Essentials of Hyperbaric Oxygen Therapy: 2019 Review

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Proper appreciation of what HBO_2 can do and has been rigorously shown to be able to do can guide clinicians to make better choices in the use and referral of patients for HBO_2 across 14 approved indications.

Hyperbaric oxygen therapy (HBO_2) continues to be an opportunity for clinicians to better manage a variety of clinical problems. This thematic issue of *Missouri Medicine* covers the major indicated uses of HBO_2 and its rationale so that clinicians can make better informed choices.

From its beginnings in combating poorly understood pathophysiologies in divers and construction workers under increased pressure environments to its more contemporary applications in wound healing and critical illnesses, hyperbaric oxygen now complements many therapies for better patient outcomes.

We herein give an overview of HBO_2, its emergent uses, common elective uses, presentations of decompression sickness that could present to a general practitioner and also how HBO_2 complements coordinated management of difficult wounds such as Diabetic Foot Ulcers with other modalities like negative pressure wound therapy (NPWT).

This issue of *Missouri Medicine* is meant to familiarize more clinicians about hyperbaric oxygen so that practices can improve.

Here are some basics about HBO_2 and then we will look at HBO_2 emergencies and then several elective uses of HBO_2.

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Clinical hyperbaric oxygen treatment is defined as placing a patient's entire body in an increased pressure environment and having that patient inspire 100% oxygen for a specific diagnosis and for a defined period of time and treatments.[1] The usual minimum acceptable pressure for clinical treatment is 1.4 atmospheres absolute or 1.4 ATA.[2] Atmospheres absolute is a scale that incorporates the total pressure being exerted upon the body regardless of where the body is, i.e. at sea-level or in a pressure chamber.[3] 1.4 ATA can be simplified to be thought of as 1.4 times the usual, environmental pressure any patient's physiology is feeling at idealized sea-level.

HBO_2 treatments are typically delivered in hyperbaric chambers that can be a single patient at one time (i.e. monoplaced Figure 1) or a room sized accommodating multiple patients at the same pressure (i.e. multi-place chambers Figure 2) With improvements in material sciences chambers have gone from mostly metal enclosed multi-place chambers to clear acrylic monoplace chambers. Monoplace chambers are lighter, smaller, easier to install and less expensive to retrofit into existing medical spaces. Additionally, clinicians should appreciate there are key differences in referring patients to HBO_2 centers that are multiplace vs those that are monoplace.

Multiplace chambers are engineered rooms that are filled with compressed air and the patients receive their therapeutic 100% oxygen by donning hoods or masks. Multiplace chambers can have a caregiver in the chamber with the patients and patients can receive hands on care during their treatment sequences. Patients may sit in chairs or lay on gurneys to receive their treatments as a group going down to a defined depth and treatment time common to them all. Monoplace chambers are usually clear acrylic tubes filled with oxygen that an individual patient lies in semi-recumbent or beach chair position and typically watches TV through the clear walls of the chamber. They are typically lighter and less expensive to retro-fit into

Figure 1: Monoplaced Chamber


Figure 2: Multiplaced Chamber

existing spaces than multiplace chambers. The entire interior of a monoplace chamber can typically be filled with 100% oxygen and patients only don a mask or hood to breathe regular air to reset their seizure thresholds or other oxygen toxicities. Monoplace chambers can now allow on-going treatments, including IV fluids or IV medications or physiologic monitoring, as they have specially engineered past through ports for tubing and wires, but typically no one else is in the chamber with the patient. Treatment times and sequences may be individualized.

