CME

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Hyperbaric Oxygen Therapy

Key Points

1. Define hyperbaric oxygen
2. Understand the history and physiology of HBOT
3. Determine the current indications for HBO treatment
4. Identify contraindications, risk factors and side effects

Introduction

Many physicians have had little or no exposure to hyperbaric oxygen therapy (HBOT) or often have misconceptions about its use and effectiveness. However, in recent years there has been a rapidly growing interest due to the scientific model that has been applied, and medical facilities throughout the world are adding HBOT as adjunctive therapy for many varied conditions.

Hyperbaric oxygen therapy is defined as breathing 100% oxygen while in an enclosed system that is pressurized to greater than one atmosphere (sea level). It is <u>not</u> a topical therapy in which only the affected portion of the body is enclosed in an oxygen rich compartment. This therapy does not penetrate the skin to any specific degree and does not raise tissue PO_2. Medicare does not reimburse for this type of hyperbaric oxygen (HBO) treatment. Effectiveness is achieved only when pure oxygen is inhaled for a specific time period based on the diagnosis.

There are two types of HBO chambers: multiplace and monoplace. The multiplace chamber is attended inside by trained personnel and allows one or more patients to be treated with oxygen via mask, hood, or endotracheal tube. Oxygen-filled monoplace chambers are more common due to economics, and are similar in size and shape to a large tanning bed. A clear acrylic exterior allows the patient to communicate with the technician and utilize audio/video sources outside the chamber. For safety reasons (flammability) no electronics or objects of any kind are allowed inside. Fatalities have occurred due to incidents related to sparks from a child's toy, cell phones or from fumes generated by adhesives or print in books and magazines. The fumes act as an ignition source which can result in a fire. There has been no incidence of fire at any North American facilities.[1]

Historical Perspective

In 1662 a British physician constructed the first primitive hyperbaric chamber or "domicilium." Attached to the chamber was a pair of large organ bellows furnished with valves that allowed for compression or decompression. Another venture using hyperbaric technology included the 1928 steel bell hospital, or "hyperbaric hotel." It was six stories high with 72 rooms and luxury amenities including a piano on each floor. The AMA closed it down because no scientific evidence was available to justify the treatment of diabetes, cancer, and other conditions with compressed air. Legitimate use of hyperbarics was initiated during underwater bridge construction utilizing caissons. The first significant medical application of HBOT occurred in 1937 for the treatment of decompression illness (the bends). Cardiac surgeries in the late 1950s were sometimes performed in specially built hyperbaric operating rooms, but the costs and risks of this venture were no longer considered viable once the heart/lung machine was perfected.[2]

Physiology

Normally when breathing air which is 21% oxygen at sea level, 97% of Hb is saturated and plasma has 3% saturation. Sea level pressure is defined as 1 atmosphere (atm). It is also equivalent to 0 pounds per square inch (psi) and 1 atmosphere absolute (ATA). When the chamber is put under pressure these values all increase. A common treatment pressure is 2 ATA which equals a psi of 14.7. This would be the same pressure a diver would endure at 33 feet of sea water.

When the occupant is breathing 100% oxygen at 2 ATA the Hb remains fully saturated while the plasma concentration of O_2 increases linearly as more oxygen diffuses into the plasma. This O_2 enriched plasma is then carried to the tissues where the oxygen diffuses outward. In fact, in the 1966 landmark publication, Life Without Blood, Boermea reported the process of exchange transfusion with plasma expanders to produce hemoglobin levels of essentially zero. The experimental pigs remained functionally oxygenated via sufficiently elevated plasma oxygen levels at 3.0 ATA. It was therefore proven that plasma alone could do the work of red blood cells if subjected to oxygenated pressure. Arterial PO_2 elevation to 2200 can be achieved with 3.0 ATA. This is equivalent to a deep-sea dive to 66 feet. With a standard two hour therapy this effect can be expected to last two to four hours. Oxygen diffusion varies as a direct relationship to the concentration of oxygen in the circulating plasma. At 3.0 ATA the diffusion radius of oxygen into the extravascular compartment increases from a normal distance of 64 microns to 247 in the hyperbaric environment. This allows for more of the ischemic tissue to be perfused by oxygen.

Many positive healing effects are associated with HBOT. Angiogenesis, for example, has been shown to be positively influenced as well as others shown below.

Physiologic Benefits of HBOT

1. Improves leukocyte function and bacterial killing
2. Antibiotic potentiation
3. Enhances collagen synthesis and cross linking
4. Improves cellular metabolism and host immune response
5. Direct toxic affect to anaerobic bacteria
6. Inactivates clostridium toxin
7. Activates osteoclasts

Current Indications

The Undersea Hyperbaric Medical Society (UHMS) has been instrumental in promoting evidence based uses for HBOT, and only accepts treatments and protocols for medical conditions that have been shown in research to have significant benefits to the patient.[3] Each of these conditions is also covered by Medicare and most insurers.

1. Air or gas embolism
2. Carbon monoxide poisoning with or without cyanide poisoning
3. Clostridial myositis and myonecrosis (gas gangrene)
4. Crush injury, compartment syndrome and other acute ischemias
5. Decompression illness (the bends)
6. Enhancement of healing in selected problem wounds (diabetic foot ulcers)
7. Exceptional anemia
8. Intracranial abscess
9. Necrotizing soft tissue infections (includes necrotizing fasciitis and brown recluse spider bites)
10. Refractory osteomyelitis
11. Delayed radiation injury (soft tissue and bonynecrosis)
12. Failed or failing skin grafts and flaps
13. Thermal burns

There are "off-label" uses for HBOT which include Lyme disease, MS, AIDS, Chronic Fatigue Syndrome, CVA, myocardial infarction, bowel anastomosis and many others. Unfortunately, scientific, evidence-based studies are lacking.

