MEDICAL EDUCATION SYSTEMS

Hyperbaric Oxygen Therapy

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Hyperbaric Oxygen Therapy

Introduction

The purpose of this CEU is to present healthcare professionals with an overview of hyperbaric oxygen therapy and the care required before and after this therapeutic intervention. There will be some repetition in the review of the topics since we have looked at HBO from several different perspectives. We hope you enjoy studying about this therapeutic intervention.

Learning Objectives

Upon successful completion of this course, you should be able to:

1. Identify and discuss the uses and the relative and absolute contraindications of hyperbaric oxygen (HBO) therapy.
2. Identify and explain the concepts and physiology underlying HBO therapy, as well as potential side effects.
3. List and discuss the key elements of planning and implementing care for pre- and posttreatment patients.

Brief History and Definition of HBO Therapy

The air we breathe contains 21% oxygen. Providing 100% oxygen by face mask has certain benefits but providing pure oxygen in a pressurized chamber offers distinct therapeutic benefits. Hyperbaric oxygen therapy is the administration of 100% oxygen at two to three times atmospheric pressure. The pressure of the air at sea level is considered to be one atmosphere. Each 33 feet below sea level is considered another atmosphere. For example, if one dives 99 feet below the surface of the water, one would have dived to a pressure of four atmospheres. This pressure can be created artificially in specially designed chambers.

Hyperbaric oxygen therapy has been used for over a century, but not to any great degree until only a short time ago. Hyperbaric chambers have been in use since 1662, but have only been used clinically since the mid 1800's. Their use in treating deep sea divers with decompression sickness was discovered in the 1930's and clinical trials in the 1950's demonstrated even more benefits from HBOT.

The most widely-known application of hyperbaric oxygen therapy is in the treatment of decompression illness, also known as "the bends," which can occur when scuba diving. Today hyperbaric oxygen is used for a multitude of illnesses and conditions, but its use remains controversial. Some of the controversy surrounding the use of hyperbaric oxygen therapy is its application for "unapproved" conditions and as a "health rejuvenation tool." (More history to be presented later in this CEU)

Mechanisms of Action

Hyperbaric oxygen therapy has multiple effects on the body which include:

- **Pressure:** Any free gas trapped in the body will decrease in volume as pressure exerted on it increases (Boyle's Law). This is useful in the treatment of decompression sickness and arterial gas embolism.

- **Hyper-oxygenation:** The elevated pressure in the chamber increases the amount of oxygen present in the blood ten to thirteen times normal. The elevated level of oxygen supports compromised tissues having marginal blood flow. The flooding of the body with oxygen forces toxins like carbon monoxide from the body.

- **Vasoconstriction:** Elevated oxygen levels cause vasoconstriction, which causes reduced blood flow without affecting tissue oxygenation because of the extra oxygen in the blood. This aids in reducing edema, thus controlling compartment pressures in crush injuries, and is also effective in treating thermal burns.

- **Angiogenesis:** Hyperbaric oxygen therapy promotes the growth of new blood vessels.

- **Bactericidal:** Saturation of the tissues with oxygen slows the spread of certain toxins and is effective in killing anaerobic bacteria. Many of the body's bacterial defense mechanisms are oxygen dependent. When tissue oxygen drops, leukocyte effectiveness is decreased. Because of this, the beneficial effect of HBOT is utilized in the treatment of gas gangrene and necrotizing infections.

- **Anti-ischemic:** Hyperbaric oxygen physically dissolves extra oxygen into the plasma (Henry's Law). The quantity of oxygen carried to ischemic tissue is increased thus promoting healing.

The number of treatments and the time between treatments varies depending on the condition. Acute conditions may require treatment for ten days or less, while chronic conditions may require months of therapy. Most sessions last two hours (including compression and decompression time) and are administered once or twice a day on an outpatient basis if possible.

Types of Chambers

There are over 208 hyperbaric oxygen therapy centers in the United States and Canada, some of which are independent centers and others being hospital-based centers. There are three basic kinds of chambers in these centers: monoplace, dualplace, and multiplace.

Monoplace chambers accommodate one patient. They are pressurized with 100% oxygen which the patient breathes directly. The chamber is capable of providing monitoring, fluid resuscitation, and ventilatory support.

Dualplace chambers accommodate two persons: either two patients or a patient and an attendant. They are pressurized with air and the patient breathes oxygen through a built-in system. This system utilizes a large, clear hood placed over the patient's head to deliver 100% oxygen.

Multiplace chambers accommodate between four and twenty-four patients. They also are pressurized with air and the patients breathe oxygen through a similar built in system as the dualplace chamber. These chambers are large enough for stretchers, critical care patients, and medical staff.

All chambers have the capability of communication with those outside through an intercom system. Most chambers allow the patient to sleep, watch TV, or listen to music during the session.

Associated Agencies

There are two primary agencies that oversee the use of hyperbaric oxygen therapy. The American Board of Hyperbaric Medicine certifies physicians as hyperbaricists. These physicians are specially trained in the use of hyperbaric oxygen therapy.

The Undersea and Hyperbaric Medicine Society (UHMS) was founded in 1967 and is the major scientific society for hyperbaric oxygen therapy in the United States. The Hyperbaric Oxygen TherapyCommittee of the UHMS, developed in 1976, reviews published data regarding hyperbaric oxygen therapy and publishes periodic reports of recommended medical indications for hyperbaric oxygen therapy. The UHMS categorizes diseases by their need for treatment with hyperbaric oxygen therapy. The criteria for each category are:

Currently Accepted Conditions

Disorders Involving Gases

Decompression Sickness: Decompression sickness (the bends) is the most widely known condition for which

hyperbaric oxygen therapy is prescribed. This condition primarily affects scuba divers and is seen frequently in such areas as California and Florida. Decompression sickness occurs when there is production of nitrogen bubbles in the circulation. As the diver ascends to the surface, the underwater pressure decreases. Nitrogen bubbles form in the bloodstream when the pressure decreases too rapidly and these bubbles migrate to the joints causing extreme pain. These gas bubbles may embolize, travel to the brain, and cause death. By returning the diver to a simulated depth, the return to normal atmospheric pressure can be made in a slower, more controlled manner. This allows the nitrogen to be exhaled rather than accumulating and causing distress.

Embolism: Air or gas embolism is similar to decompression sickness. Gas pockets that develop in the vessels obstruct, them causing perfusion problems. Treatment theory is based on Boyles' Law. Reduction in the volume of the gas bubble allows it to pass through the circulation easier, thereby relieving any obstructions.

