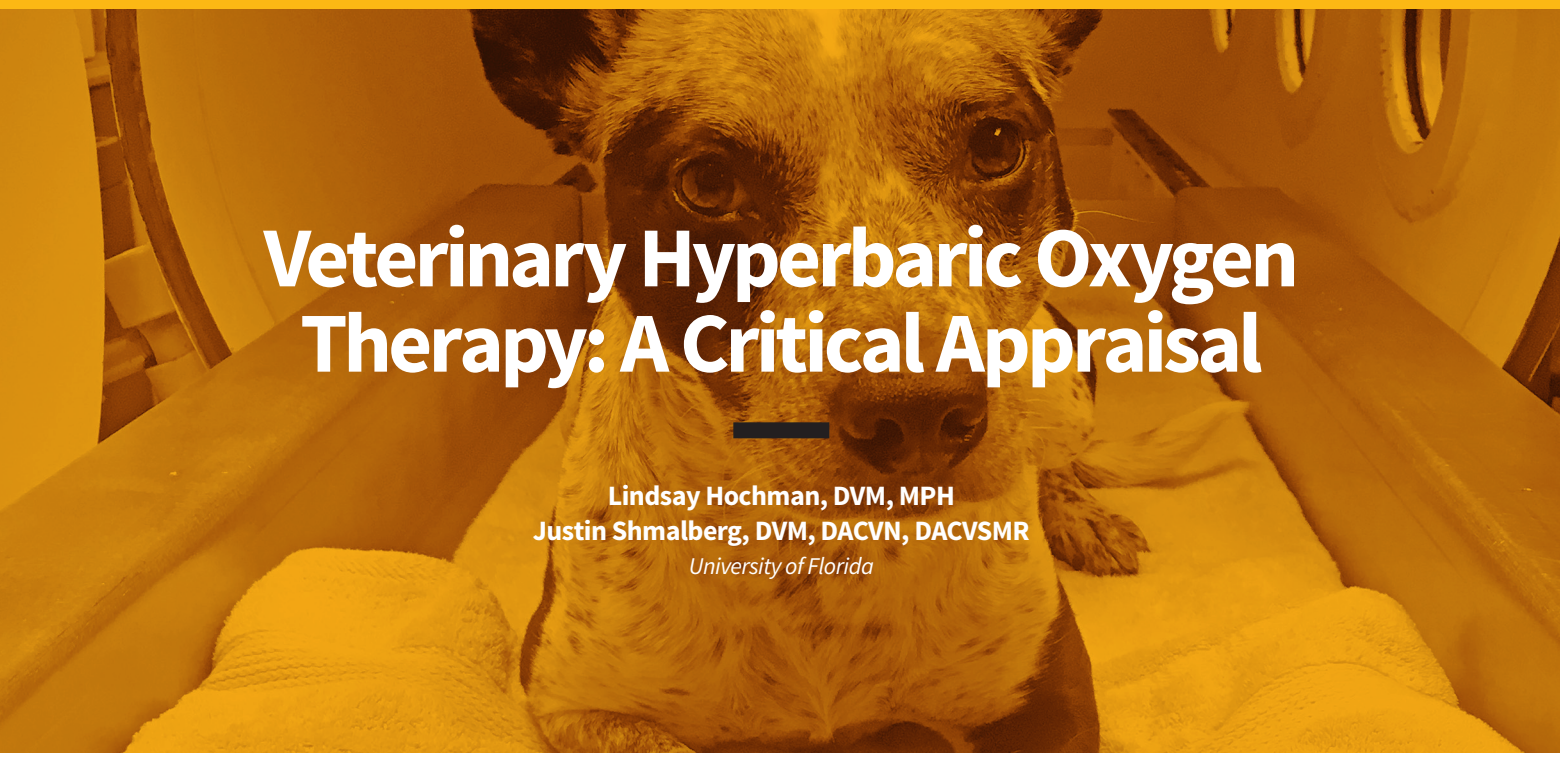

Veterinary Hyperbaric Oxygen Therapy: A Critical Appraisal

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ISSUE

HYPERBARIC OXYGEN THERAPY (HBOT) IS A COMPARATIVELY NOVEL TREATMENT IN VETERINARY MEDICINE AND ONE THAT HAS GENERATED BOTH INTEREST AND CONTROVERSY.

