Safety in Animal Hyperbaric Oxygen Systems

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The following is a chapter of the soon-to-be-released second edition of *Hyperbaric Facility Safety: A Practical Guide.*

Introduction

Safety in the use of hyperbaric chambers for animal care is of primary importance and a major focus area for every hyperbaric program. Personnel and patient safety should be the primary focus. Prevention of incidents and emergencies should be the first consideration. Prevention is accomplished through adequate and proper personnel training, established operational protocols, and the use of certified equipment that is installed and housed in accordance with established safety standards.

A good hyperbaric safety program includes proper program oversight; knowledge; leadership; adherence to laws, standards and guidelines; adequate facilities; equipment constructed to accepted standards; personnel training and retraining; and the establishment of a risk assessment plan and emergency protocols.

Resources for Regulatory Guidance

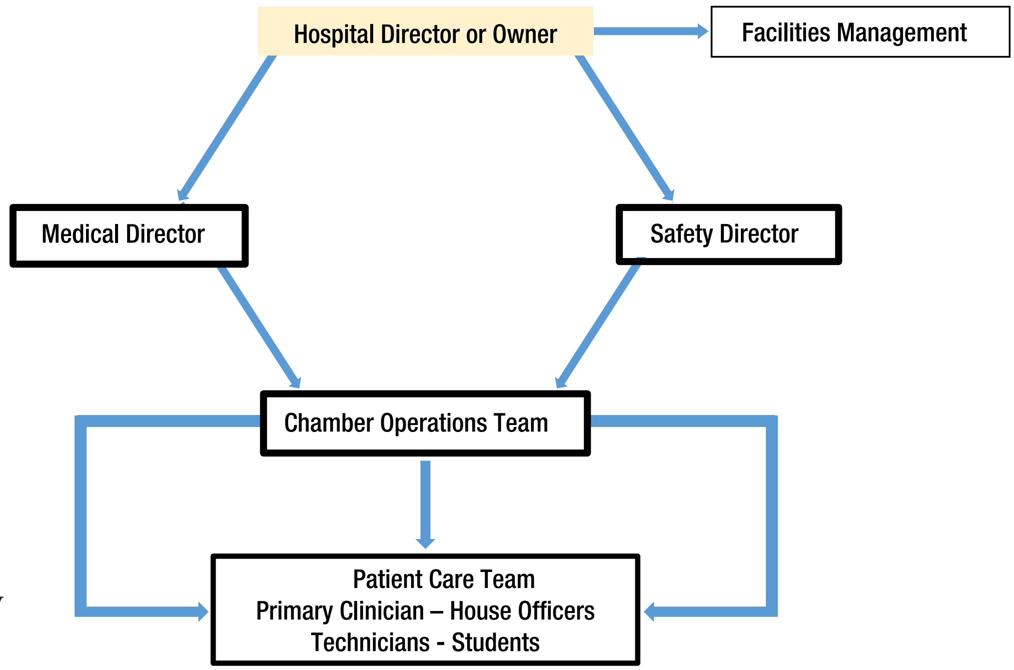
An abbreviated list of governing and guiding bodies can be found in Table 1. At the writing of this chapter, work was still being done on defining more specific standards and guidelines for animal hyperbaric oxygen (HBO_2) therapy (HBOT). All standards are subject to periodic changes and it is the responsibility of the hyperbaric facility to keep up with the latest editions. Many of the standards and guidelines for human hyperbaric therapy also apply for its use in animals. Guidance for the production, inspection and certification of animal hyperbaric chambers should follow the same parameters as those used for human chambers [American Society of Mechanical Engineers (ASME) publishes the Boiler and Pressure Vessel Code (BPVC, 2017) and ASME Pressure Vessels for Human Occupancy PVH-O 1&2, 2016].[1-2] Any alteration of the original pressure boundary requires retesting of that boundary before the chamber can be certified for use. The responsibility for maintenance and inspection of acrylic interfaces lies with the chamber user. The National Fire Protection Association's (NFPA) *NFPA 99 - Health Care Facilities Code, NFPA 50 - Standards for Bulk Oxygen Systems*, and *NFPA 101 - Life Safety Code* each contain information on the use of HBO_2 in humans. *NFPA 99,* Chapter 14 (2018) pertains to hyperbaric facilities and contains brief references to safety for Class C animal chambers. A separate standards document exists for fire and life safety in animal facilities (*NFPA 150, Fire and Life Safety in Animal Housing Facilities Code*, 2019). This document does not currently address the inclusion of a hyperbaric system in an animal facility. The Compressed Gas Association (CGA) publishes guidelines for the use of and handling compressed gases, gas containers, gas purity, and gas identification. These guidelines apply to the use of compressed gas regardless of the type of facility (industrial, medical, recreational, etc.).

Table 1. Governing and Guiding Organizations

Organization	Acronym
American Society of Mechanical Engineers	**ASME**
National Fire Protection Association	**NFPA**
Food and Drug Administration	**FDA**
American Society for Testing and Materials	**ASTM**
Compressed Gas Association	**CGA**
Resources	**Acronym**
Undersea and Hyperbaric Medical Society	**UHMS**
National Board of Diving and Hyperbaric Medical Technology	**NBDHMT**
Veterinary Hyperbaric Medicine Society	**VHMS**
International Hyperbaric Medicine Association	**IHMA**

The Occupational Safety and Health Administration (OSHA) oversees facilities, equipment, and operations with regard to personnel safety. The Food and Drug Administration (FDA) considers a hyperbaric chamber as a Class II medical device. However, there is little oversight of chambers used for clinical hyperbaric therapy in animals. Other resources that provide guidance for the hyperbaric facility include the Veterinary Hyperbaric Medicine Society (VHMS), the Undersea and Hyperbaric Medical Society (UHMS), the National Board of Diving and Hyperbaric Medical Technology (NBDHMT), and the American Society for Testing and Materials (ASTM). They also provide information on material oxygen compatibility and device and system design for oxygen service.

Figure 1. Hyperbaric Program Oversight



Clinical Hyperbaric Medicine Program – Oversight

The oversight of an animal hyperbaric medicine program and facility should follow the same basic template as that used in human hyperbaric programs, whether that program resides in a small veterinary practice or in a multi-veterinarian referral center. The difference would be the scale. Management of the facility is critical in developing and deploying an effective safety program. Figure 1 summarizes the ideal hyperbaric program oversight scheme. This suggested scheme should not discourage the small center from providing animal hyperbaric services and managing a hyperbaric program. Often the roles mentioned here may be assumed by one person even though the team approach is ideal because it provides levels of checks and balances.