Carbon Monoxide Poisoning and Smoke Inhalation: Hyperbaric oxygen therapy is also used in the treatment of carbon monoxide poisoning and smoke inhalation. By flooding the body with oxygen, toxic substances are rapidly eliminated from the plasma, and oxygen replaces the carbon monoxide in the red blood cells. Most hyperbaric oxygen therapy treatment centers treat carbon monoxide poisoning when the patient presents with symptoms of carbon monoxide toxicity. Sixty-two percent of facilities, however, hold to a minimum level of carbon monoxide presence as admission criteria to their centers.

Category I: Disorders in which HBO therapy is definitely helpful.
Category II: Disorders with which HBO therapy is useful as an adjunct therapy.
Category III: Conditions in which HBO therapy may be helpful, but has not been proven as a satisfactory treatment.
Category IV: Conditions in which HBO therapy would be theoretically beneficial, but has not yet been studied.

Wound Management

Effects of HBO Therapy
Hyperbaric oxygen therapy has many effects that aid in wound management. Oxygen is lethal to anaerobes. Because oxygen supplied under pressures greater than one atmosphere increases tissue oxygen tensions. Hyperbaric oxygen therapy also increases oxygen content and diffusion capability, increasing tissue oxygen tensions. Hyperbaric oxygen therapy has also been shown to increase the destructive ability of leukocytes. It enhances connective tissue regeneration through the stimulation of fibroplast growth and increased collagen formation.

Further benefits of hyperbaric oxygen therapy include decreasing tissue edema and promoting revascularization. Lastly, wound management is further aided by the inhibition of toxin formation of bacteria.

***Clostridia* Myonecrosis**: *Clostridia* myonecrosis, otherwise known as gas gangrene, is a severe infection caused by gram positive bacteria of the *Clostridia* variation. This is a severe complication of trauma, fractures and open wounds. Approximately 67,000 amputations are performed each year among diabetics due to gangrenous wounds. The *Clostridia* bacteria produce exotoxins that destroy living tissues. Because oxygen supply to tissues is reduced in the presence of this bacteria, hyperbaric oxygen therapy is provided to increase tissue oxygen tensions. This inhibits toxin formation and destroys the anaerobic *Clostridia* bacterium, thereby reducing the need for amputation.

Necrotizing Soft Tissue Infections: HBO therapy slows both aerobic and anaerobic bacterial growth: it increases leukocyte effectiveness, thereby decreasing aerobic bacterial growth, and the increased oxygenation directly inhibits anaerobic growth. Use of HBO therapy can reduce mortality significantly.

Other Wounds: Other types of wounds that can be successfully treated with adjunct hyperbaric oxygen therapy include:
- Crush injuries (benefit shown in approximately 60% of cases if initiated within six hours of injury)
- Compartment syndromes
- Acute traumatic ischemias

- Refractory osteomyelitis (benefit shown in approximately 60% to 85% of cases)
- Radiation tissue damage
- Thermal burns
- Compromised skin grafts and flaps
- Diabetic wounds

Anemia Treatment

Hyperbaric oxygen therapy has been shown to be a good adjunct treatment for acute anemia cases, as well as for the maintenance of tissue oxygenation. Hyperbaric oxygen therapy increases the amount of oxygen dissolved in plasma, thereby increasing the amount of oxygen available to the body tissues. The more oxygen that is available to the body, the higher the saturation levels are in the blood.

Oxygen levels in the blood (PaO2) have been shown to increase as high as 1500 - 1800 mm/Hg (normal is 97-105 mm/Hg) when oxygen is delivered under hyperbaric conditions. There also is evidence that hyperbaric oxygen therapy increases the flexibility of red blood cells and aids patients with blood anemias (i.e., sickle cell crisis).

Other Effects and Diseases Treated

There are other beneficial effects of hyperbaric oxygen therapy that are still being investigated.

Migraine Headaches: Research indicates that hyperbaric oxygen therapy acts as an alpha-adrenergic drug, which causes vasoconstriction. This may prove to be beneficial to patients with conditions such as migraine headaches. Patients receiving normobaric oxygen feel less relief from their migraine headache than those receiving hyperbaric oxygen therapy. This difference may be associated with the vasoconstrictive effects of the therapy or it may be due to increases in the rate of energy production and neurotransmitter-related metabolic reactions. More research is needed to verify this finding.

Other diseases that have yet to be proven as receiving benefit from hyperbaric oxygen therapy, and on which studies are currently being performed, are:

- Sports injuries (related to wound management). Aging
- Lupus
- Scleroderma
- Multiple sclerosis
- Rheumatoid arthritis
- Closed head injury
- Sickle cell crisis (related to anemia benefits)
- Hydrogen sulfide or carbon tetrachloride poisoning
- Frostbite (wound management)
- Cerebrovascular Accident (stroke)
- Fracture healing and bone grafting.
- Spider bite (Brown Recluse & *Loxasceles reclus*a)
- Spinal cord injury

Hyperbaric oxygen therapy is also being investigated as a treatment modality to shorten the duration of colds and flu and to reduce the effects of alcohol intoxication. Further studies are also being performed regarding its use in the treatment of:

- Myocardial infarction (reduces ischemia)
- Near drowning

- Electrocution (burns)
- Chronic fatigue syndrome
- Cardiac dysfunction
- Chronic obstructive pulmonary disease
- Alzheimer's Disease
- AIDS
- Cyanide poisoning

Adverse Effects

The most common side effect of HBO therapy is a "crackling" sound in the ears between treatments. This can be relieved by clearing the ears in the same way as in the chamber during treatments. Much less frequently, a temporary change in vision is experienced. This alteration in vision returns to its normal state within six to eight weeks after treatment has finished.

Other adverse effects associated with the administration of hyperbaric oxygen therapy are primarily due to barotraumatic responses within the body. Middle ear pain and bleeding, development of mucus plugs, and sinus discomfort are among these adverse reactions.

Medical personnel managing the dive can be either outside the chamber (as in a monoplace chamber) or inside the chamber (as in a dualplace or multiplace chamber). Personnel in the chamber are subjected to the same dive conditions as the patient and run the risk of air embolism, decompression sickness, and nitrogen narcosis. All personnel must have a recent dive physical and be cleared for chamber dives.

Contraindications

Contraindications for administration of hyperbaric oxygen therapy include:

- Pneumothorax
- Severe chronic obstructive pulmonary disease with carbon dioxide retention
- History of thoracic surgery
- Chronic sinusitis
- Pregnancy

Safety Considerations

Because of its use in an oxygen-enriched environment, most safety measures revolve around issues related specifically to oxygen: fire and static electricity. For these reasons there must be no smoking in or around the hyperbaric chambers. There are a number of preparations necessary before each treatment which include:

- No smoking. Tobacco constricts blood vessels and limits the amount of blood and oxygen that can be delivered to tissues.

