Hyperbaric Oxygen Therapy Emergencies

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Each individual patient must be weighed to see that the additional value of HBO_2 is a good match to improve that patient's long-term outcome.

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Abstract

Emergent indications for HBO_2 are not only for some of the most serious conditions, but also may be the only modality to directly target the patient's pathophysiology. They are to begin emergently or urgently, but may be limited by either the instability of the patient's condition or transfer logistics. Often these emergent treatments involve several treatments in the first 24 hours for best outcomes. If one considers the effects of HBO_2 upon the body while breathing 100% oxygen at pressure many benefits become evident. This article will concisely review hyperbaric oxygen's emergent indications.

Introduction: DCS and AGE

Decompression Sickness (DCS) in Table 1 is one of the most historically well studied indications for HBO_2. We would no longer be ethically able to run a research study on the benefits of HBO_2 with a control arm that didn't have some recompression as it is memorialized as a standard of care for severe DCS.[1, 2, 3, 4] Should a patient have a history of being subjected to being at increased pressure and come out of that pressurized environment with complaints, then DCS should be in the patient's differential diagnosis and HBO_2 offered. The Diver's Alert Network maintain a 24-hour call center should such a DCS event occur: 1-919-684-9111[5]. When identified, oxygen and supportive care should begin and as soon as possible HBO_2 at an appropriate recompression pressure and therapy duration sequence that can be worked out with both local EMS and diving medicine consultations. Treatment can begin with the "4 R's" (Recognize symptoms, Respond with Oxygen, Relay with EMS/DAN, Recompress early).[6] Although major decompression sickness events are easier to identify with antecedent diving as well as classic signs of DCS of joint pain and frank neurological impairment, occasionally sport and amateur divers can have variants that get missed. DCS can occur even with shallow depths of 20 feet and even in certain circumstances in less than 1 meter of water.[7, 8] Treating for decompression sickness can involve longer treatment sequences at higher pressures and therefore deserves coordination with organizations like DAN or with physicians with training in diving medicine.

The most severe examples of DCS are actually where bubbles form in the tissues and vasculature—essentially becoming arterial or venous gas emboli. Although this is very unusual outside of extreme pressure events like submariners escaping from a sinking submarine, in the modern era it happens with medical instrumentations as air gas embolii. Counterintuitively, bubbles forming in tubes meant to have liquid flow through them do not just float along, but obstruct that flow of liquid. In

the body, traumatically rub up against the endothelium causing inflammatory cascade activation.[9,10] A wide variety of exposures can result in arterial or venous gas embolii from head up surgical procedures, exposures of vessels or the lung, cannulations during cardiopulmonary bypass or extracorporeal oxygenation or even during hemodialysis or central line manipulations, endoscopy insufflations — all can inadvertently introduce air into the circulatory system.[11] On top of that, there are patients who have an occult communication between the right and left heart or the arterial and venous systems, and these patients are even more susceptible to arterial or gas emboli causing stroke-like presentations. Patients who may have an occult but still potential mechanism to introduce gas into their vascular system who have stroke like changes in mental status, focal neurological deficits, cardiac arrhythmias than can progress to arrest, tachypnea, hypotension, hypocapnia or pulmonary edema should have a presumptive diagnosis of an air gas embolism entertained[12] Demonstrating the actual gas emboli by imaging even in the face of severe neurological symptoms is not recommended as time consuming and can be falsely negative[13,14] and the diagnosis should be suspected with both the mechanism and exam findings. These patients can have waxing and waning symptoms that can lead clinicians astray.[15] Emergent hyperbaric treatment can be difficult as the patients may have instabilities that preclude any safe transfer and also the numbers of centers that can offer critically ill, intubated patients are themselves limited in the US. Depending upon the nature of the DCS or gas embolism, patients may need to be screened later for other problems like endocardial cushion defects or patent intra-cardiac shunts with an echocardiogram. But like DCS, gas embolism when it occurs should be considered for emergent HBO_2 to achieve the best outcomes.