Table 2. Responsibilities for Hyperbaric Patient Care and Safety

Position	Responsibilities
Hospital Director	• Manages all hospital operations – financial, facilities, personnel, communications, etc. • Might be the owner of a practice
Hyperbaric Medical Director	• Veterinarian • Working knowledge of HBOT • Knowledge of the side effects, contraindications, and their prevention/management • Makes recommendations concerning the efficacy of HBOT in patients in consultation with the primary care team • Recommends HBOT protocols for patients • Works in collaboration with the safety director to assure patient and personnel safety
Hyperbaric Safety Director	• Recognition of hazards • Policies and procedures development • Oversight of safety training and education • Analysis/problem solving – decision-making and risk assessment • Equipment and facilities maintenance needs
Chamber Operations Team	• Day-to-day chamber operation • Patient management • Chamber maintenance and hygiene
Primary Patient Care Team	• Works with HBOT medical director in making decisions for HBOT for each patient • All other care associated with the patient outside of HBOT, which includes treatments, diagnostics, etc. • Directs and coordinates other members of the primary care team

The responsibilities of medical director, safety director, and chamber operation team should include completion of a quality basic hyperbaric medicine course. In addition, the role of safety director connotes additional training in a quality safety director certificate course. Table 2 lists some of the responsibilities of each team responsible for the patient before, during, and after hyperbaric oxygen therapy. Although multiple roles can be assumed by one individual, there should be adequate redundancy in training so coverage of the hyperbaric treatment program is

Figure 2. Veterinary Hyperbaric Oxygen (VHO) Large Animal Chamber Photo Courtesy of S. Hoberg

Figure 3. Veterinary Hyperbaric Oxygen (VHO) Small Animal Chamber Photo Courtesy of S. Hoberg

Figure 4. Mobile Equine HBOT Chamber. Photo Courtesy of MEHOT

consistent. For example, appropriate coverage by adequately trained individuals occurs when someone is on vacation, ill, etc. This is important in maintaining continuity in the safety program for each facility.

Animal HBO_2 Treatment Systems and Facilities

The following is a list of known animal-specific hyperbaric chamber manufacturers/distributors and a brief description of their product. Some of these distributors are no longer actively supplying vessels; however, their products are still in use. Note that different products will vary in design and operation, thus it is important that relevant in-service training be provided by the chamber manufacturer/distributor at time of purchase/installation.

VHO (Veterinary Hyperbaric Oxygen, formerly Equine Oxygen Therapy): US distributor of small and large animal chambers (manufactured in the United States initially by Gulf Coast Engineering). This chamber is pressurized using 100% O_2. As such, there are no other breathing apparatuses or inlet lines required. The chamber should be housed in a temperature-controlled room for patient comfort and safety. This chamber console operates pneumatically (operated by air). A separate compressed air supply is required to power the chamber control system. The console uses standard power supply for the LCD screen and other electric components. This chamber also has real time O_2% and inside chamber temperature and humidity readings. Electricity supplies the chamber lights and monitoring cameras. Later models from this company have a digital screen lock so power is required to pressurize. A backup battery provides power in the event of an outage. Decompression is possible with no power supply. The door is fully manual and requires nothing other than muscle to operate.

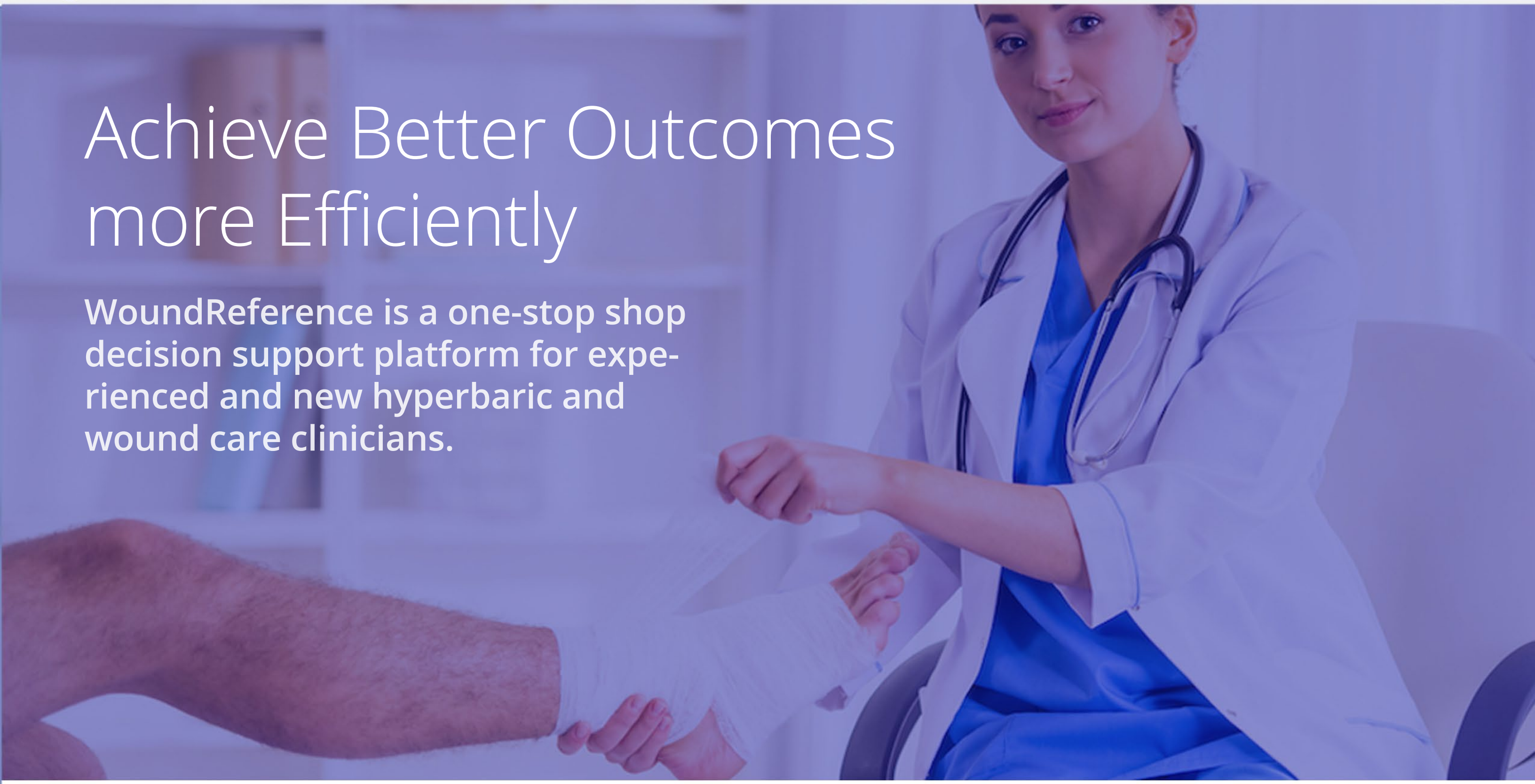
The purpose-built, steel-with-acrylic windows, small animal chamber offered by VHO is also compressed with O_2 and the controls are fully pneumatic using the O_2 supply. This chamber has real time O_2% and inside chamber temperature and humidity readings. Power is required externally for the lighting source. The door is fully manual. These chambers have minimal operational components and all operations are manual (including decompression).