- Inform the hyperbaric team of all medicines the patient is taking. Some medications change the body's response to oxygen.

- Any signs of illness such as fever, cough, sore throat, nausea, or other symptoms should be communicated to the hyperbaric team. Treatments may need to be delayed until symptoms resolve.

- Patients should be informed not to drink carbonated beverages for 4 to 6 hours prior to treatment with hyperbaric oxygen. Because of the gas laws affecting gases within the body, these beverages may be

hazardous.

During treatments, the patient should be advised:
- Wear the cotton scrubs provided or all cotton clothes. No synthetic clothing or pantyhose. Cotton reduces the potential for static electricity.

- No makeup or lip balm

- No hairspray, deodorant, lotions, oils, or creams due to static electricity effects and the use of petroleum products in these items

- No contacts or glasses

- Remove dentures and partial plates

- No perfume or shaving lotion

- No metal objects including jewelry or staples in books or magazines

In brief, Hyperbaric oxygen therapy has been proven to be a beneficial first line or adjunct therapy for a multitude of diseases. Because of its minimal side effects, it is a relatively safe therapy for the patient. Its use, however, may remain controversial for many years due to its potential for abuse.

Overview of Interventions

John Davidson, age seven, is admitted to a general pediatric unit from an outpatient clinic for treatment of a crush injury to his right leg, which hasn't responded to traditional wound care (including antibiotic therapy and wet-to-dry dressings) at home. Assessment shows a healthy child of average weight and development, with stable vital signs. The dressing on John's right leg extends from the knee to the ankle, and foul-smelling serosanguineous drainage is evident. Capillary refill time to the toes on the right foot is six to eight seconds, and the toes are cold to the touch, with pallor and diminished voluntary movement, as compared with the toes on the left foot. Doppler assessment reveals diminished blood flow to the right leg. The physician has notified the family that a course of hyperbaric oxygen (HBO) therapy, the best option to "save" John's leg, has been ordered for a one-hour period twice daily for two weeks.

Although respiratory technicians trained in HBO therapy (certified hyperbaric technicians, or CHTs) or certified hyperbaric registered nurses (CHRNs) will operate the equipment and monitor a patient during its use, staff nurses are responsible for the patient both before and after treatment. All caregivers need to understand HBO therapy and be aware of the contraindications, potential side effects, and drug interactions, as well as the appropriate treatment interventions.

The most well-known use of HBO therapy has been in the treatment of decompression illness; when a diver ascends too rapidly, intravascular nitrogen bubbles form faster than they can be exhaled. The illness can be asymptomatic or characterized by symptoms such as vertigo and joint and limb pain, and can lead to paralysis and death. During construction of the Brooklyn Bridge in the late 1890s the condition became known as "the bends" because afflicted caisson workers walked with a stooped gait (a caisson is a watertight chamber used for underwater construction). The effectiveness of HBO therapy in treating decompression illness has been well documented,[1] but this is actually one of its rarer applications today.

The most common use of HBO therapy among pediatric patients is for carbon monoxide poisoning, for which it's the treatment of choice to prevent long-term effects on the central nervous system.[2, 3] Among adults, the most common uses include the treatment of tissue hypoxia, necrosis, gas gangrene, osteomyelitis, blood loss anemia,

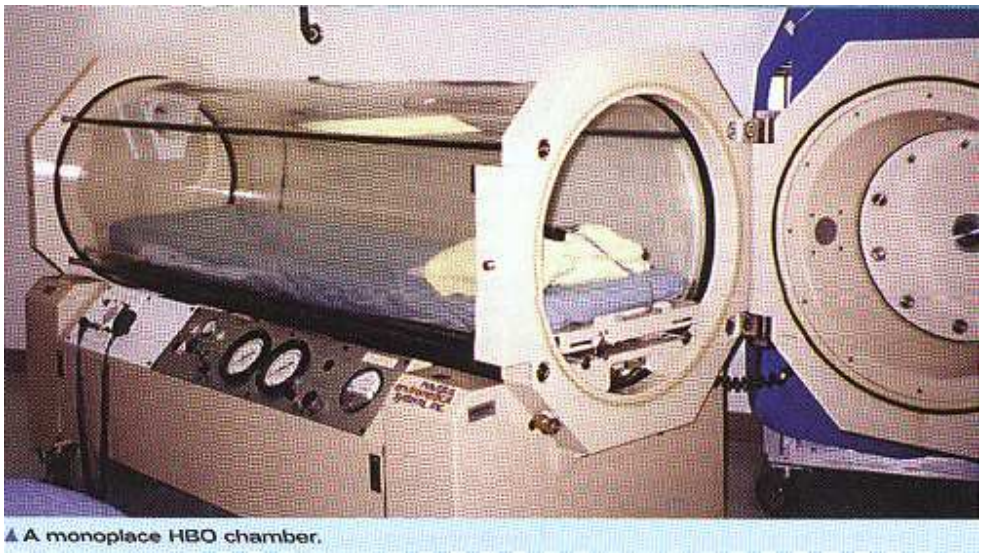
osteoradionecrosis, and compromised skin grafts or flaps. In both populations, typical uses also include the treatment of anaerobic infection, crush injury, thermal burns,[4] gas embolism, and Bell's palsy.[5]

Although other uses of HBO therapy are still considered experimental, some independent outpatient clinics do offer treatment with hyperbaric oxygen to patients who can afford to pay privately. For example, increased tissue oxygenation is thought to benefit patients who have suffered a stroke or who have cerebral palsy. But the clinical evidence of the value of such uses is incomplete, and research is ongoing.

The Undersea and Hyperbaric Medical Society approves the use of hyperbaric therapy for the following conditions, which are accepted by third-party payers and Medicare[6]:

- air embolism
- thermal burns
- carbon monoxide and cyanide poisoning
- traumatic ischemias such as compartment syndrome or crush injuries
- anemia resulting from exceptional blood loss
- nonhealing wounds
- anaerobic cellulitis or gas gangrene
- necrotizing soft tissue fasciitis, including moist gangrene
- decompression illness ("the bends")
- acute peripheral arterial insufficiency
- osteomyelitis
- radiation tissue damage, including osteoradionecrosis
- actinomycosis
- intracranial abscesses
- compromised skin grafts or flaps

This course discusses primarily the use of single-patient (monoplace) chambers and focuses on the care giver's pre- and posttreatment responsibilities with both pediatric and adult patients: patient and family education; physical and psychological assessment and preparation; coordination of continuity of care; monitoring for complications; and provision of emotional support.



A monoplace HBO chamber.

