Hyperbaric Oxygen Therapy

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INTRODUCTION

Hyperbaric oxygen therapy uses 100% oxygen delivered at atmospheric pressure 2-3 times normal atmospheric pressure. Hyperbaric oxygen therapy is used to treat carbon monoxide poisoning, decompression sickness, wound infections, and many other pathological conditions. For many of the clinical conditions for which hyperbaric oxygen therapy is used, there is no *definitive* evidence that hyperbaric oxygen is effective. Also, it has not been unequivocally established who should receive hyperbaric oxygen therapy, when they should receive it, or for how long. Although there is no conclusive evidence that hyperbaric oxygen therapy is effective, clinical experience strongly indicates that, for certain patients and situations, it can help. The therapy is widely used, and it is relatively safe and simple to use.

OBJECTIVES

When the student has finished this module, he/she will be able to:

1. Identify a definition of hyperbaric oxygen therapy.
2. Identify how oxygen is transported in the blood.
3. Identify the most important therapeutic mechanism of hyperbaric oxygen therapy.
4. Identify three clinical conditions for which hyperbaric oxygen can be used.
5. Identify two toxic mechanisms of CO poisoning.
6. Identify the therapeutic mechanism of hyperbaric oxygen in CO poisoning.
7. Identify three indications for using hyperbaric oxygen to treat CO poisoning.
8. Identify an absolute contraindication for using hyperbaric oxygen.

9. Identify the most common side effect of hyperbaric oxygen therapy.

10. Identify a relatively common, serious side effect of hyperbaric oxygen therapy.

THE ROLE OF OXYGEN IN THE BODY

Oxygen is essential for life. Oxygen is used by the body during oxidative phosphorylation, the process by which (most) adenosine triphosphate (ATP) is formed. Without oxygen the body cannot manufacture enough ATP to satisfy the metabolic needs of the cells and tissues. The oxygen content of atmospheric air is 21%. Almost all – 97% - of the inhaled oxygen that is transported by the blood is bound to hemoglobin. The remainder is dissolved in plasma and under normal circumstances this oxygen can only provide a small amount of what is needed by the tissues. Hemoglobin is a protein-iron complex that has four binding sites for oxygen molecules. Oxygen is released from hemoglobin to the tissues depending on the difference between the oxygen pressure (PO_2) in the blood and the PO_2 in the tissues.

HOW DOES HYPERBARIC OXYGEN THERAPY WORK?

Under normal circumstances, the process of respiration and the oxygen content of the inspired air can deliver an amount of oxygen that is sufficient to satisfy the metabolic needs of the tissues. However, if the tissue demands for oxygen exceed the capability of the vascular system and the lungs to deliver it, *or* there if there is a derangement of the oxygen carrying capacity of the blood, *or* if the 21% oxygen content of inspired air is not enough for the patient's needs, then supplemental oxygen therapy is needed. In the circumstances for which hyperbaric oxygen therapy is indicated, the tissue needs for oxygen are so high (e.g., wound infections) or the oxygen carrying capacity of the blood has been so severely affected (e.g., carbon monoxide poisoning) that giving normobaric (normal atmospheric pressure) supplemental oxygen, even at very high concentrations, won't be effective. Hyperbaric oxygen therapy delivers 100% oxygen at atmospheric pressures that are 2-3 times normal atmospheric pressure. This increases the amount of oxygen dissolved in plasma, and this is the basic, *primary* mechanism that justifies much of the use of hyperbaric oxygen therapy. There are other ways that hyperbaric oxygen works, *but for the majority of the clinical conditions for which hyperbaric oxygen is used, the most important therapeutic effect is delivering more oxygen to the body.*

WHAT ARE THE INDICATIONS FOR HYPERBARIC OXYGEN THERAPY?