MEHOT (Mobile Equine Hyperbaric Oxygen Therapy): US provider of HBOT-vessels manufactured by Fink Engineering. The system is entirely self-contained, with the chamber and supporting plant assembled into a custom design standard width trailer which can easily be transported to where it is needed. Patients breathe 100% oxygen via masks while the chamber is pressurized with air. The chamber is constantly flushed with air throughout the treatment, providing ventilation and preventing the buildup of oxygen inside. The vessel can house two patients with the animals standing side by side as in a two-horse trailer.

HVM (Hyperbaric Veterinary Medicine): US distributor of small animal chambers. This is a purpose-built, small-animal steel construction chamber with two viewing ports and video monitoring. Pressurized with 100% O_2, this chamber has real-time O_2% and temperature and humidity readings. Console controls are pneumatic using the O_2 supply with external power supplying lights, viewing cameras, and monitor. The door has a manual single-lock closure with safety pin that must be closed to allow pressurization.

Sechrist: US distributor of human hyperbaric chambers, this company now offers chambers for

Figure 5. Hyperbaric Veterinary Medicine chamber. Photo courtesy of HVM



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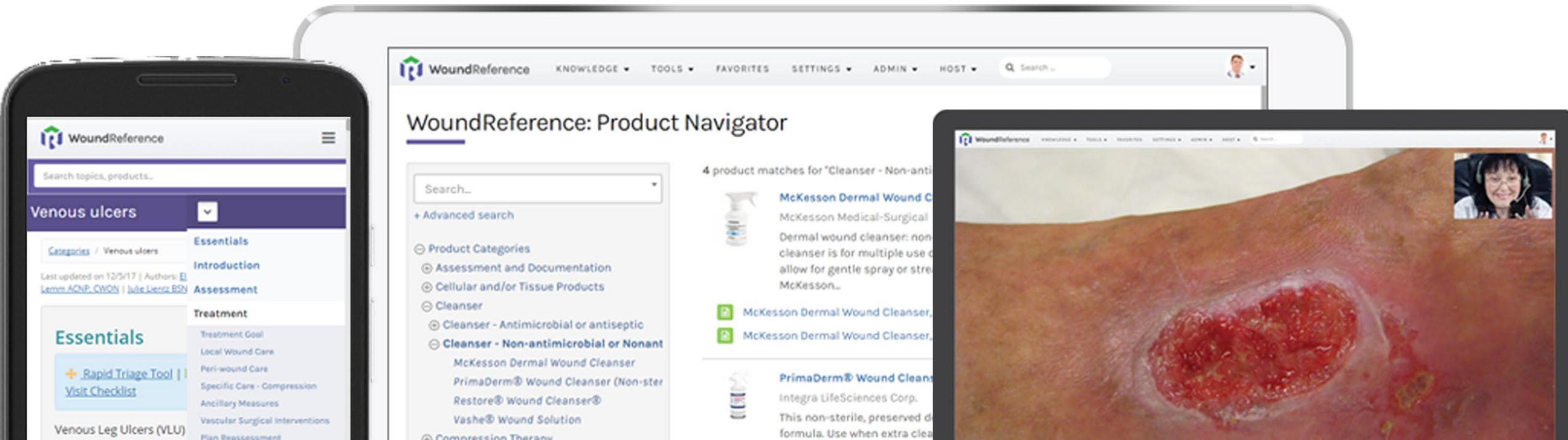


Figure 6. Sechrist animal hyperbaric chamber. Photo courtesy of Sechrist

veterinary use that have an acrylic cylindrical vessel with hyperbaric and enhanced O_2 dual modes.

Pet Pressure: US distributor of inflatable low-pressure chambers. Low pressure, fabric chambers do not meet ASME or NFPA codes even though FDA has approved them as Class II medical devices for the treatment of acute mountain sickness.

The major components of all high-pressure animal chambers are similar. All clinical chambers require an oxygen supply, and for large volumes, this is usually a liquid O_2 (LOX) supply. LOX is a cryogenic liquid that may be stored in large fixed tanks or in smaller portable dewars. To convert the liquid to gaseous oxygen, an evaporator/heat exchanger is required to allow the liquid to warm and expand into gas while passing from the storage tank into the chamber. Other smaller dewar tanks are designed to store smaller volumes of LOX than fixed systems, are portable, and contain integral vaporizers. Low-pressure chambers or small volume designs typically utilize smaller, high pressure (2000 pounds per square inch (psi) gas-only O_2 tanks.

There are many other chambers in use for animals including research-style chambers (size suits small animals) and repurposed human chambers. Buyers should ensure the chamber they are considering for purchase is one that is built to the required standards

Figure 7. Pet pressure animal chamber

of the country in which the chamber is used, and that it has not been decommissioned from previous use.

Hyperbaric chambers for clinical use on animals are located in a variety of facilities around the world. The United States currently has four universities with small animal chambers and one with both an equine and small animal chamber. These universities have and will continue to allow the next generation of veterinary students to be exposed to HBOT, ensuring the field continues to expand. Other facilities include full-service veterinary hospitals, specialty centers, rehabilitation clinics, and private equine breeding farms. At the time of this publication, the authors estimate 100+ animal hyperbaric locations across the United States, two in New Zealand, one in England, two in Australia, one in Israel, two in Mexico and an unaccounted number in China, Taiwan, and Japan.

Maintenance of Animal Hyperbaric Systems and Facilities

As with all human hyperbaric systems and facilities, maintenance programs should be established according to chamber supplier recommendations in conjunction with the facility maintenance coordinator. (See Operational Safety section for more information on maintenance and example maintenance protocols.

Fire Safety

Fire prevention is a primary safety goal during hyperbaric operations. In order to be effective at achieving this goal, it is important to understand the nature of fire. Fire is the result of a chemical reaction when oxygen, combining with fuel, in the presence of energy (heat) produces more energy (fire). This is a self-sustaining reaction as long as there is a constant supply of O_2 and fuel.

According to *NFPA-99* (2018) Chapters 14 and 16, the key points for fire prevention are to do the following:[3-4]

1. eliminate or tightly control ignition sources in the chamber (no potential spark-generating materials, steel shoes, or materials that may produce heat; chemical agents; and electrical equipment)
2. control the type of fuel sources in the chamber (no flammable materials, oils, grease, alcohols, or other products that may produce vapors)
3. limit the total quantity of fuel sources inside the chamber (If it is not necessary, leave it out. For example, bandages, dressings, etc.).