- HBOT is equivalent to drug administration, albeit in the form of pure oxygen.
- Although there are associated adverse events and risks, there is also potential for clinical utility.
- Rapidly increasing use of HBOT in general and specialty veterinary practices worldwide warrants critical appraisal of the history of the modality; its therapeutic principles, safety, and efficacy; and its application in treating specific diseases.

ANSWER

HISTORY

HBOT is most notably related to diving medicine and decompression sickness in humans.[1] No published history of veterinary HBOT is available; however, based on the available human data, several specialty practices began employing the modality 2 decades ago using hyperbaric chambers intended for use in humans. The recent appearance of veterinary-specific chambers and more publicized cases has prompted increased use,[2] with dozens of chambers now positioned in veterinary facilities across the United States, including University of Florida and University of Tennessee. In addition, CE topics on HBOT use have been featured at major veterinary conferences.

PRINCIPLES & PHYSIOLOGY

HBOT increases the dissolved plasma oxygen content according to 3 main laws that describe the behavior of gases when exposed to alterations in pressure: Henry's, Fick's, and Boyle's (see **Laws of Gas Behavior**, next page).[3] Understanding these principles is crucial to comprehending not only HBOT's mechanism of action but also its potential indications and contraindications.

HBOT = hyperbaric oxygen therapy

LAWS OF GAS BEHAVIOR[3]

- **Henry's Law:** The solubility of a gas is proportional to its pressure when in equilibrium with a liquid (ie, solubility coefficient).
- **Fick's Law:** The diffusion of a gas is proportional to the gas concentration gradient or difference in partial pressures of a gas across the tissue.
- **Boyle's Law:** With increasing pressure, the volume of a gas decreases proportionally.

In relation to HBOT, Henry's Law establishes that the higher the treatment pressure, the greater the amount of dissolved oxygen in the blood. Fick's Law explains the therapeutic potential of HBOT in chronic, nonhealing, and hypoxic wounds, as oxygen diffuses farther into tissues after leaving the capillaries and entering the interstitial fluid—fluid that would otherwise be oxygen deprived secondary to vascular compromise or local inflammation. Boyle's Law establishes that gas increases in volume in a fixed cavity if not allowed to exit and does so proportionally to the decrease in pressure, thus risking barotrauma in patients receiving a decompression protocol too rapidly.

Diffusion of oxygen into plasma, interstitial fluid, cytoplasm, and mitochondria is limited by the oxygen diffusion gradient, hemoglobin saturation, and amount of hemoglobin. Hemoglobin saturation is more than 97%, with typical oxygen concentrations (21%) at sea level (1 atmosphere absolute [ATA]); therefore, any additional hemoglobin saturation exerts minimal effect.[4] However, freely dissolved plasma oxygen is significantly increased when inhaled oxygen is increased through delivery of pure oxygen and/or pressurization of inhalant gases.[3] A commonly achieved treatment pressure of 100% oxygen at 2 ATA results in a 10-fold increase in plasma oxygen content over breathing air at sea level.[5]

The physiologic effects of HBOT have been well studied in humans and in laboratory animals. Observed changes include increased cellular energy (ie, via adenosine triphosphate) production via the presence of additional oxygen for phosphorylation, which is a limiting factor in the normal cellular environment.[6] In addition, short-term sublethal oxidative stress produced by free oxygen species can result in a compensatory increase in production of endogenous intracellular antioxidants (eg, glutathione). HBOT induces vasoconstriction of arterioles and venules during hyperbaric sessions to reduce tissue and vasogenic edema while supplying adequate oxygen. HBOT also modulates the vasodilator nitric oxide following treatment.[7] Secondary effects include anti-inflammatory, antimicrobial, and immunomodulatory, as well as angiogenic, effects.[3,8]

ATA = atmosphere absolute
HBOT = hyperbaric oxygen therapy

Treatment Overview

There is a paucity of data about use of HBOT in veterinary medicine, and no randomized, controlled clinical trials for any condition have been published. Thus, veterinarians must rely on the comparatively more robust human literature.[9,10] Documented efficacy is strongest for carbon monoxide (CO) toxicity and decompression sickness.[11-13] These are uncommonly encountered in veterinary medicine, but if a patient were presented with CO toxicity, HBOT might be effective in reducing CO half-life.[14]

Several laboratory studies in small animals exist, including one that incorporated an autogenous cancellous bone graft. This study in cats demonstrated that a median percentage of bone was marginally higher in the group that received HBOT as compared with those that did not receive treatment (58.23% vs 47.06%, respectively); on removal of a single outlier, these results were statistically significant.[15] Another feline study that featured blinded observers compared skin flap viability in which the flap color appeared subjectively healthier in the treated groups.[16]