Typical elective HBO_2 treatments are approximately 90 minutes and run between 2 and 3 ATA depending upon the therapeutic effects desired. Urgent and emergent treatments or other specialty applications may run longer and at greater pressures (often referred to as going deeper due to HBO_2's historical origins in diving). Typical elective treatments are administered Monday through Friday during regular clinic business hours that can vary from center to center. Nationally, for many reasons, only a small proportion of centers can offer treatments for critically ill patients or emergent indications at all hours of the day or night throughout any given week, weekend or holiday. There remains a national shortage of HBO_2 centers with this 24 x 7 capacity to treat sick patients urgently and emergently. Emergent and elective indications for HBO_2 will be covered in separate articles. In either elective or urgent circumstances, a clinician treating a patient with a HBO_2 indication in Table 1[4] should work with their available HBO_2 centers for an evaluation. Table 1 is taken from the UHMS indications list located on their website.[5] Indications for HBO_2 may be a chronic condition and the addition of adjunctive HBO_2 may be completely elective such as those with chronic refractory osteomyelitis. An organized list of the possible indications, by their urgency and pathophysiology and common contraindications for HBO_2 are in Table 1.[5] Clinicians should incorporate the needs of the patients being considered for HBO_2 as well as the capabilities of each hyperbaric facility.

It should be noted that other uses of oxygen from supplemental inhalation or regionally or topically are not meant to be variations in HBO_2 treatments. HBO_2 has specific billing codes and they are not to be generalized to cover other forms of the use of oxygen. Even some whole-body chambers for oxygen delivery, if collapsible and meant for emergency use or transport, may not be intended for routine on-going clinic HBO_2 therapy such that some payer sources may require treatments to be offered only in rigid chambers. Additionally, some states and some regions of the country have different guidelines

Table 1. Commonly Accepted Indications for Hyperbaric Oxygen Treatments

- Air or Gas Arterial or Venous Embolii
- Severe or Symptomatic Carbon Monoxide Poisoning
- Clostridial Myositis and Myonecrosis (Gas Gangrene)
- Selected Crush Injuries, Compartment Syndromes, and other Acute Traumatic Ischemias
- Decompression Sickness
- Selected Arterial Insufficiencies, including Central Retinal Artery Occlusion and the Enhancement of Healing in Selected Problem Wounds
- Severe otherwise Untreatable Anemias
- Certain Intracranial Abscesses
- Selected Progressive Refractory Necrotizing Soft Tissue Infections
- Chronic Refractory Osteomyelitis
- Delayed Radiation-Induced Injury with Bony or Soft Tissue Necrosis
- Compromised Skin Grafts and Tissue Flaps
- Acute Thermal Burn Injuries
- Idiopathic Sudden Sensorineural Hearing Loss

or standards of practice that must be adhered to for HBO_2 treatments to be offered or receive re-imbursement. This review is meant to familiarize clinicians with a broad overview of the basics for HBO_2 and not as rationales for covered treatments. Clinicians are directed to the NCD guidelines[6] for covered conditions that are able to be treated with HBO_2 in Missouri and should be working closely with their local practice compliance mechanisms for good documentation for HBO_2 practices.

At room temperature and pressure near sea-level the air that we breathe is only about 20% oxygen and near 80% nitrogen with other gases simplified to be trace amounts. This means the usual range for a PaO_2 (partial pressure of oxygen in an arterial blood gas) is 75 – 100 mm Hg. [7] If we supplement the fraction of inspired oxygen with either a nasal cannula or a face mask, PaO_2 materially increases well over 100 and can be measured in tissues with $PcTO_2$ (percutaneous transcutaneous partial pressure of oxygen).[8, 9] However, HBO_2 uses not only a high fractional level of inspired oxygen (100%), but also changes the pressure effects that govern how oxygen is both carried by hemoglobin and dissolved into the liquid phases of both blood and body fluids. At ordinary, atmospheric pressures the amount of oxygen (or other gases) that is dissolved into the plasma phase of blood is miniscule. The oxygen content of blood is commonly defined as (Hemoglobin concentration x 1.36 x SaO_2) + (0.0031 x PaO_2).[9] The corrective coefficient, 0.0031, to minimize the quantity of oxygen dissolved in blood goes away as pressure around the body increases and a significant and bio-available amount of oxygen is dissolved into the liquid phases of blood and body fluids. Appreciating that at therapeutic pressures the oxygen that is dissolved into body tissues and fluids is responsible for some of HBO_2 indications allows practitioners to better understand the basic science foundations for them.[10, 11, 12,13] For example, although the retina ordinarily is supported by its own nutrient central artery, HBO_2 offers the only viable treatment to date to help mitigate retinal ischemia. This is because of the central retinal artery flow is compromised or occluded, as HBO_2 is the only available means to get oxygen to retinal tissues through locally dissolved oxygen.[14, 15] It is also the means by which some patients with severe anemia and no capacity to receive hemoglobin transfusions can be improved.[16] It is also the means by which sudden sensorineural hearing loss, responds to HBO_2 treatment with other body fluids carrying nutrient oxygen to otherwise ischemic neural tissues.[17, 18, 19] The effects of HBO_2 go well beyond just driving more oxygen to be delivered into the tissues. The next most obvious effect to take into account is how our bodies react to being at pressure as well. Even simple face immersion in water can reproduce the "diving reflex," let alone when multiple components of the nervous and vascular systems detect a body is at a higher pressure. These include peripheral vasoconstriction, slowed heart rates and at times other rhythm changes, shunting of blood toward the central circulation, and release of stored RBCs in the spleen.[20, 21] Overall there is a shift in body tissue third space free water content back into the intravascular compartment that is then cleared by the kidneys, such that most patients often need to urinate after their HBO_2 treatment. Well-designed HBO_2 centers have their own dedicated bathrooms to accommodate this common need as patient come out of the chamber. Additionally, this shift from extravascular tissue third space to intravascular circulating volume exerts a cardiac load on the heart which needs to pump that increased mass of volume until cleared by the kidneys and this may unmask a congestive heart failure picture in at risk patients. Therefore, referred patient's histories of compromised cardiac output may need further work up, prior to HBO_2, with echocardiography to see that their cardiac function, often using the ejection fraction as a common surrogate, is sufficient for the HBO_2 treatment load.