Burn rates are dramatically increased under hyperbaric oxygen conditions; therefore, fires in a hyperbaric chamber can quickly become catastrophic. This, combined with a quick escape not being possible, means prevention is the frontline approach to fire safety. Reducing the risk of fire is achieved by following the NFPA guidelines of ELIMINATE, CONTROL, LIMIT any products or equipment inside the chamber. With equines and other animals, this will include shoes (no steel), blankets (none), bandages, dressings, topicals (limited to only necessary and allowable products), and grooming products (none). Having animals as patients means we do not have to be concerned about them trying to take anything inside the chamber. However, the potential risk is the lack of the education of owners who may have applied something to their animal.

Operators are encouraged to "feel and smell" patients to check for products that may be a concern. Essential oils, grooming sprays, etc. may prove volatile in the HBO_2 environment.

NFPA 99 does not require but does permit automatic fire suppression and flame detection systems in hyperbaric facilities. NFPA requires fire extinguishing systems inside all multiplace chambers (chambers that permit multiple patients and are pressurized with air). US hyperbaric facilities covered by *NFPA 99* (this also includes France, Italy, and Poland) require deluge or water spray systems in multiplace chambers. Deluge systems are not required by NFPA in chambers pressurized with oxygen.[5]

Operational Safety Procedures

A sound operational safety program is woven into every aspect of the total hyperbaric program. Facilities should be constructed according to recommendations laid out in *NFPA 99*.[5] Requirements may differ depending on the location of the chamber in the veterinary hospital or clinic or in a separate building. Chambers should be constructed and certified according to human standards and guidelines (ASME and PVHO).[1-2] The layout of the hyperbaric facility should allow for safe ingress and egress of patients and personnel and should include at least two, clear exit points. Attention should be paid to local codes as well as fire wall construction that protects the chamber facility and clinic/hospital. Other considerations include the access to an adequate oxygen source and the safe venting of exhausted oxygen. Each facility should have access, on site, to standards and guideline resources (e.g. *NFPA 99*).

Proper facility oversight is crucial in the deployment of a successful safety program (See Clinical Hyperbaric Medicine Program-Oversight section). There are four essential responsibilities that should be covered by the management team: medical director, safety director, chamber operations team, and primary patient care team. In small veterinary clinics and hospitals multiple oversight responsibilities may be shouldered by one individual, but ideally these responsibilities should be shared for a better system of checks and balances. There should be more than one person trained in the actual chamber operations, so that treatment and safety consistency can be maintained in the absence of one or more personnel.

It is recommended that at least one individual be a certified veterinary hyperbaric technologist (CHT-V) by the National Board of Diving and Hyperbaric Medical Technology and that the safety director complete a basic safety director course. The medical director and safety directors should have basic knowledge of hyperbaric medicine. The medical director should have veterinary medical knowledge and the safety director advanced knowledge in hyperbaric systems and operations. The two work together to ensure patient and personnel safety. For example, the safety director makes decisions about what can and cannot accompany a patient into the chamber, whereas the medical director would make more decisions about the patient's suitability to withstand the hyperbaric environment. The chamber operations team conducts the daily treatment protocols and should have a basic working knowledge of animal behavior, effects of hyperbaric therapy, side effects and their prevention/management, as well as a sound working knowledge of chamber operation. There should be sufficient operations personnel to provide consistent coverage when one or more people are absent. The patient primary care team are the people responsible for the entire patient management from history, physical exam, diagnosis, and treatment. They work closely with the hyperbaric medical director, safety director, and the treatment team to ensure safety with each hyperbaric treatment.

Training and re-training is the foundation of a quality safety program. Everyone involved with the delivery of hyperbaric oxygen therapy should have completed an approved basic training course that contains basic physics, physiology, application, indications, and side effects, including animal-related information in these areas. Most basic hyperbaric information applies across mammalian species, including man and domestic animals. However, there are differences in the various species of animals, and it is important for hyperbaric teams to be aware of those differences. It is also extremely important that hyperbaric personnel have animal experience and a knowledge of animal behavior and management. One unique challenge in animal hyperbaric therapy lies in the number of species veterinarians care for and there are significant challenges in applying this therapy in exotic and non-traditional animal species. It is preferred to have at least one individual trained and board certified in animal hyperbaric therapy (CHT-V; NBDHMT) on staff. The hyperbaric medical director and the safety director should complete a basic course and the safety director an approved safety course. Technical training for operating the chamber is usually provided by the individual chamber manufacturers. This training does not include the theory and practice of hyperbaric medicine.

At a minimum, personnel should have annual operational and safety refresher training and updating. Valuable, additional training can be found in the areas of chamber acrylics and maintenance.

All training should be documented. A log should be maintained for all training sessions which includes date, type of training provided, provider, and attendees. Each attendee should receive a training certificate indicating that they completed the training. Chamber operations staff should have documented initial and recurrent competency testing covering basic operations, maintenance, and emergency procedures.

Chamber operation protocols are specific to each chamber. A copy of the operation manual should be readily available to all hyperbaric personnel. A laminated copy of the step-by-step operation of the chamber should be maintained at the chamber. All emergency protocols should also be available at the chamber, and the chamber operations team should have firsthand knowledge of the procedures. As part of the annual training exercises, staff should be refreshed with all standard and emergency protocols and be asked to run through all procedures and discuss various potential common emergency situations.

Chamber maintenance is an important aspect of the safety program. Proper chamber performance is critical in day-to-day normal operations. Proper function and reliability is crucial when an incident or emergency occurs. It is the responsibility of the individual hyperbaric programs to establish a consistent maintenance protocol for all chambers. Chamber maintenance should also include following the chamber manufacturer's recommended maintenance schedule designed for their specific chamber. The maintenance protocol may include daily, weekly, monthly, semiannual, and annual inspections, testing, certifications, test pressurizations, cleaning and disinfection, as well as maintenance of the chamber area and accessory equipment. All conducted maintenance procedures, inspections, and repairs should be dated and documented, with approval given by the safety director for the chamber's return to service. A sample list of chamber testing is included in Table 3.

Table 3. Maintenance, Inspection, and Testing

***Routine Frequent** Inspection and/or Testing*			
Chamber/Equipment	**Frequency**	**Minimum Frequency** *	
Oxygen Sensor	**At each** treatment	**14 days**	
Temperature/humidity	**At each** treatment	**14 days**	
Door seal	**At each** treatment	**14 days**	**Leak testing**
Penetrations/ports	**At each** treatment	**14 days**	**Leak testing**
Acrylic ports	**At each** treatment	**14 days**	**Leak testing**
Acrylic tubes	**At each** treatment	**14 days**	
***Routine Less** Frequent Inspection/Testing*			
Over pressure relief valve (PRV)	**Annual**	**Annual**	**Pressure check** and certification
Fire suppression system	**Annual**	**Annual**	**Test**

* **when** chamber is used infrequently

Risk Management

Risk management is a systematic process of identifying and evaluating the potential risks that may be involved in a projected activity or undertaking. Risk assessment identifies and analyzes events that may negatively impact patients, personnel, assets, and/or the environment and makes a determination of an acceptable level of risk. This evaluation is followed by a coordinated application of resources to eliminate, minimize, and control probability and impact of an unfortunate event. Although risk management sounds like a daunting process, it actually something done every day.

