prolonged normothermic porcine cardiopulmonary arrest.* Resuscitation, 2008. **78**(2): p. 200-14.
10. Yogaratnam, J.Z., et al., *Hyperbaric oxygen preconditioning improves myocardial function, reduces length of intensive care stay, and limits complications post coronary artery bypass graft surgery.* Cardiovasc Revasc Med, 2010. **11**(1): p. 8-19.
11. Shalaby, M. and S. Eltarabily, *The Effect Of Sport Diving On Stem Cells CD34+ And Complete Blood Picture.* The Swedish Journal of Scientific Research, 2015. **2**: p. 45.
12. Rink, C., et al., *Oxygen-sensitive outcomes and gene expression in acute ischemic stroke.* J Cereb Blood Flow Metab, 2010. **30**(7): p. 1275-87.
13. Fuller, G.G. and J.K. Kim, *Compartmentalization and metabolic regulation of glycolysis.* J Cell Sci, 2021. **134**(20).
14. Judge, A. and M.S. Dodd, *Metabolism.* Essays Biochem, 2020. **64**(4): p. 607-647.
15. Shytle, R.D., et al., *Retrospective Case Series of Traumatic Brain Injury and Post-Traumatic Stress Disorder Treated with Hyperbaric Oxygen Therapy.* Cell Transplant, 2019. **28**(7): p. 885-892.
16. Chen, J.Z., et al., *Comparison of pulsed versus continuous oxygen delivery using realistic adult nasal airway replicas.* Int J Chron Obstruct Pulmon Dis, 2017. **12**: p. 2559-2571.
17. Godman, C.A., et al., *Hyperbaric oxygen induces a cytoprotective and angiogenic response in human microvascular endothelial cells.* Cell Stress Chaperones, 2010. **15**(4): p. 431-42.
18. Harch, P.G., *Hyperbaric oxygen in chronic traumatic brain injury: oxygen, pressure, and gene therapy.* Med Gas Res, 2015. **5**: p. 9.
19. Peña-Villalobos, I., et al., *Hyperbaric Oxygen Increases Stem Cell Proliferation, Angiogenesis and Wound-Healing Ability of WJ-MSCs in Diabetic Mice.* Front Physiol, 2018. **9**: p. 995.
20. Fosen, K.M. and S.R. Thom, *Hyperbaric oxygen, vasculogenic stem cells, and wound healing.* Antioxid Redox Signal, 2014. **21**(11): p. 1634-47.
21. Jones, M.W., et al., *Hyperbaric Physics*, in *StatPearls*. 2022, StatPearls Publishing Copyright © 2022, StatPearls Publishing LLC.: Treasure Island (FL).
22. King, S.J. and R.R. Greenlee, *Successful use of the Gamow Hyperbaric Bag in the treatment of altitude illness at Mount Everest.* Journal of Wilderness Medicine, 1990. **1**(3): p. 193-202.
23. James, P.B., *Hyperbaric oxygenation for cerebral palsy.* The Lancet, 2001. **357**(9273): p. 2052-2053.
24. Neubauer, R.A., S.F. Gottlieb, and A. Miale, *Identification of hypometabolic areas in the brain using brain imaging and hyperbaric oxygen.* Clinical nuclear medicine, 1992. **17**(6): p. 477-481.

25. Neubauer, R.A., *Idling neurons.* Lancet, 1990. **335**(8699): p. 1217.
26. Neubauer, R.A., S.F. Gottlieb, and R.L. Kagan, *Enhancing "idling" neurons.* Lancet, 1990. **335**(8688): p. 542.
27. Hallenbeck, J.M. and A.J. Dutka, *Background Review and Current Concepts of Reperfusion Injury.* Archives of Neurology, 1990. **47**(11): p. 1245-1254.
28. Holbach, K.H., A. Caroli, and H. Wassmann, *Cerebral energy metabolism in patients with brain lesions at normo- and hyperbaric oxygen pressures.* Journal of Neurology, 1977. **217**(1): p. 17-30.
29. Van Meter, Keith et.al., Hyperbaric oxygen improves rate of return of spontaneous circulation after prolonged normothermic porcine cardiopulmonary arrest, Resuscitation, (2008) 78, 200-214

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The TOR Institute	IHMF Research Center	ANDI International
1315 Hwy 182 E	212 Stacks Rd, Suite A	74 Woodcleft Ave
Morgan City, LA 70380	Ennis TX 75119	Freeport NY 11520
(985) 397-4692	(703) 505-7530	(516) 546-5137