The Undersea and Hyperbaric Medical Society-approved indications for hyperbaric oxygen therapy are:

- Acute thermal burn injury
- Air or gas embolism
- Carbon monoxide poisoning

- Carbon monoxide poisoning complicated by cyanide poisoning
- Central retinal artery occlusion
- Compromised tissue flaps and grafts
- Crush injury, compartment syndrome or other acute, traumatic injuries
- Decompression sickness
- Delayed radiation injury (Bony and soft tissue necrosis)
- Enhancement of wound healing in specific wounds
- Intracranial abscess
- Necrotizing soft tissue infections
- Osteomyelitis
- Severe anemia

Acute thermal burn injury, carbon monoxide poisoning, and **enhancement of wound healing** will be covered in this module.

HYPERBARIC OXYGEN THERAPY AND CARBON MONOXIDE POISONING

Carbon monoxide (CO) is a toxic gas that is produced by the combustion of carbon-containing fuels such as gasoline, natural gas, oil, etc. Carbon monoxide binds very intensely to hemoglobin: it has an affinity for hemoglobin that is 250 times that of oxygen. (Note: the combination of CO and hemoglobin is called carboxyhemoglobin, COHb). It also interferes with cellular respiration, it decreases the release of oxygen from hemoglobin to the tissues, and it is a potent vasodilator. All of these pathologic mechanisms greatly decrease oxygen carrying capacity, oxygen utilization, and oxygen delivery and produce intense hypoxemia. In the brain, CO causes tissue death by damaging cell membranes and it also initiates an inflammatory process that can cause serious, permanent neurological damage. Common signs and symptoms of CO poisoning include acidosis, arrhythmias, dizziness, dyspnea, headache, myocardial damage, tachycardia, and seizures.

Hyperbaric oxygen therapy is commonly used to treat CO poisoning. It increases the dissociation of COHb, it rapidly and dramatically decreases CO levels (the half-life of COHb while breathing room air is 4-6 hours, but it is 20-30 minutes with hyperbaric oxygen), it increases the plasma concentration of oxygen, and it increases dissociation of CO from cytochrome oxidase. These are important because they correct hypoxemia, but the *biggest* benefit of using hyperbaric oxygen therapy for CO poisoning is decreasing and/or preventing the leukocyte-mediated inflammation that causes neurological damage. **There is strong, convincing evidence that hyperbaric oxygen therapy can prevent neurological damage and/or**

decrease the severity of the damage, and that is why hyperbaric oxygen is used to treat CO poisoning.

There are no universally agreed upon criteria (e.g., age, COHb level, specific signs and symptoms) that outline which patients suffering from CO poisoning should – or should not –
be treated with hyperbaric oxygen. Most sources agree if the patient has any of the following demographic characteristics, laboratory values, or signs/symptoms, the patient should be treated with hyperbaric oxygen:

- Age > 50 years
- Arrhythmias
- Cardiac damage or ischemia
- COHb > 25%
- Loss of consciousness
- Metabolic acidosis
- Persistent depressed level of consciousness
- Seizure

Hyperbaric oxygen seems to be most effective for treating CO poisoning if it can be administered within 6 hours of the exposure, but later treatment may be helpful. Some treatment centers will administer several rounds of therapy, but some feel one is sufficient; at this time, there is no definitive evidence in favor of or against either approach. The endpoints of therapy are not well defined.

HYPERBARIC OXYGEN THERAPY AND WOUND HEALING

Hyperbaric oxygen has been used to treat chronic foot ulcers in patients with diabetes and to treat other types of non-healing wounds. It has many therapeutic mechanisms of action. It is bacteriostatic and bacteriocidal and these antimicrobial effects are very important as hypoxia impairs resistance to infection. It also increases oxygenation of tissues. As the rate of wound healing is directly related to the level of tissue oxygenation, and wound ischemia is the most common cause of failure to heal, the benefits of hyperbaric oxygen for wound healing are obvious. Hyperbaric oxygen therapy decreases inflammation and he increased oxygen content in the tissues promotes new blood vessel formation, collagen synthesis, and other components of tissue repair.