The ultimate goal is the prevention of an incident or emergency. Risk assessment in the delivery of animal hyperbaric therapy is focused on two specific aspects: assessing risk involving the patient and assessing the chamber environment.

Patient Safety

Each patient is selected for treatment based on the efficacy of HBOT in treating the patient's current diagnosis.[7] The patient's medical history, diagnosis, current physical and behavioral statuses, and current therapies are evaluated to ensure no contraindications exist and that there is a reasonable assurance the patient can tolerate the high-pressure, high-oxygen environment. It is imperative that the hyperbaric treatment team have a knowledge of the indications and contraindications for HBOT and the potential side effects of the high-pressure environment. The risk for seizure during therapy and barotrauma are among the most common complications. The goal is the prevention of untoward side effects and injury to the patient while in the chamber. The patient should have a basic physical examination prior to hyperbaric treatment, regardless of how many exams have been done previously.

For example, a fever can develop in a patient in a very short period of time and may not have been detected since the last physical examination. Each patient is then assessed for risks involved in providing the treatment. The medical director, safety director, and primary patient care teams should interact to ensure the patient's safety,

but ultimately the safety director makes the final decision on whether to treat or not. The patient must also be assessed based on the current therapies being administered. A knowledge of drugs and other substances that may have the potential to create complications for the patient while in the chamber is important. If substances have been used that might cause an untoward event, a risk assessment should be done to determine if the drug/substance is critical to a positive outcome and how much risk it might create versus the benefits of hyperbaric treatment.

In animals, a temperament and behavior evaluation is important. The placement of animals into a strange environment, such as a hyperbaric chamber, may cause undesirable behavioral changes that could endanger the patient as well as create a problem in the chamber environment. For example, an anxious two-year-old Thoroughbred stallion unwilling to enter the chamber and kicking periodically should be considered for sedation for his treatment. If wearing shoes, he is a good candidate to become irritated in the chamber and potentially injure himself as well create a spark with the contact of his shoes with the chamber wall.

Most animals are quiet in the chamber, but some have to be managed with additional restraint or sedation.

Chamber Environment

The second consideration in assessing risk is the chamber environment and how it might be altered to create potential risks. The evaluation of substances and devices associated with the patient or requested to accompany the patient into the chamber is part of the risk assessment process. Unlike human HBOT, our patients do not consciously carry unacceptable items into the chamber. However, there may be substances placed on the patient by the owner or primary treatment team that pose a high risk in the pressurized hyperbaric environment. Examples might include petroleum jelly around a wound or draining lesion, Velcro collar or boot, essential oils, external fracture fixator, etc. If such a substance or device is present, a risk vs. benefit analysis should be performed. If there is a high risk, is there an alternative low risk option, can the risk be eliminated and still have an optimum patient outcome, or should the hyperbaric treatment be postponed or cancelled. The primary concern in a high oxygen, high pressure environment is the risk for fire (See Fire Safety section.). Elimination of ignition sources and reduction of fuel sources are the two main goals. There is one innate risk that accompanies most of our domestic mammal patients and that is the presence of hair. Hair is very flammable in the presence of high oxygen and pressure. The management of this risk begins with the elimination of any potential ignition source in the chamber. This is especially critical in the majority of the animal chambers since they are pressurized with 100% oxygen and some (large animal) contain a large volume of gas. Steps that should be taken to eliminate ignition from static electricity include maintenance of chamber humidity at levels 50% or greater, moistening or wetting the patient, application of a grounding system or strap that may be integrated into the restraint devices or floor of the chamber, and removal of any devices that can produce an electrical current or spark. High humidity aides in reducing static electricity. Often the medical grade

Figure 8. Sample Go-No Go List

Go-No Go List Equine Hyperbaric Therapy

GO	NO GO	
MATERIALS & EQUIPMENT **Cotton halters/brass** hardware **Cotton ropes** **Cotton wraps** **Elastikon** **Cotton gauze** **Polyethylene tubing,** IV sets **IV catheters–must** be capped appropriately **Heimlich valves,** chest drains **100% cotton** towels	**MATERIALS & EQUIPMENT** **Nylon/polyester anything** **Electrical devices** including battery-operated **Heating devices,** patches, chemical warmers **Anything that** might produce a spark **Steelmetal horseshoes** **Velcro** **Vet-wrap or** comparable **Horse blankets,** non-cotton blankets	
MEDICATIONS **Alpha-2 agonists** **Diazepam** **Other medications**	**MEDICATIONS/TOPICALS** **Alcohol, including** alcohol preps **Petroleum-based products** **Baby oil** **Petrolatum** **Ointments** **Fly sprays,** other topicals **Hoof packing,** hoof paints	**CONDITIONS - ABSOLUTE CONTRAINDICATION** **Untreated pneumothorax** **CONDITIONS - RELATIVE CONTRAINDICATIONS** **Upper-respiratory obstruction** **Fever** **History of** seizure **Uncontrolled hemorrhage**
***Consult hyperbaric** technician, safety officer for materials not on the GO list and materials not commonly placed in the chamber. Need and risk assessments must be performed and documented.*	**MEDICATIONS - RELATIVE CONTRAINDICATIONS** **Cis platinum** **Disulfram** **Doxorubicin** **Mafenide acetate** **Opiates**	

oxygen entering the chamber is very dry and tends to reduce humidity as does very a dry environmental scenario.

There are many visual aids that help remind staff of the need for vigilance and continual evaluation. Examples of these aids are provided in Figures 8-10. A “Go–No Go” list contains common items, drugs, topicals, conditions, etc. which can or cannot go into the chamber. It is impossible to cover every possibility in such a list, but it usually contains the most common or frequently encountered items. This list will vary between facilities and programs. The list is also fluid and can change frequently as new information is uncovered about various items. The risk assessment tree can be used as a guide for evaluating items/procedures/devices that are not on the Go–No Go list. Figure 8 is a sample decision tree that utilizes the Go–No Go list to make decisions. Also helpful is the risk assessment guide for need assessment. (See Figure 9.)

Because of the large volume of our large animal chambers and the fact that we use 100% oxygen to pressurize most of our chambers (large and small animal), a prudent philosophy is one of *conservatism*.