History, Definitions, and Physical Laws

History. The development of hyperbaric medicine is closely associated with the history of diving equipment. Aristotle recorded that Alexander the Great used a "glass barrel" as a diving chamber in 320 BCE. In the 1530s Guglielmo de Loreno developed the first diving bell. In 1691 Edmund Halley improved the design by devising a

way to replenish the air supply; he eventually built a diving chamber that enabled him to remain 60 feet underwater for one hour. In 1865 Benoit Rouquayrol and Auguste Denayrouse patented a compressed-air tank for underwater breathing. By adapting a car regulator in 1942 and 1943, Jacques-Yves Cousteau and Emile Gagnan invented a way to deliver compressed air automatically to a diver as he breathed; their "Aqua-Lung" was a modern forerunner of today's scuba (**s**elf-**c**ontained **u**nderwater **b**reathing **a**pparatus).

As early as 1662 experimental clinical applications of hyperbaric medicine were reportedly used with patients who had tuberculosis and other chronic diseases. In the 1830s hyperbaric chambers were used in France to improve circulation, although there was apparently no rationale for the treatment and no way to measure the partial pressure of oxygen in the blood. A French civil engineer, M. Triger, was the first to describe decompression illness symptoms in humans: in the 1840s he reported that caisson workers suffered from muscle cramps and sharp pains after prolonged exposure to increased atmospheric pressure, and noted that in such environments candles burned faster and the quality of the human voice changed. Larger chambers accommodating more than one person were subsequently built for use by patients who needed treatment from a caregiver during a session or were unable to lie down as required in a monoplace chamber. By 1879 a mobile hyperbaric operating room, originally developed for spas, was in use.

HBO therapy was introduced in the United States in 1861, primarily as treatment for "nervous" disorders and influenza and other respiratory conditions. But lack of research evidence of its effectiveness limited its use until the 1930s, when Behnke and Shaw began successfully employing it to treat decompression illness. Currently, magnetic resonance imaging and color spectrum–based computed tomography scans can be used to evaluate the effectiveness of HBO therapy, and research continues to expand and direct its use. However, the initial installment expenses are significant: HBO chambers range in cost from about $85,000 for a single-person unit to more than $500,000 for one that can accommodate two or more people, and the necessary facility modifications can run more than $200,000. But a patient's treatment costs, though they vary depending on the provider and the third-party payer, are generally not prohibitive, ranging from about $100 to $220 per treatment hour.

Definitions. *Hyperbaric oxygen therapy*, an adjunctive treatment, involves the administration of 100% oxygen at increased atmospheric pressure. Pressure can be expressed using various units, including millimeters of mercury (mmHg) and atmospheres absolute (ATA). Atmospheres absolute is the sum of atmospheric and hydrostatic pressures—in other words, the total pressure of the weight of air (and for divers, water) exerted on the body. The average atmospheric pressure exerted at sea level is 1 ATA; HBO therapy typically administers oxygen at 1.5 to 3 ATA.

Administration occurs within a *hyperbaric chamber*, an airtight enclosure capable of withstanding high internal pressures. Three types currently exist. A *monoplace* chamber accommodates one patient lying on a padded, built-in platform that glides in and out on rollers. In 1977 there were only 30 such chambers in the United States; by 1997 there were more than 300.[7] *Multiplace* (multiperson) chambers may be as large as a room, and most accommodate between two and seven people. Patients may be either seated or supine. If necessary, a care giver can accompany the patient into the chamber; both are subject to increased atmospheric pressure, but the care giver breathes air, while the patient receives 100% oxygen through a face mask. Small, *topical* chambers are designed to fit only over the body part to be treated.

How it works. The inhalation of pure oxygen at higher than normal pressure causes the patient's plasma and hemoglobin to become supersaturated, enhancing oxygen delivery to all tissues. The higher pressure also drives oxygen directly through the skin, raising the oxygen level in all tissues by that route as well.

HBO schedules vary. Most conditions require intermittent treatment: a typical session lasts between 60 and 90 minutes, with one or two sessions prescribed daily for two to four weeks. Carbon monoxide poisoning and decompression illness are always treated with a single, longer session.

Each session consists of three phases: compression, constant pressure, and decompression. To understand what a patient is likely to experience during each phase, it will help to know the laws of physics that apply.

- *Dalton's law* states that the total pressure of a gas mixture is equal to the sum of the partial pressures of each gas in the mixture; for example, the total pressure of air equals the sum of the partial pressures of nitrogen, oxygen, and air's other component gases. Although HBO therapy typically uses 100% pure oxygen, room air may be used, or helium added (to treat nitrogen narcosis), without adversely affecting atmospheric pressure.

Compression. During this phase, atmospheric pressure inside the chamber is raised to a prescribed level above normal. This generally takes between six and 10 minutes to achieve, and sometimes as long as 30 minutes.

- *Boyle's law* states that if the temperature and mass of a gas remain constant, its volume will be inversely proportional to its pressure (as pressure increases, volume decreases). Therefore, the volume of any gas-containing body cavity will change as the pressure of the external environment increases or decreases. For example, as atmospheric pressure rises during compression, pressure will temporarily be greater outside the body than inside the eustachian tubes, and may push the tympanic membrane inward. The patient may also report feeling "weight" around him, similar to the sensation of being underwater.

- *Gay-Lussac's law* states that if the volume of a gas remains constant, its pressure will be directly proportional to its temperature. Thus, from an optimal starting temperature inside an HBO chamber of 70°F, temperature may increase to as high as 80°F during compression (the patient may report feeling warm) and decrease to as low as 65°F during decompression (the patient may report feeling cool).

Constant pressure. Atmospheric pressure is held at a prescribed level above normal for a prescribed length of time, usually between 60 and 90 (and not more than 120) minutes. Prescribed treatment pressure and duration of chamber time will be determined by the type of pathogen present at a wound site and other factors such as the degree of revascularization around the affected tissues.

Decompression. Atmospheric pressure inside the chamber is decreased to normal. Decompression generally takes between six and 10 minutes but can last as long as 30 minutes.

▲ A topical HBO chamber.
(Photo courtesy of Advanced Hyperbaric Technologies, Inc.)

Benefits of HBO

For wound healing and other approved indications, evidence has shown benefits of HBO therapy, including

increased tissue oxygen perfusion. Elevated blood oxygen levels can last for as long as four hours posttreatment, benefiting hypoxic areas such as chronically infected, wounded, or irradiated tissues.

