Hyperbaric oxygen therapy

Definition

Hyperbaric oxygen therapy (HBOT) is breathing 100% oxygen while under increased atmospheric pressure.

Oxygen Chambers

When a patient is given 100% oxygen under pressure, hemoglobin is saturated, but the blood can be hyperoxygenated by dissolving oxygen within the plasma. The patient can be administered systemic oxygen via 2 basic chambers:

- Type A, multiplace;
- Type B, monoplace.

Both types can be used for routine wound care, treatment of most dive injuries, and treatment of patients who are ventilated or in critical care.

Multiplace chamber

Multiplace chambers treat multiple patients at the same time, generally with a nurse or another inside observer who monitors the patients and assists with equipment manipulation or emergencies. Patients in a multiplace chamber breathe 100% oxygen via a mask or close-fitting plastic hood. Multiplace chambers can usually be pressurized to the equivalent of about 6 atmospheres of pressure.

If a different mixture of gas (nitrogen or helium mixture) is desired, the mixture can be given, via the mask, to only the patient, not the employee. All equipment used with patients, such as ventilators and intravenous lines, is put into the chamber with the patient. Since the employee is breathing air during the treatment (not using a mask), his or her nitrogen intake must be monitored, as this presents a risk for problems similar to those sometimes developed by scuba divers (eg, decompression sickness [DCS]).

Rectangular hyperbaric chamber.

Interior of rectangular chamber.

Cylindrical multiplace chamber.

Monoplace chamber

A monoplace chamber compresses one person at a time, usually in a reclining position (see image below). The gas used to pressurize the vessel is usually 100% oxygen. Some chambers have masks available to provide an alternate breathing gas (such as air). Employees tend to the patient from outside of the chamber and equipment remains outside the chamber; only certain intravenous lines and ventilation ducts penetrate through the hull. Newer Duoplace chambers can hold 2 people; their operation is similar to that of a monoplace chamber.

Monoplace chamber.

Hyperbaric Physics and Physiology

Physics of Hyperbaric Medicine

The physics behind hyperbaric oxygen therapy (HBOT) lies within the ideal gas laws.

- The application of Boyle's law ($p_1\ v_1 = p_2\ v_2$) is seen in many aspects of HBOT. This can be useful with embolic phenomena such as decompression sickness (DCS) or arterial gas emboli (AGE). As the pressure is increased, the volume of the concerning bubble decreases. This also becomes important with chamber decompression; if a patient holds her breath, the volume of the gas trapped in the lungs overexpands and causes a pneumothorax.
- Charles' law ($[p_1\ v_1]/T_1 = [p_2\ v_2]/T_2$) explains the temperature increase when the vessel is pressurized and the decrease in temperature with depressurization. This is important to remember when treating children or patients who are very sick or are intubated.
- Henry's law states that the amount of gas dissolved in a liquid is equal to the partial pressure of the gas exerted on the surface of the liquid. By increasing the atmospheric pressure in the chamber, more oxygen can be dissolved into the plasma than would be seen at surface pressure.

The clinician must be able to calculate how much oxygen a patient is receiving. In order to standardize this amount, atmospheres absolute (ATA) are used. This can be calculated from the percentage of oxygen in the gas mixture (usually 100% in HBOT; 21% if using air) and multiplied by the pressure. The pressure is expressed in feet of seawater (fsw), which is the pressure experienced if one were descending to that depth while in seawater. Depth and pressure can be measured in many ways; some common conversions are 1 atmosphere (atm) = 33 feet of seawater (fsw) = 10 meters of sea water (msw) = 14.7 pounds per square inch (psi) = 1.01 bar.

Hyperbaric Physiology

The table below summarizes the physiologic mechanisms of HBOT with their clinical application

Mechanism	Clinical application
Hyperoxygenation*	DCS/AGE CO poisoning Central retinal artery occlusion Crush injury/compartment syndrome Compromised grafts and flaps Severe blood loss anemia
Decrease gas bubble size	Air or gas embolism
Vasoconstriction †	Crush injury/compartment syndrome Thermal burns
Angiogenesis	Problem wounds Compromised grafts and flaps Delayed radiation injury
Fibroblast proliferation/collagen synthesis	Problem wounds Delayed radiation injury
Leukocyte oxidative killing ‡	Necrotizing soft tissue infections Refractory osteomyelitis Problem wounds
Reduces intravascular leukocyte adherence	Crush injury/compartment syndrome
Reduces lipid peroxidation	CO poisoning Crush injury/compartment syndrome
Toxin inhibition	Clostridial myonecrosis
Antibiotic synergy	Necrotizing soft tissue infections Refractory osteomyelitis

Additionally, evidence is growing that HBOT alters the levels of proinflammatory mediators and may blunt the inflammatory cascade. More studies are needed to further elucidate this complex interaction.
As HBOT is known to decrease heart rate while maintaining stroke volume, it has the potential to decrease cardiac output. At the same time, through systemic vasoconstriction, HBOT increases afterload. This combined effect can exacerbate congestive heart failure in patients with severe disease; however, clinically significant worsening of congestive heart failure is rare.

Contraindications

As with most medical treatments, absolute and relative contraindications exist with the use of hyperbaric oxygen therapy (HBOT).

Absolute Contraindications to Hyperbaric Oxygen Therapy

Absolute Contraindications	Reason Contraindicated	Necessary Conditions Prior to HBOT
Untreated pneumothorax	Gas emboli Tension pneumothorax Pneumomediastinum	Thoracostomy
Bleomycin	Interstitial pneumonitis	No treatment for extended time from use of medication
Disulfiram	Blocks superoxide dismutase, which is protective against oxygen toxicity	Discontinue medication
Doxorubicin	Cardiotoxicity	Discontinue medication
Sulfamylon	Impaired wound healing	Discontinue and remove medication
Cisplatin	Impaired wound healing	No treatment for extended time from use of medication

Relative Contraindications to Hyperbaric Oxygen Therapy

Relative Contraindications	Reason Contraindicated	Necessary Conditions Prior to HBOT
Asthma	Air trapping upon ascent leading to pneumothorax	Must be well controlled with medications
Claustrophobia	Anxiety	Treatment with benzodiazepines
Congenital spherocytosis	Severe hemolysis	None; HBOT for emergencies only
Chronic obstructive pulmonary disease (COPD)	Loss of hypoxic drive to breathe	Observation in chamber
Eustachian tube dysfunction	Barotrauma to tympanic membrane	Training, PE tubes
High fever	Higher risk of seizures	Provide antipyretic
Pacemakers or epidural pain pump	Malfunction or deformation of device under pressure	Ensure company has pressure-tested device and learn to what depth
Pregnancy	Unknown effect on fetus (Previous studies from Russia suggest HBOT is safe.)	None, but HBOT may be used in emergencies
Seizures	May have lower seizure threshold	Should be stable on medications; may be treated with benzodiazepines
Upper respiratory infection (URI)	Barotrauma	Resolution of symptoms or decongestants

Complications to Hyperbaric Oxygen Therapy

Barotrauma
Ear pain, fullness
Muffled hearing
Sinus pain or bleeding
Tooth pain
Dry cough
Chest pain or burning
Decreased vital capacity
Round or oval window blowout
Immediate deafness
Tinnitus
Nystagmus, vertigo, or both
Visual refraction change
Progressive myopia with prolonged number of treatments
Clouding of vision

Oxygen toxicity
Seizure
Dry cough
Chest pain or burning
Decreased vital capacity

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