Figure 9. Risk Assessment Decision Tree

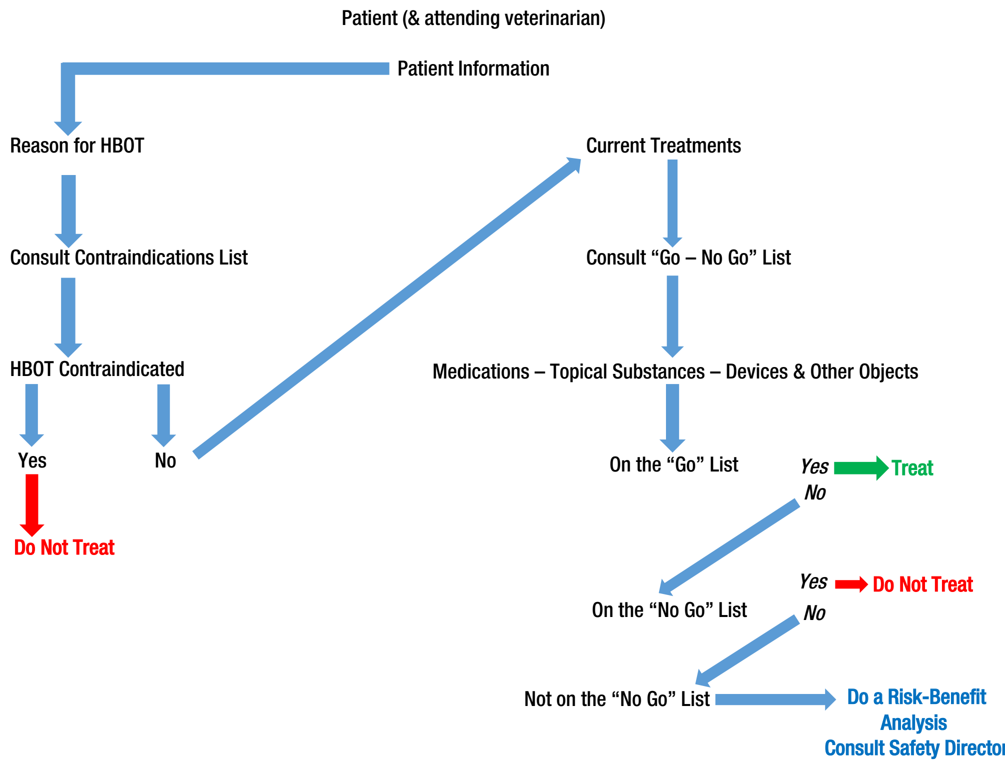


Figure 10. Sample Guide for Assessment of Need

If the item has no effects on the medical outcome of the patient, then don’t place it in the chamber.

If the item is needed for a positive medical outcome for the patient, then assess the risk of placing it in the chamber.

If the item has a high risk, ask if there is an alternative with low or no risk.

Frequency of placement in the chamber doesn’t matter if there is not or very low risk. Must evaluate risk vs. benefit.

Low cost is preferable, but safety, outcome, and comfort take precedent over cost.

In general, simple items are easier to evaluate risk than complex items, but safety and outcome take precedent over complexity and simplicity.

Alternatives that are safe, no or low risk, should be considered if required for a positive medical outcome and comfort.

Safety and Patient Evaluation – Preparation

Proper patient evaluation and preparation is a critical part of the safety protocol in any hyperbaric medicine program. As previously mentioned, the evaluation of the patient includes a review of the following: patient history; current diagnosis and medical/surgical problem list; current therapies; pre-treatment physical examination; and temperament evaluation. A patient evaluation checklist is often useful for completeness and consistency and serves as a part of the hyperbaric medical record. A risk level can also be assigned to each patient. (See tables 4 and 5).

The goal of patient preparation is to eliminate/reduce potential fuel sources and to eliminate any ignition sources. Patient preparation begins with grooming to make sure that the hair coat is clean and free of any debris. During this examination, make sure there are no topicals present that might be contraindicated or not previously evaluated. This is also a good time to evaluate the hair coat, particularly if it is extensive, for static electricity and the potential need for wetting the hair coat. The environmental humidity and temperature should also be taken into account especially in dry environments and colder times of the year. At a minimum, horses should have the mane and tail wetted and the body wiped with a wet towel. A maneuver that may also help increase humidity includes placement of wet towels or a tray of water in the chamber. Large animal chambers may also be thoroughly wetted down and water left in the floor drain reservoir.

Grooming includes cleaning the hooves of large animals to remove bedding, manure, and hoof packing that might be present. When topicals are identified that cannot go into the chamber, removal by bathing the entire patient and/or cleaning the area may be necessary (e.g. petroleum jelly around a wound). All horses should have steel shoes removed to eliminate potential contact with the metal of the chamber leading to the creation of a spark.
All devices on the patient should be evaluated and removed if not needed. Collars and halters should be removed. Only cotton halters are allowed if required. If devices cannot be removed, then covering them may be prudent, even though oxygen is very penetrating (e.g. covering external metal fixators with cotton and Elastikon). Never place a substance in the chamber that can produce excessive heat (e.g. a fiberglass cast that is still curing). Make sure that no electrical, battery-run devices are on the patient. Check the chamber for any devices that may have been dropped by personnel (e.g. cell phones). Vascular devices should be securely capped. Catheters with air-filled cuffs should have the cuffs deflated or the cuffs filled with a liquid substance (saline). A thorough examination and common sense are important in preparing the patient. A conservative approach is ideal in animal hyperbaric therapy.

Table 4. Example Patient Checklist

Patient Management Checklist

Item	√	Comments
Patient Evaluation		
Review medical history and signalment		
Review diagnosis		
Review current treatments		
Red Flags	**Yes**	
	No	
Patient Examination		
TPR completed		
Auscult cardiopulmonary system		
Upper respiratory exam/signs		
Temperament evaluation		
Red Flags	**Yes**	
	No	
Patient Preparation		
Evaluate for potential ignition sources		
Evaluate for reduction of fuel sources		
Red Flags	**Yes**	
	No	
Groom		
Bathe		
Cover devices		
Remove substances		
Wet the patient		
Evaluate for the need for sedation		
Determine need for physical restraint		
Documentation		
Complete general hyperbaric record – Update daily		
Determine current barometric pressure and record		
Complete hyperbaric patient monitoring form for each treatment		
Determine need for pre- and post-pictures, video etc.		
Risk Level		