Emergent Uses from Appreciating Distal Flow and Ischemia Problems

The paradigm of obstructed flow and ischemia to distal tissue beds also explains several other emergent and urgent HBO_2 treatment indications. Acute arterial insufficiencies, traumatic ischemic injuries, and crushes, compartment syndromes all interrupt the usual nutrient, perfusing and oxygenating flow to distal tissue beds. Here is where HBO_2 might have a very important adjunctive effect upon tissues ability to survive and heal. This can be visualized also where a central zone of a thermal burn might be unrecoverable but the surrounding tissue zones with partial injuries are struggling with poor flow, edema, poor oxygenation and excessive inflammatory responses. For this group of emergent indications HBO_2 supports the distal tissues with some level of oxygenation support and also improves collateral flow through effects like edema control and overly harmful inflammatory effects.[16, 17] However, HBO_2 should be coordinated with overall resuscitation and critical care goals, formal vascular restoration of flow where indicated, compartment releases and debridement that make delivery and any subsequent analysis of HBO_2 difficult to do well.

HBO_2 effects also are dependent upon the tissue beds being injured, too. It may be that the difficulties in really proving the value of HBO_2 lies in that some tissue beds are more resilient oxygenating flow problems. As opposed to larger tissue beds it HBO_2 may be effective in smaller, focal applications. For example, central retinal artery occlusion (CRAO) is fortunately not very common, but is very illustrative of some of the best effects of emergent HBO_2 as really the only way to directly supply nutrient oxygen to tissues.[18, 19] The retinal tissues are highly sensitive and need adequate oxygen to maintain their functionality. HBO_2 allows some direct diffusion of oxygen to those otherwise ischemic retinal tissues and buys time for the central retinal artery to recanalize.[20, 21] Furthermore CRAO is a model to consider that HBO_2 may also have its maximal benefit where it impacts upon a relatively small tissue bed, but one where every margin amount of tissue lost has major functional effects upon the visual acuity long term. Like DCS and AGE, these emergent indications need multiple treatments in the first 24 hours and then these treatments can be more spaced out over the subsequent days for full effect. Should a patient present with sudden changes of vision they should undergo a neurological evaluation as well as considering the possibility of CRAO and HBO_2 be offered in coordination in concert with ophthalmology for proper patient selection and on-going therapies such as beginning ambient pressure oxygenation, looking at other contravening factors such as intra-ocular pressures, other pro-occlusion inflammatory conditions like arteritis, capturing the degrees of vision loss and instituting HBO_2 emergently and within 24 hours of symptoms.[22] However, unlike other classes of potential HBO_2 emergent patients, patients with CRAO may be hemodynamically stable and even meet the capabilities of HBO_2 centers that otherwise do not treat critically ill or unstable patients.

The emergent applications of HBO_2 share other common paradigm themes. First it may partly explain the value of HBO_2 in other applications where preservation and healing of small tissue beds may make a big functional outcome difference for patients, such as for CRAO. This may partly explain its value in well selected DM foot

Table 1. HBO_2 Emergent and Urgent Indications[5]
Note some of these extend across a spectrum from emergent to urgent to more elective application.

- Arterial or venous gas emboli
- Decompression illness
- Acute Arterial Insufficiencies such as Central Retinal Arterial Occlusion
- Gas gangrene, clostridial soft tissue infections, other myonecroses and necrotizing skin and soft tissue infections
- Crush injuries, compartment syndromes and other acute traumatic ischemias
- Intracranial abscesses
- Severe anemias
- Flaps and grafts that are failing
- Thermal burns
- Idiopathic sudden sensorineural hearing losses HBO_2 most effective if offered early
- CO and CN poisoning

ulceration patients and in those with intracranial abscesses or even for tissue flaps or localized tissue injury beds. Second, emergent HBO_2 can now be appreciated in how it might salvage that distal tissue bed struggling to remain viable.[23, 24, 25] It will deliver nutrient oxygen where perfusing flow might be less than normal in traumatic ischemias and compartment syndromes[26] and even in thermal burns.[27] This is also the mechanism of action for grafts and flaps where transplanted tissues may be struggling to re-grow their vascular based foundations to survive. As in the other indications, patients with grafts and flaps that are becoming compromised still need to be assessed for other causative factors, but HBO_2 may be an additional tool to help salvage tissue.[28] Finally, CRAO where oxygen is diffused through non-blood flow media like intra-ocular choroidal fluid illustrates how non hemoglobin tissue fluids begin to carry nutrient oxygen at pressure, which is also the mechanism for HBO_2 newest approved indication: Idiopathic Sudden Sensorineural Hearing Loss (ISSNHL). Here oxygen is dissolved into the lymphatics to support the neural functioning of the inner ear in ISSNHL[29] Like CRAO, ISSNHL has few other clinical options and highlights HBO_2 as really the only way to support the nerve tissues of the inner ear in a way that has improved outcomes.[30]