One of the most important contra-indications to HBO_2 is also related to direct pressure effects on the patient's body: undrained pneumothoraxes, bullae or blebs. Any contained, enclosed air space anywhere, but particularly in the chest will collapse when subjected to pressure and then re-expand when the pressure is let up. This can convert simple a pneumothorax to a tension pneumothorax. Most HBO_2 centers require a recent chest radiograph to rule out any pneumothorax. If a patient has bullous disease or blebs or other at-risk conditions like emphysema or COPD, then they should be screened with first a CXR and then with further imaging such as CT scanning to better quantify and manage the severity of their disease.

Referring clinicians should also appreciate that during a HBO_2 treatment typically a patient's blood sugar is lowered. This lower blood sugar is also synergistic to lower an individual's seizure threshold while breathing oxygen at pressure. Interrupting the continuous exposure to oxygen for 5-10 minutes at regular intervals will reset their likelihood of a seizure without having to take them out of their pressurized environment. Multi-place chamber patients reset with air breaks by removing their oxygen treatment hoods or masks. All HBO_2 programs should screen for seizure risks, especially in a diabetic patient and those on anti-seizure medications.

To properly screen and manage patients at risk as well as to properly recommend and apply HBO_2 where indicated, several training paradigms exist for clinicians to use HBO_2 well. Current training pathways might begin with immersion CME mini-courses. At a minimum, clinicians should have the beginning baseline standard of a 40-hour accredited training course to supervise straight forward uses of HBO_2. Those interested in a broader range of HBO_2 applications complete a dedicated one-year fellowship in HBO_2 and Undersea Medicine and with a written board certification. Even shy of full board certification there are now several on-line programs, (i.e. the UHMS PATH program) that have high quality CME for physicians to more properly incorporate HBO_2 into their practices.

In conclusion, HBO_2 offers many opportunities to improve specific patient problems across a spectrum of fascinating basic science and clinical evidence. Clinicians should be aware of these included HBO_2's indications as a starting point for how to best incorporate HBO_2 into their practices; and what might be available for patients in sometimes very difficult clinical circumstances. Oxygen, when viewed as a drug, is similar to many drugs that have varied indications with varying levels of evidence for its use. HBO_2 treatments, like all medical treatments, are an added expense and although can be offered in a safe environment still have side effects and potential risks. Individual clinicians and patients are encouraged to look at HBO_2 like other clinical recommendations with a risk-benefit analysis grounded in the best available evidence to choose the best available treatment options to optimize clinical outcomes across the spectrum of indications in Table 1.

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Disclosure

None reported.

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