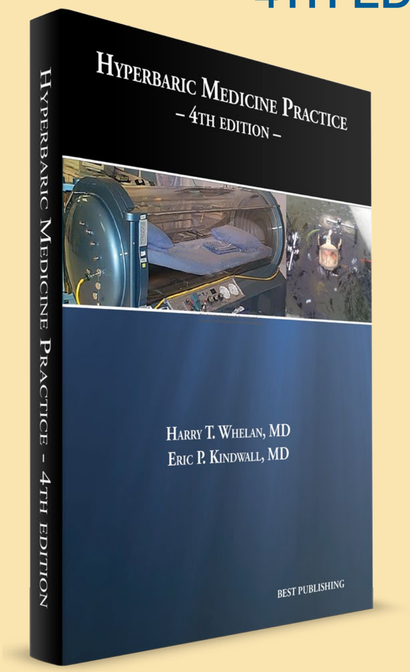
Emergency Protocols

Every effort should be made to prevent the occurrence of incidents and emergencies. However, being properly prepared for the possibility of an emergency occurrence will aid in the prevention of personnel and patient injury and the damage of equipment and facilities. Each hyperbaric program should develop their own emergency protocols and tailor them to their specific program. The first step in the prevention of an emergency is the posting of proper signage in the chamber facility and associated areas. The signage should include the following:

- Oxygen in use . . . no smoking or other ignition sources allowed
- Remember chamber oxygen is usually vented to the outside
- Reminding people that human occupancy/treatment in an animal chamber is not allowed
- Improper operation of this device (chamber) can cause serious injury

HYPERBARIC MEDICINE PRACTICE

4TH EDITION *by Dr. Harry Whelan and Dr. Eric Kindwall*



Harry T. Whelan, MD, lead editor, collected some of the most renowned practitioners in hyperbaric medicine to create this revised and updated 4th edition, which adds new information of interest to all in the field of diving and clinical hyperbaric medicine.

New contributors have written or revised most chapters, but many authors have returned to update their chapters. New chapters cover areas recently approved for hyperbaric oxygen treatment, such as idiopathic sudden sensorineural hearing loss and central retinal vein occlusion. There are also chapters about submarine rescue and problems that pertain to technical and rebreather diving.

This book will be an essential addition to the library of physicians, nurses, CHTs, CHRNs, and allied health professionals who practice clinical hyperbaric medicine and those involved with the treatment of injured divers.

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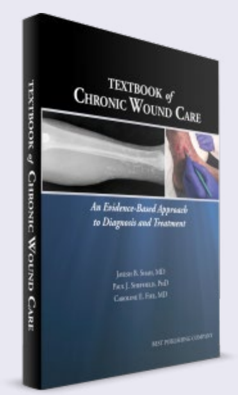
TEXTBOOK *of* CHRONIC WOUND CARE

An Evidence-Based Approach for Diagnosis and Treatment

by Jayesh B. Shah, MD, Paul J. Sheffield, PhD, and Caroline E. Fife, MD

Available on Amazon and BestPub.com



This textbook is a companion reference book for the *Wound Care Certification Study Guide, 2nd Edition*. This book belongs in the library of every practitioner who treats chronic wound care patients. It proves to be a valuable text for medical students and all health-care professionals—doctors, podiatrists, physician assistants, nurse practitioners, nurses, physical and oocupational therapists—in various settings. It provides thorough understanding of the evidence-based multipdisciplinary approach for caring for patients with different kinds of wounds.

This textbook provides the best diagnostic and management information for chronic wound care in conjunction with evidence-based clinical pathways illustrated by case studies and more than 350 pictures in addition to up-to-date information for the challenging chronic wound care problems in an easy-to-understand format.

Features

- Chapters are written by more than 50 well-respected leaders in the specialty of wound care.
- Balanced evidence-based multidisciplinary approach to chronic wound care
- Exclusive key concepts in every chapter for a quick review
- Excellent resource for preparation of wound care certification exams with 250 questions and answers
- Chapters specifically focused on wound care in different care settings
- Chapter on telehealth and wound care addressing the future of chronic wound care
- Deep understanding of value-based care in wound care in the United States
- Chapter on healthcare payment reform and the wound care practitioner
- Separate sections on approach to wound care in various countries globally

Table 5. Example Criteria for Patient Risk Level

Risk Level Criteria

Level	Evaluation Criteria
1	**Nothing in** the medical history that would contraindicate treatment in high-pressure high-oxygen environment **No current** treatments that preclude the use of HBOT **No absolute** or relative contraindications present in this patient **Pre-treatment examination** is within normal limits, no respiratory complications **Nothing present** that is listed on the "No-Go" list **No devices,** substances, medications, etc. that require a risk assessment **No potential** ignition or heat sources present on the patient **Excellent to** good temperament
2	**History may** contain information that could result in complications **Primary reason** for HBOT is a respiratory problem **Disease present** that has produced systemic compromise, requires risk assessment **Nothing present** that is on the "No-Go" list **No absolute** contraindication present in this patient **Relative contraindication** present that may be manageable in the hyperbaric oxygen environment **Presence of** treatment/substances (topicals etc.) that could be a fuel source, minor risk assessment, requires removal and bathing **Presence of** devices that cannot be removed and may require covering
3	**One or** more of the following is present: **Item present** which is on the "No-Go" list **Significant pulmonary** system disease or alteration **Presence of** an absolute contraindication **High fever,** multiple relative contraindications **Treatments that** would predispose the patient to the development complications **Devices, substances,** medications etc. that have an unknown response to high **oxygen/high pressure** and will require a significant risk assessment **Things present** that would/could result in ignition or heat generation

and even death to patients in the chamber and to people operating and/or in the vicinity of the chamber

- Step-by-step procedures for fire outside the chamber, fire inside the chamber, rapid decompression, and decompression rates. All common potential emergency protocols should be described and placed in a folder which is located chamber side.
- Bulleted, step-by-step procedure list for various scenarios visible on the chamber or wall makes it convenient for chamber operators to refer to it during an emergency situation

The development and written description of a rapid decompression protocol may be useful in many common emergency situations. The speed of decompression will depend on the individual chamber. The tolerance of various animal species for rapid decompression is not known and extrapolation from the human diving community can be used as a rule of thumb. Using the base rate of 0.5 ft/sec, the total time from a pressure of 2 Atmospheres Absolute (ATA), 2.5 ATA, and 3.0 ATA would be 1 minute, 1.5 minutes and 2.2 minutes, respectively. Some chambers may not be able to achieve these fast rates, some patients may not tolerate these rates, and more time may be required.

Fire is one of the main emergencies that should be addressed in any hyperbaric emergency management program.

There are five general principles/maneuvers that should be considered in managing this type of emergency: 1) determination of the location of the fire, inside or outside of the chamber; 2) use of fire suppression systems; 3) discontinuation of oxygen flow into the chamber; 4) exhaust of existing oxygen in the chamber; and 5) depressurization.