Emergent Indications that Further Capitalize Upon Dissolved Oxygen

Diffusing nutrient oxygen through various fluids explains not only the emergent beneficial effects for CRAO and for SSNHL, but also highlights the effects of HBO_2 for carbon monoxide poisoning and in severe anemias. In both of these indications it is the dissolution of oxygen at pressure that becomes beneficial. HBO_2 also more effectively displaces CO and CN molecules from occupying hemoglobin sites in a shorter time frame. Data continues to accumulate that in certain circumstances, myocardial ischemia or in pregnancy hyperbaric oxygen may have advantages over simple supplemental oxygen for better longer-term outcomes.[31,32]

High Oxygen Tensions May Also Assist in Bacterial Clearances

The last emergent effect grouping emergent indications for HBO_2 highlights another mechanism of action of high-tension oxygen: that it can be directly toxic to certain microorgansims. Gas Gangrene, Clostridial soft tissue infections or other necrotizing skin and soft tissue infections and even some intracranial abscesses are also emergent or urgent indications with a time dependent component if HBO_2 is have its fullest impact.[33] HBO_2 is directly toxic to many of the causative organisms.[34] High tension oxygen environments are often directly toxic to these organisms, inhibit their growth or cause them to down shift into more latent forms and decrease some of their most clinically harmful toxin elaboration. If available, HBO_2 should be considered along with the clinical priorities of earlier diagnoses, immediate aggressive surgical debridement and IV antibiotics along with critical care resuscitation goal directed therapy. The pathophysiologies are often dependent upon the actual organisms causing the necrosis—but share common features of worsening local tissue loss and systemic toxicities that need critical care resuscitation, surgery and antibiotics as first line therapies. Early incorporation of HBO_2 with several treatments in the first 24 hours are recommended to get hyperbaric's full effects. Intracranial abscesses can also be a subset of necrotizing infections, albeit often out of sight in the brain and its closely associated soft tissues, and often with organisms, including fungal pathogens, that feel the effects of higher oxygen concentrations directly.[35] Unlike many soft tissue infections, surgical extirpation of the source abscess may be technically very difficult or morbid. Combining surgery or other drainage maneuvers, antibiotics, neurological and overall critical care support with timely HBO_2 can offer the patient the best possible outcome for infections that may otherwise be resistant to eradication.[36]

All of these emergent or urgent indications are time dependent if they are to be maximally beneficial. HBO_2

should be immediately instituted as soon as feasible for any severe decompressions sickness or gas emboli based upon the patient's history and physical exam. Once distal ischemia of either soft tissues or neuronal tissue reach necrosis this cannot be reversed. Each of these emergent diagnoses need to be suspected based upon the patient's presenting history and physical, some have criteria that need to be established often in concert with other specialties—but all share the common theme of early, emergent if not urgent institution of HBO_2 if it to be maximally beneficial. Often these indications need quick cyclining of HBO_2 with two to three treatments to be given in the first 24 hours of appreciating the HBO_2 indication diagnosis and screening for safety and appropriateness. Hyperbaric oxygen can also be used in infectious emergencies: skin and soft tissue infections, clostridial myonecrosis, and brain abscesses. Often physicians are seeking to decrease mortalities, but it may be more beneficial to consider that hyperbaric's use limits tissue losses for better outcomes. Emergent or urgent HBO_2 remains a challenge for all in terms of picking out appropriate patients, logistically arranging their care for early and repeated HBO_2 sequences as well as simultaneously meeting all the other care needs of the critically ill. Each individual patient must be weighed to see that the additional value of HBO_2 is a good match to improve that patient's long-term outcome.

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Disclosure

None reported. **MM**