- *Henry's law:* The degree to which a gas enters into solution in a liquid (such as plasma) is directly proportional to the partial pressure of the gas to which the liquid is exposed. Thus, the solubility of oxygen in plasma is enhanced by HBO.

enhanced wound healing. HBO therapy increases the partial pressure of arterial oxygen (PaO2), resulting in vasoconstriction, which can aid the treatment of trauma wounds by reducing edema, reducing capillary pressure, and allowing a better flow of hyper-oxygenated plasma to the tissues. Hyperoxia also enhances collagen formation, which is vital to healing.

increased neo- and revascularization. HBO therapy is intermittent: periods of hyperoxia (during treatments) alternate with periods of either normal oxygenation or hypoxia (between treatments). This pattern results in increased capillary formation and improved circulation to tissues.

inhibition of anaerobic toxins. Increased tissue oxygenation causes bacteriostasis of anaerobic bacteria, including gas gangrene toxins.

Other potential benefits of hyperbaric therapy are still being investigated.

Side Effects

Ears, nose, and throat. Gas-filled cavities such as the paranasal sinuses expand during HBO therapy, and otic or sinus barotrauma may occur. Swallowing, which temporarily increases pressure in the middle ear, can open the eustachian tubes and help equalize pressure. But an upper respiratory infection can obstruct the eustachian tubes. And because a child's eustachian tubes are shorter and straighter than an adult's, children are predisposed to otitis media, which, if present, raises the risk of otic barotrauma during HBO therapy.

Transmission of sound is altered at higher than normal atmospheric pressure, resulting in temporary changes to vocal quality and pitch. As atmospheric pressure increases, so does atmospheric density, which affects how the vocal cords vibrate and may cause the voice to sound either higher or lower than usual.

Eyes. Some patients report either better or worse vision during HBO therapy, resulting from changes to the shape of the lens, which tends to flatten under increased atmospheric pressure. This can result in temporary myopia, and it can worsen existing myopia in adolescents and adults. Changes in visual acuity are less noticeable in pediatric patients because eye tissues don't mature until after age seven. Although such changes are temporary, recovery of previous visual acuity may be slow.

Lungs. In a patient with an obstructed airway (for example, as a result of asthma or a tumor), the trapped air can result in pulmonary barotrauma when the gas expands, causing alveolar overdistention and rupture. Pneumothorax or gas embolism can also occur.

As atmospheric pressure increases, gas density increases also, making breathing more difficult. Patients who experience dyspnea or are intubated may have increased respiratory problems in a hyperbaric chamber.

Oxygen can be toxic to the lungs. After 72 hours of continuously breathing 100% oxygen at increased atmospheric pressures, the alveolar lining can be damaged.[8] However, the intermittent nature of HBO therapy means there is minimal risk to pulmonary function.[9] Signs and symptoms of pulmonary oxygen toxicity include chest discomfort, burning on inspiration, cough, and difficulty breathing.

Central nervous system. Neurologic oxygen toxicity caused by HBO therapy occurs most often when hyperbaric pressure reaches 4 ATA but can occur at any time during treatment. Signs and symptoms include tremors and seizures.

Cardiovascular system. Cardiac output is dependent on oxygen levels in the tissue. HBO therapy increases tissue oxygenation, resulting in reduced cardiac output and bradycardia. Signs and symptoms include slowed pulse when compared with baseline.

When divers ascend too rapidly, gas embolisms can occur in tissues and blood vessels. (Although gas embolism is also a slight risk during HBO therapy, the decompression rate is controlled to prevent this complication.)

Relative and Absolute Contraindications

Relative contraindications. The following conditions may place patients at higher risk during HBO therapy.

Upper respiratory infection can preclude clearing of the eustachian tubes and equalizing of internal (sinus) and external pressure. If HBO therapy is essential, patients with such infections should receive decongestants beforehand. Alternatively, the primary care physician may insert tympanostomy pressure-equalizer (PE) tubes or perform a myringotomy before HBO therapy is initiated.

Otitis media is a relative contraindication, unless PE tubes have been inserted.

Hypertension. HBO therapy causes vasoconstriction and can result in hypertensive crisis. The risk diminishes if the patient's hypertension is well controlled by medication.

Graves's disease or any thyroid disorder being treated with thyroid hormone increases the metabolic rate. In conjunction with HBO therapy, this can cause oxygen toxicity. A dosage adjustment may be necessary, and the patient must be closely monitored.

Seizure disorders (such as epilepsy). HBO therapy can disrupt the process (known as the hemoglobin–oxygen buffering mechanism) by which oxidizing free radicals are removed from tissue. This can result in the oxidation of polyunsaturated fatty acids that are normally present in cells; because central nervous system tissue has a high lipid content, it is highly vulnerable.[8] Thus, central nervous system oxygen toxicity lowers the seizure threshold in patients susceptible to seizures. Seizure disorders may necessitate a dosage adjustment or the addition of a benzodiazepine before HBO therapy is administered.

High fever can lead to convulsions in the HBO chamber. Young, febrile children who have seizure disorders may have a toxic reaction to HBO, caused by an increase in the partial pressure of carbon dioxide (PaCO2) level, and the resultant cerebral edema can provoke seizures. A lower atmospheric pressure of oxygen may be required to help normalize the PaCO2 level in a febrile patient. Hypothermia blankets and other cooling measures may be prescribed.

Diabetes mellitus types 1 and 2. HBO therapy has been shown to lower blood glucose levels.[10, 11] Special precautions must be taken, including monitoring blood glucose levels before and immediately after treatment.

Menstruation can lead to a greater risk for decompression illness in the early phase of the menstrual cycle[12]; even a slight increase in discharge at any time during the course of treatment must be brought to the HBO therapy physician's attention for evaluation.

Eye pathology, including any optic nerve or retinal disorder, necessitates evaluation by an ophthalmologist before administration of HBO therapy.

Pregnancy. There should be no adverse effects from HBO therapy if treatment isn't prolonged (no session lasting longer than 120 minutes). But even with short, intermittent treatment sessions, there is a small risk to the fetus that high oxygen levels will stimulate the muscles around the ductus arteriosus to contract, closing it and causing fetal death.

Infancy. In premature infants, high oxygen levels can be toxic to the eye vasculature and can worsen bronchopulmonary dysplasia. In neonates, retrolental fibroplasia is a prominent risk factor when the infant is placed in a high-oxygen atmosphere. The potential for oxygen toxicity (manifested by bronchopulmonary dysplasia in an infant with pulmonary surfactant deficits or in an infant receiving assisted ventilation) must be considered.

Absolute contraindications. The following conditions absolutely contraindicate the administration of HBO therapy.

Some types of congenital heart disease. Any cardiac anomaly that results in restriction of right ventricular outflow to the lungs might require the ductus arteriosus to remain patent for the patient to survive. HBO therapy can be lethal to such a patient because oxygen promotes the closure of the ductus arteriosus.