Hyperbaric oxygen is a well established therapy for treating wounds. Randomized clinical trials have shown that when it is used to treat ischemic foot ulcers caused by diabetes, it increases healing and decreases the incidence of leg amputation. Patients who will benefit from hyperbaric oxygen therapy are those with a wound that is hypoxic and those who respond to hyperbaric oxygen therapy. In order to identify appropriate

candidates for hyperbaric therapy, the oxygen pressure of the tissues is measured, and the patient is given a brief trial of hyperbaric oxygen. The wound must have a transcutaneous oxygen pressure less than 35 mm Hg (this indicates serious tissue hypoxia), and the oxygen pressure of the tissue must rise to >200 mm Hg after 10 minutes of hyperbaric oxygen therapy at 2-2.4 times normal atmospheric pressure.

HYPERBARIC OXYGEN THERAPY AND ACUTE THERMAL BURNS

Treating acute thermal burns is one of the approved indications for hyperbaric oxygen therapy. Although there is some support for using hyperbaric oxygen therapy to treat thermal burns caused by heat this does not appear to be a popular or widely used treatment for this type of injury. There is more experience and apparently more acceptance for using hyperbaric oxygen therapy to treat thermal burns caused by cold, i.e., frostbite. Frostbitten tissues are damaged by extreme cold, and are further damaged by damage tot the microcirculation. Conventional treatment for frostbite focuses on increasing circulation to the affected area, and in several case reports hyperbaric oxygen therapy has been shown to increase circulation and improve healing.

HOW IS HYPERBARIC OXYGEN DELIVERED?

Hyperbaric oxygen is delivered in a sealed chamber. The chamber may fit one patient a monoplace chamber) or it can fit several patients, a ventilator, a nurse, etc. The atmosphere in a monoplace chamber is 100% oxygen and the atmospheric pressure is 2-3 times higher than normal. In a multiplace chamber, the ambient air is compressed to an atmospheric pressure 2-3 times higher than normal and the patients breathe 100% oxygen from an outside source.

Hyperbaric oxygen seems to be most effective for treating CO poisoning if it can be administered within 6 hours of the exposure, but later treatment may be helpful. Most patients who have been exposed to CO receive one session of hyperbaric oxygen: a session is typically two hours long. Some treatment centers will administer several rounds of therapy, but some feel one is sufficient; at this time, there is no definitive evidence in favor of or against either approach. Patients who are being treated for non-healing wounds may be treated several times a week for many weeks.

CARING FOR THE PATIENT RECEIVING HYPERBARIC OXYGEN THERAPY

Hyperbaric oxygen therapy is relatively safe and simple. If the patient is clinically stable and is being treated for a non-healing wound or an acute thermal injury, no specific or special measures are needed to prepare the patient for the procedure, but the patient should be advised that he/she may feel claustrophobic during the session. If the patient is being treated for CO poisoning or is clinically unstable, pulmonary status and blood pressure must be closely monitored. Hypercapnia can increase the risk of seizures and seizures are relatively common toxic effect of CO poisoning. Hyperbaric oxygen decreases blood pressure, so if the patient is hypotensive or is receiving vasopressors, the blood pressure this can be a concern. Patients who have been intubated may need to be sedated, and the endotracheal tube cuff should be deflated and then filled with sterile saline because the high atmospheric pressure in the chamber will collapse the air in the cuff.

There are not many side effects of hyperbaric oxygen therapy and the most common ones are mild and self-limiting. Middle ear barotraumas such as bleeding, pain, and eardrum perforation occur in about 2% of all patients. Some hyperbaric treatment centers will insert tubes in the ears or perform a myringotomy (a small incision of the eardrum) to prevent ear barotraumas. Air embolization and pulmonary barotrauma are very rare adverse effects. Seizures are possible. The incidence has been reported to be 0.3% to 2.5%, but they can be managed with standard care and the patients do not suffer neurological damage. Transient myopia may occur if the patient has nore than 40 hyerbaric sessions, but after the therapy is stopped, vision returns to normal. Lung damage is a well-known complication of prolonged oxygen therapy, but very few hyperbaric oxygen therapy protocols would expose a patient to this risk. The absolute contraindications of for hyperbaric oxygen therapy are uncontrolled pneumothorax and current or recent treatment with adriamycin, belomycin, or doxorubicin.