A study in canine cardiac arrest patients showed improved neurologic outcome in both neurologic deficit scoring and reduced neuronal death postarrest in dogs that received HBOT.[17] Dogs have also been used as a model for the effects of HBOT on the CNS, with positive results reported in the HBOT-treated groups subjected to complete global cerebral ischemia,[18] spinal cord compression,[19] and ischemic spinal cord injury.[20]

Anecdotal veterinary treatment applications in various species have involved crotalid envenomations, refractory osteomyelitis, reperfusion injury, myocardial ischemia, pancreatitis, and anaerobic infections.[8,21,22] Results from a retrospective study of HBOT suggest that the following conditions were frequently treated: compressive and vascular myelopathies, crotalid envenomation, surgical or traumatic wounds, and atypical infections.[23] The reliance of HBOT practitioners on low-grade evidence has likely

prompted some to withhold advocacy for the treatment until additional information is made available by proponents.

Treatment Mechanics

A hyperbaric chamber requires substantial and reliable grounding to prevent static or other sparks that can pose a fire risk. An appropriate chamber must be purchased or leased, and oxygen must be delivered to a fixed chamber location. Patients should be supervised during the entire process, and prohibited materials (eg, synthetic bandages or fabrics, electronics, petroleum-based drugs or ointments) should be avoided, as they can be flammable or pose a static electricity spark risk.

Total treatment times vary among practitioners, but a standard time of approximately 1.25 hours (inclusive of a gradual pressurization and depressurization period) has been documented.[23] IV access and therapy may be difficult unless the chamber is equipped with a special ingress port. Use of sedatives with vasoconstrictive properties (eg, α_2-agonists) should be avoided until additional information is available. Although many patients appear to relax during the session, chamber noise and confinement may be a source of anxiety for others. Treatments are often repeated and may be performed once or twice daily over several consecutive days, depending on the condition being treated and apparent patient response.

Complications & Contraindications

Oxygen toxicity is the foremost concern with HBOT, with a grand mal seizure being the primary sign in animals.[23] However, the incidence is likely low based on limited data at 2 ATA for 45 minutes,[23] and the risk is dose dependent.[24,25] Intrasession seizures are managed with gradual decompression and monitoring. There are no reports of any epileptic predisposition following HBOT-induced seizures.

Barotrauma has not been reported in the veterinary literature, but the theoretical possibility is explained by Boyle's Law (see ***Principles & Physiology***, page 37). Trauma to the tympanic membrane or lungs is a primary concern. Any potential for entrapment of air in critical structures, such as in pre-existing pulmonary bullae or pneumothorax, should be avoided, and patients with these conditions should likely not receive treatment. Other important considerations in veterinary patients include sedation (if necessary), minimizing static electricity, avoiding exposed metal implants, and constant monitoring by trained team members.[26]

Recent HBOT-related deaths of a patient while in a small animal chamber and of both an attendant and a patient in an equine chamber explosion highlight the need for appropriate safety precautions.[27,28] Training courses are provided by veterinary-specific chamber manufacturers and third-party hyperbaric technologist programs. Owners should be informed of the risks for oxygen toxicity and for barotrauma before each HBOT session.

CLINICAL POTENTIAL & LIMITATIONS

Despite a recent increase in interest and prevalence of veterinary HBOT, it remains a less accessible modality, with only a few options (if any) available in each state. Resources such as the Veterinary Hyperbaric Medicine Society (vhbot.org) and Hyperbaric Veterinary Medicine (hvmed.com) provide location maps of US veterinary clinics that have a chamber. Although cost varies by institution, the average cost of HBOT (based on treatment time and ongoing plan) is approximately between $100 and $200 per session. Because of the potential financial and geographic limitations, it is important to discuss the entire hyperbaric treatment plan with the client and set reasonable goals before initiating therapy or suggesting referral.

CONCLUSION

Because of its physiologic effects in other species, HBOT holds therapeutic promise in animals and deserves clinical and research attention. However, the therapy is not benign, and understanding the basics of HBOT and possible complications is critical. Because the clinical information, apart from expert opinion and research experiments with small numbers, remains minimal, research is essential to expand information about the physiology behind the modality, condition-specific treatment parameters, and appropriate and efficacious indications for use in veterinary patients.

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