Obstructed airway or restrictive airway disease (such as asthma) can cause local trapping of air during HBO decompression. The expanding gas can lead to alveolar rupture. In the case of emphysema with carbon dioxide retention, the retention of CO2 also causes respiratory acidosis and cerebral edema, which can lead to respiratory depression, hypoxia, and death.

Recent thoracic surgery. Air trapped in the thorax can expand during HBO therapy and result in pneumothorax.

Untreated pneumothorax can become a tension pneumothorax during HBO therapy.

Unstable seizure disorders (such as unstable epilepsy). If a patient has a seizure inside a monoplace chamber, the provider can't immediately give care. (Unstable seizure disorders are not absolute contraindications to HBO therapy if the patient can be treated in a multiplace chamber.)

Pregnancy is an absolute contraindication for HBO therapy if treatment lasts more than 120 minutes in a given session. Therapy longer than 12 continuous hours greatly increases the risk of the fetal ductus arteriosus closing, resulting in fetal death. (Although 12 continuous hours of treatment is an unusual prescription, it has been used to treat decompression illness.)

Infancy. When an infant with a congenital heart defect is dependent on a patent ductus arteriosus for survival, HBO therapy is absolutely contraindicated.

Preparation and Pretreatment

Education, including an explanation of risk, and the obtaining of informed consent constitute the first steps in preparing patients for HBO therapy. Explain to patients and their families what to expect during and after a treatment session, and give them the opportunity to talk about their concerns before therapy begins.

Assessment includes physical, psychological, and psychosocial evaluation. Record current vital signs. Note in particular the presence of upset stomach, headache, sinus conditions, cold or flu, and ear pain. Include blood glucose testing if the patient has diabetes. Note the most recent voiding times for bladder and bowel. Include a dental treatment history; temporary dental fillings can trap air, which will expand during decompression, causing severe pain.

With a patient new to HBO therapy, note risks with regard to diagnosis; and with all patients, note changes in overall status as they occur. Maintain communication with the multidisciplinary team. (For example, you may find that a woman undergoing daily HBO therapy has begun to menstruate, placing her at higher risk for decompression illness. In such a case, notify the HBO therapy physician and other members of the team. Delay of HBO therapy for a few days may be indicated.)

In conjunction with HBO therapy, the following all increase the risk of oxygen toxicity: steroid use, fever, history of seizures, vitamin E deficiency, use of vasodilators or antioxidants, acetazolamide treatment, and low pH level (acidosis). Close patient monitoring will be required; delay of HBO therapy may be indicated.

There is an inherently higher risk of a flash fire in an oxygen-rich environment under increased atmospheric pressure. All standard precautions related to oxygen therapy hazards should be posted and observed in and around the HBO unit. All materials that support combustion, items that can hold static electricity, and objects that may discharge sparks must not be permitted in or near the HBO chamber. No synthetic rubber, plastic (including Styrofoam), or metal items can be taken into the chamber.

Ensure that all removable items have been removed, including jewelry, dental spacers, ear plugs, hair clips, and canvas splints. HBO therapy is rarely given so soon postoperatively that surgical clips or staples would still be in place, but if the patient has these or orthopedic hardware, cardiac valves, or temporary dental fillings, notify the HBO therapy physician of their presence. Contact lenses should not be worn in the HBO chamber: the increased pressure slightly changes the contour of the eye and possibly that of the contact lens also, which can result in injury. Battery-powered toys, radios, hearing aids, or other devices, as well as any metal or "friction" toys (anything that can hold static electricity) cannot be taken into the chamber. Cosmetics, hair sprays or gels, alcohol-based creams, oils, and mafenide (Sulfamylon) cream or powder must also be removed because all contain combustible ingredients. All food must be left outside the chamber.

Make sure that the patient is wearing clean, 100% cotton clothing and coverings. (Check labels; even patient gowns are sometimes made of blended materials, such as cotton and polyester.) A woman who is menstruating should wear only all-cotton sanitary pads or tampons. Infants should wear cotton diapers.

Secure dressings using only paper tape. Check extension tubing on all IV lines and make sure any attached metal items (such as clamps) have been removed. Make sure that the ends of any nasogastric tubes are secured with the correct plugs or caps. Petrolatum gauze covered by an occlusive dressing on a chest tube insertion site may be allowed in the chamber.

HBO therapy results in short-term decreased immune system response that enhances allografts, but patients must be monitored for infections.[13] Therefore, immunizations should not be given just before or during the course of therapy.

Otic barotrauma, such as effusion and otitis media, is a common complication of HBO therapy, especially in infants and young children. To help equalize internal (ear and sinus) and external pressures, infants who are not allergic to latex may be given a latex pacifier to suck on. (Most pacifiers are made of synthetic rubber, a petrochemical product, which is not safe for use inside an HBO chamber.) Young children can be taught how to yawn, swallow, or mimic chewing. Adolescents and adults may also be taught to perform gentle Valsalva maneuvers. Pretreatment with vasoconstricting nose drops or spray may be prescribed to prevent occlusion of the eustachian tubes. For patients who require repeated HBO therapy, insertion of tympanostomy PE tubes may be considered.

Before beginning HBO therapy with a patient who has an endotracheal tube, check for upper respiratory infection and ask about history of pulmonary problems such as restrictive airway disease. Endotracheal tube cuffs inflated at normal atmospheric pressure will decrease in volume as atmospheric pressure increases. Pretreatment precautions include inflating the cuff with saline instead of air, to preserve cuff integrity under pressure; this will help prevent dislodgment of the tube.

Patients are usually medicated before HBO therapy. Drugs commonly used include diazepam to reduce anxiety and the risk of oxygen convulsions; oxymetazoline nasal drops to clear nasal passages and reduce eustachian tube blockage; and vitamin E (given orally) to protect against pulmonary oxygen toxicity and reduce the risk of related convulsions.

During compression, the rise in temperature may cause the patient to feel too warm. (The temperature rise can often be controlled by venting, a process managed by the CHT or CHRN.) Patients may use a cool, wet, cotton washcloth in the chamber to sponge themselves as needed. During constant pressure and decompression, patients will experience evaporative, convective, and conductive heat loss. Infants and young children will require special efforts to maintain normal body temperature, because they have a larger body surface area proportional to weight than do adults. Cotton blankets may be pre-warmed and kept nearby for use as needed.

Pediatric patients. Obtaining parents' informed consent should be part of the education process; telling parents and children what to expect both during and after treatment helps all involved. The better parents understand HBO therapy, the better they'll be able to help reduce their child's anxiety and increase adherence to required activities or restrictions. Note the presence of otitis media, the effects of confinement and isolation during treatment, the quality of interactions between parent and child, and the stability of vital signs.