A fire protocol will vary slightly depending on the location of the fire. For example, a fire in the immediate area of the chamber may be handled different than one outside of a 2-hour fire door or wall. A fire inside the chamber will be managed slightly differently than one outside of the chamber. Those chambers with deluge systems should have the system activated in the instance of an internal chamber fire. Figures 11 and 12 are examples of protocols for emergency shutdown procedures in the case of fire. They may not be appropriate for all chamber types and facilities but merely indicate some of the components of such a protocol.

Other potential incidences that may require emergency-type maneuvers or rapid shutdown include loss of electrical power, patient seizure or other major patient complications, loss of oxygen supply, and loss of compressed gas supply. Preparedness for these scenarios will decrease operator stress and improve response efficiency.

Documentation of the activation of an emergency protocol is imperative. This documentation should include the emergency or incident, protocol initiated, outcome, date, and time. *Remember anything not recorded did not occur.*

Figure 11. Example of an Emergency Shutdown Procedure.
Procedures are chamber-specific and the following are only examples of what a protocol might look like.

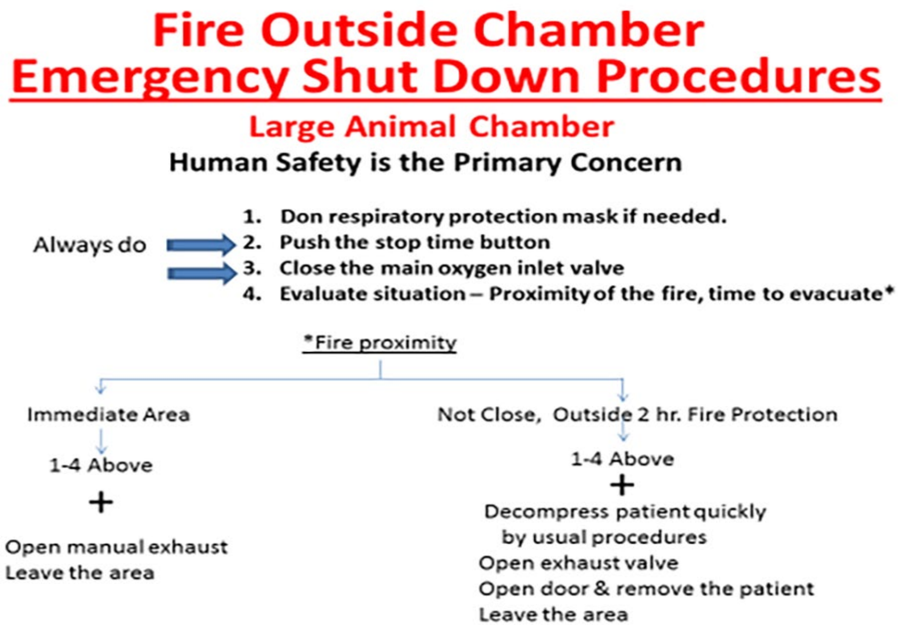
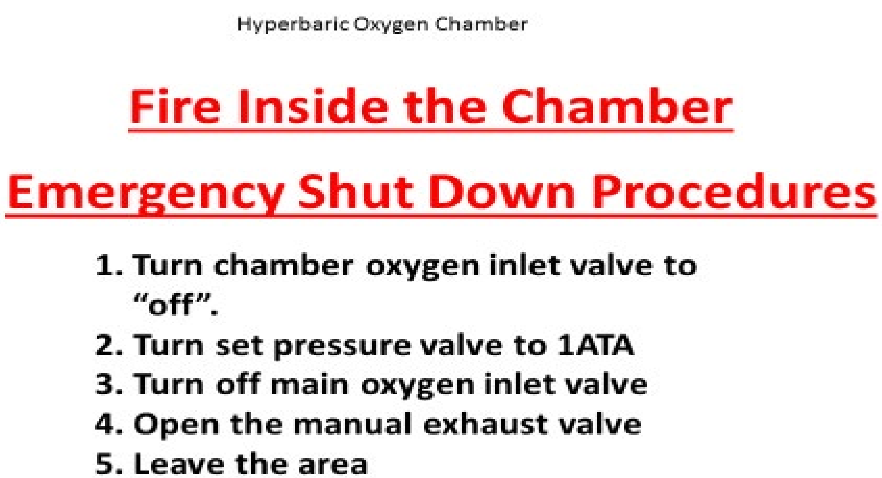


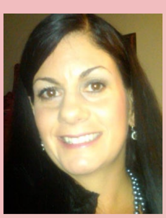
Figure 12. Example of an Eemergency Shutdown Procedure



Summary

Safety touches all aspects of a quality animal hyperbaric oxygen treatment program. *Prevention* is key and is woven into every aspect of the development and deployment of clinical hyperbaric oxygen therapy. The standards and codes are there to guide us. Oversight provides a system of checks and balances and supports team development for consistency of patient care and safety. In this equipment-laden discipline, proper maintenance of equipment and facilities is crucial to the safety program. Paramount to following the mantra of prevention is a knowledge of the effects of HBO_2 on the patient and on the treatment environment (chamber). Basic and advanced training followed by consistent re-retraining is ideal to maintain a proper level of expertise and knowledge. Most historical incidences and emergencies, both in human and animal HBOT, have occurred due to human error. A thorough and consistent evaluation coupled with proper preparation of the patient are frontline procedures that are crucial in the prevention of incidences and emergencies. On a daily basis we are evaluating risk and making decisions concerning the elimination or reduction in those things that that might ultimately lead

About the Authors



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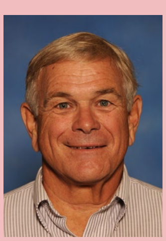

DENNIS R. GEISER, DVM, CHT-V: Undergraduate education occurred at Colorado State University, awarded BS in Microbiology 1968. Doctor of Veterinary Medicine from the University of Illinois 1972. Clinical private practice small animal and equine in San Jose California 1972-1974. Completed a residency in equine medicine and surgery at Michigan State University in 1976. Private equine referral practice in Ocala, Florida 1976-1978. Instructor through Professor at University of Tennessee 1978 – 1996. Section chief of anesthesia 1985 – 1996. Interim head and head of Large Animal Clinical Sciences 1996- 2004. Became Assistant Dean for Organizational Development and Outreach 2005- present. Special interest in anesthesia and hyperbaric medicine. Current responsibilities include Director of Continuing Education for the College, medical director of the UTCVM small and large animal hyperbaric medicine program, board member of the Veterinary Hyperbaric Medicine Society, member of the taskforce for animal simulation in teaching, member of the committee for marketing and communication.

to an unsafe treatment environment. The development and deployment of a sound safety program will significantly reduce the need for the initiation of emergency protocols. However, even with the best of safety programs, unexpected incidences can happen and therefore the presence of and training in emergency procedures is important. Documentation is the last important aspect of the safety program. Documentation includes treatment logs, maintenance, training, and incidence occurrences.

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