Distraction during treatment can be invaluable. Monoplace chambers usually have acrylic windows and are equipped with a microphone and speakers to permit two-way conversation. Let parents know that they may read to their child; patients can also watch television or videotapes through the window. Few toys can be taken into a hyperbaric chamber—cotton stuffed toys and all-cotton blankets are allowed, but toys that could hold static electricity or produce sparks are not. Conscious sedation may be indicated in anxious children (in which case an advanced practice care giver or HBO therapy physician monitors the patient, in cooperation with the CHT or CHRN). More restrictive restraints usually result in increased anxiety and "fighting," which could lead to vomiting or aspiration and are not recommended for use in a monoplace chamber to which immediate access is limited.

If an infant or young child is on mechanical ventilation, a myringotomy may be necessary to prevent otic barotrauma, as any nasopharyngeal edema can obstruct the eustachian tubes.

Older adolescents and adults. As with younger patients, distraction is often effective in allaying fear. Family members can talk with the patient, or the patient can watch television or videotapes. Adolescents or adults may be given a mild sedative such as diphenhydramine before therapy begins, if needed (young children are prone to paradoxical hyperactivity reactions to this medication).

Because caffeine interferes with the absorption of oxygen by the tissues, all caffeinated beverages should be withheld 12 to 24 hours before treatment.[14] (The amount of caffeine in chocolate and most other sources is not high enough to be clinically significant.)

Smoking causes vasoconstriction and can impair tissue healing. Further, burning tobacco produces carbon monoxide, which competes with oxygen in binding to hemoglobin, thus decreasing its oxygen-carrying capacity. Encourage patients not to smoke any form of tobacco for the duration of HBO therapy. Pharmacologic assistance or social support may be necessary. Assessment for this risk factor is essential in all patients requiring HBO therapy, especially adolescents, who may already have begun smoking, usually without their parents' knowledge.

Potential Drug Interactions with Hyperbaric Oxygen Therapy	
Doxorubicin (Adriamycin)	At least one week should separate HBO therapy and doxorubicin therapy to avoid increased mortality resulting from cardiac toxicity.
Mafenide (Sulfamylon)	Frequently used for burn therapy, mafenide is contraindicated in an HBO environment. Both the powder and cream forms are hydrocarbon based and are therefore combustible.
Steroids	Steroids can cause oxygen toxicity and convulsions. If steroid treatment is essential, anticonvulsants should be prescribed and the patient should be observed closely for signs of convulsions.
Morphine or meperidine	Narcotics and high oxygen concentrations each cause respiratory depression. This results in increased blood flow to the brain to maintain tissue oxygen perfusion; but it can also precipitate oxygen toxicity, manifested by convulsions.
Anesthetics	Local anesthesia is safe in HBO chambers. General anesthesia poses safety risks (in terms of both dosages and flammability). Ketamine (Ketalar) is safe to use in the chamber but requires an anesthesiologist in attendance to deal with emergency respiratory complications.
Anticonvulsants	Anticonvulsants are often used prophylactically in HBO chambers. However, oxygen-induced damage to the central nervous system is still a risk if HBO treatment is prolonged.
Barbiturates	These drugs may be used to suppress convulsions, but they do not relieve oxygen toxicity to the tissues. Observe for respiratory depression. Diazepam (Valium) or lorazepam (Ativan) are the drugs of choice to reduce anxiety and suppress

	convulsions in the HBO chamber.
Insulin	The blood glucose levels of patients with diabetes may fall rapidly during HBO therapy. The care giver should check blood glucose levels pre- and post- HBO. Sliding-scale insulin dosages and orange juice should be available.
Acetazolamide (Diamox)	This drug prevents oxygen-induced vasoconstriction, thereby increasing cerebral blood flow, which in turn predisposes patients to convulsions resulting from oxygen toxicity. The drug is contraindicated with HBO therapy above 2 ATAs of pressure. To prevent convulsions, diazepam may be given with acetazolamide.
Thyroid hormone (natural or synthetic)	Administration of thyroid hormone or the presence of Grave's disease during HBO therapy increases the metabolic rate, causing oxygen toxicity. HBO therapy is not recommended for those patients receiving thyroid hormones.
Chlorpromazine (Thorazine)	This drug protects against oxygen toxicity convulsions by acting on the sympathetic nervous system and having an antiepinephrine effect. Observe for tremors or convulsions if high doses are used or carbon monoxide poisoning is involved.
Sources: McDougald JA. *The essentials of hyperbaric medicine.* Riverside (CA): Riverside General Hospital; 1991; McArthur CLI, Lockridge H. *The essentials of hyperbaric medicine. 2nd ed.* Riverside (CA): Riverside General Hospital; 2000; Kindwall EP. Contraindications and side effects of HBO treatment. In: *Hyperbaric medicine practice. 2nd ed.* Flagstaff (AZ): Best Publishing; 1995. p. 47-55; Miller BF, Keane CB. *Miller-Keane encyclopedia and dictionary of medicine, nursing and allied health. 6th ed.* Philadelphia: Saunders; 1997; Wilson BA, et al., editors. *Nurses' drug guide.* Norwalk (CT): Appleton & Lange; 2000; *Skidmore-Roth L. Mosby's 2000 nursing drug reference.* St. Louis: Mosby-Yearbook; 2000; Lininger SW, editor. *A–Z guide to drug–herb– vitamin interactions.* Rocklin (CA): Prima Health; 1999.	

During the Treatment Sessions

The main adverse reactions that can occur during HBO therapy include barotrauma, gas embolism, oxygen toxicity, claustrophobia, and anxiety. Monitor and document vital signs frequently and check that the equipment necessary to handle these potential complications is readily available.

Monitor for substernal chest discomfort or pain, dyspnea, cough, pain on inspiration, and tremors or seizures, which may indicate pulmonary oxygen toxicity.

Check for signs of anxiety. Any significant vital sign changes or restlessness should be reported to the HBO therapy physician. Reassure the patient and family members, and provide diversion for the patient during treatment. Administer antianxiety medications as ordered. Note the patient's response to these interventions. Although HBO therapy cannot be terminated without adequate decompression time, the CHRN may begin decompression early if she thinks the patient isn't responding well.

Monitor the patient's level of consciousness and blood pressure pre- and posttreatment, and observe for signs of nitrogen narcosis—euphoria, followed by impaired judgment, disorientation, and decreased coordination—especially if compressed air is used instead of 100% oxygen (as it may be when treating decompression illness). Although the risk for nitrogen narcosis decreases when 100% oxygen is used, nitrogen is present in the air we breathe and in our bodies. As with decompression illness, if decompression occurs too fast, more and larger bubbles may form and can mechanically deform tissue and obstruct blood vessels, causing nitrogen narcosis. But note that high nitrogen levels produce an anesthetic effect on the brain. A patient with decompression illness or nitrogen narcosis may be asymptomatic, with no complaints of muscle or joint aches and exhibiting no muscle tremors, or seizures.

Observe closely for muscle twitching or seizures during decompression, which may indicate oxygen toxicity. If either occurs, decompression should be stopped until vital signs are stabilized.

Routine decompression and removal of the patient from the chamber can usually be accomplished within 15 minutes; these have been performed in fewer than 90 seconds in emergency situations. But rapid decompression and removal occurring in less than six minutes carry increasing risks, including that of closure of the glottis, which is life threatening. Any decision to do so must involve weighing all the risks.

Drugs are not usually administered inside a monoplace chamber because caregivers don't have immediate access to patients; thus, there's no danger of implosion of glass vials. Drugs are sometimes administered (by the CHRN, not the staff care giver) inside a multiplace chamber. The larger the glass vial, the greater the implosion risk; only 10-cc or smaller vials should be used. If drug administration is required during a treatment session, the oral or IV route (using a high-pressure iv pump) is preferred. Intravenous solutions in glass bottles should not be used unless appropriate precautions are taken to prevent a large bolus of the IV solution from being forced into the patient's circulatory system during decompression. Since vasodilation occurs immediately after therapy, an uncontrolled release of a drug that was peripherally administered during the HBO therapy may occur, which can result in a toxic response. Drugs should not be stored in an HBO chamber, as this can alter their potency.

Post-HBO

Barotrauma, causing bleeding and edema of the eustachian tubes and other structures of the middle ear and possible rupture of the tympanic membrane, may not become evident until after the treatment session ends. Patients may complain of earache. Tympanic rupture usually is evidenced by ear drainage within an hour posttreatment; other problems can manifest more slowly. Hearing loss, tinnitus, a sensation of excessive sinus pressure, tooth pain, or nystagmus may indicate a serious complication and should be reported to the HBO physician and recorded in the patient's chart.

Tinnitus, paresthesia or tingling, blurred vision, and palpitations are all signs of oxygen toxicity affecting the central nervous system. These conditions must be reported to the HBO therapy physician and closely monitored. It's essential that they be recorded in the patient's chart so that progress can be assessed.

If substernal chest pain and cough develop between treatment sessions, with no evidence of other causes, the HBO therapy and primary care physicians should be notified before the next treatment session. These can be early indicators of pulmonary oxygen toxicity.

Headache or pain over the sphenoid or frontal sinus can indicate complications involving the sinuses.

Patients who experience worsened vision should be cautioned not to seek a new prescription for corrective lenses, as most patients' eyes return to pretreatment acuity within a few months after HBO therapy has ended.

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Examination

Select the ***best*** answer to each of the following items. Mark your responses on the Answer form.

1. The air we breathe contains _____ oxygen.

a. 9.5%
b. 15%
c. 21%
d. 33%

2. Hyperbaric oxygen therapy is the administration of _____ oxygen at two to three times atmospheric pressure.

a. 40%
b. 60%
c. 75%
d. 100%

3. Multiplace chambers accommodate between four and _____ patients.

a. seven
b. fifteen
c. twenty-four
d. fifty five

4. The _____ was founded in 1967 and is the major scientific society for hyperbaric oxygen therapy in the United States.

a. Jacques Cousteau Society
b. Undersea and Hyperbaric Medicine Society (UHMS)
c. Hyperbaric Oxygen Therapy Committee
d. American Hyperbaric Therapy Society (AHTS)

5. Hyperbaric oxygen therapy is also used in the treatment of _____ poisoning and smoke inhalation.

a. carbon dioxide
b. carbon monoxide
c. nitric oxide
d. all of the above

6. *Clostridia* myonecrosis, otherwise known as _____, is a severe infection caused by gram positive bacteria of the *Clostridia* variation.

a. the bends
b. gas gangrene
c. gas embolism
d. fibroplast infection

7. Research indicates that hyperbaric oxygen therapy acts as an alpha-adrenergic drug, which causes vasoconstriction.

a. True
b. False

8. The most common side effect of HBO therapy is a "crackling" sound in the ears between treatments.

a. True
b. False

9. Much less frequently, a temporary change in vision is experienced. This alteration in vision returns to its normal state within six to eight days after treatment has finished.

a. True
b. False

10. Contraindications for administration of hyperbaric oxygen therapy include:

a. History of thoracic surgery
b. Pneumothorax
c. Severe chronic obstructive pulmonary disease with carbon dioxide retention
d. All of the above

11. The most common use of HBO therapy among pediatric patients is for carbon monoxide poisoning.

a. True
b. False

12. The Undersea and Hyperbaric Medical Society approves the use of hyperbaric therapy for many conditions, which are accepted by third-party payers and Medicare.

a. True
b. False

13. As early as _____ experimental clinical applications of hyperbaric medicine were reportedly used with patients who had tuberculosis and other chronic diseases.

a. 1492
b. 1662
c. 1830
d. 1867

14. _____ states that the total pressure of a gas mixture is equal to the sum of the partial pressures of each gas in the mixture; for example, the total pressure of air equals the sum of the partial pressures of nitrogen, oxygen, and air’s other component gases

a. *Boyle's law*
b. *Dalton's law*
c. *Gay-Lussac's law*
d. *Henry's law*

15. HBO therapy decreases the partial pressure of arterial oxygen (PaO2), resulting in vasoconstriction, which can aid the treatment of trauma wounds by reducing edema, reducing capillary pressure, and allowing a better flow of hyper-oxygenated plasma to the tissues.

a. True
b. False

16. Oxygen can be toxic to the lungs. After 72 hours of continuously breathing 100% oxygen at increased atmospheric pressures, the alveolar lining can be damaged.

a. True
b. False

17. *Menstruation* can lead to a greater risk for decompression illness in the early phase of the menstrual cycle; even a slight increase in discharge at any time during the course of treatment must be brought to the HBO therapy physician's attention for evaluation.

a. True
b. False

18. HBO therapy was introduced in the United States in _____, primarily as treatment for "nervous" disorders and influenza and other respiratory conditions.

a. 1800
b. 1830
c. 1861
d. 1907

19. The following conditions absolutely contraindicate the administration of HBO therapy:
a. some types of congenital heart disease
b. obstructed airway or restrictive airway disease (such as asthma)
c. recent thoracic surgery
d. all of the above

20. HBO therapy results in long-term decreased immune system response that enhances allografts, but patients must be monitored for infections.

a. True
b. False

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