Outpatients treated at facilities such as the Carle Wound Healing Center typically include nonacute individuals who are able to breathe on their own, do not require IVs or other medical lines, and do not require extensive medical monitoring. The majority of cases treated at these facilities include refractory diabetic foot wounds and osteomyelitis, failed flaps and grafts, radiation induced injury to soft tissue and bone, and osteoradionecrosis (ORN).

The typical patient who develops ORN has had prior radiation for head or neck cancer. The irradiated tissue thereafter suffers from hypoxia, hypocellularity and hypovascularity, leaving the patient at considerable risk for infection and nonhealing especially if an injury occurs to that tissue. The simple procedure of pulling a tooth in a formerly irradiated jaw can have devastating consequences. The mandible may be unable to heal leading to bony necrosis and overwhelming infection causing significant pain and disfigurement. There is very good evidence supporting the use of prophylactic HBOT as a precaution for these at-risk patients. The Marks protocol is 20 HBOT treatments (dives) before the dental procedure, then 10 post-dives to improve the chances of proper healing.[4] Also, if a patient already suffers from ORN, then HBOT is unfortunately the only treatment that may improve healing.

The epidemic of diabetes has subsequently resulted in an explosion of diabetic foot ulcers and amputations. Many of these are avoidable with early treatment. HBOT is one of the therapies that can be used for recalcitrant ulcers. To qualify, the patient must have been under treatment for 30 days with a Wegner's grade 3 or 4 ulcer, which essentially means the ulcer extends to bone or is associated with abscess. The patient should have a vascular evaluation to determine the need for revascularization, as this may be the reason for not healing. Finally, if all the above criteria are met but there remains some doubt about using HBO, a transcutaneous oxygen test (T_CPO_2) with a 100% O_2 challenge could also be helpful. To obtain the T_CPO_2 valve a heated probe is placed near the wound where values are initially obtained on room air. The heated probe causes capillary bed dilation with a corresponding release of oxygen molecules that are quantified by the probe. A second value is obtained while the patient has been breathing 100% oxygen. If there is a significant increase in the T_CPO_2 value the patient may be considered for HBOT treatment. For the diabetic foot ulcer the patient would typically have 30 consecutive daily dives, excluding weekends. The number of treatments varies depending on the diagnosis.

Radiation soft tissue necrosis is seen in patients who have had radiation treatment. Obviously most radiation treatments have been given for cancer; however, patients may have been irradiated for acne, Pilonidal cysts and various other conditions that have since fallen out of favor. A trauma or surgical incision upon irradiated tissue may result in slow or no healing. HBOT can dramatically improve these wounds as well as radiation-caused cystitis, proctitis, or enteritis. Patients who experience failed grafts or flaps, evidenced by necrotic edges, signs and symptoms of ischemia, hematoma, or infection are good candidates for HBOT. Only three to five dives may be required to save the flap.

Individuals suffering from chronic refractory osteomyelitis are candidates for HBOT if the following criteria are met:

1. No response after a four to six week course of antibiotic treatment
2. Failure to respond to surgical debridement
3. Positive imaging or biopsy
4. Recurrence of persistent infection despite six months of treatment

Contraindications, Risk Factors and Side Effects

Once a person is recognized as a candidate for HBOT, a history and physical must be obtained to determine if there are any contraindications to therapy.

1. Untreated pneumothorax
2. Prior chemotherapy treatment with Adriamycin or Bleomycin, current treatment with Cis-platinum, or Antabuse
3. Early model pacemakers not designed to tolerate pressure

Relative Contraindications Include

1. URI and chronic sinusitis – patients need to be able to "clear their ears" during the dive, which feels similar to ears popping during an airplane descent. If there is an accumulation of fluid in the ear, treatment may need to be delayed. Alternatively myringotomy tubes may be used to alleviate this issue.
2. Seizure disorder
3. Severe COPD or emphysema
4. High fever may lead to seizure. No diving if temperature is greater than 100°F.
5. History of spontaneous pneumothorax

Side Effects

1. Ear barotrauma – the most common complication of HBOT. This can frequently be avoided with proper patient education.
2. Sinus squeeze – discomfort felt in the sinuses with pressurization
3. Temporary myopia – with multiple treatments patients may notice some difficulty with distant vision while enjoying the temporary ability to read without glasses. This resolves within two months after completing HBOT.
4. Dental pain – air space left under a filling

5. Claustrophobia – with newer larger chambers this is less than 10 % and can be alleviated with benzodiazepines before treatment
6. Seizures – very rare from oxygen toxicity

Normal Treatment Procedure

The patient presents to the facility and changes into a 100% cotton gown. After reminded and checked for contraband, items that pose a risk for creating a spark, the vital signs are recorded. The blood sugar must be greater than 100 mg/dL as this level usually decreases during the dive. The physician performs a pre-dive exam and reviews all the vital information. Once cleared for the dive, the patient must be very diligent in clearing the ears during the first three feet of the descent, as this is the most significant period for barotrauma. The descent phase takes approximately 10 minutes. Once at "bottom" or fully pressurized, the patient remains for 90 minutes during which time s/he can watch an outside TV or listen to music. The decompression or ascent phase also takes approximately 10 minutes and is monitored by a technician who is in attendance from start to finish. After the treatment is completed, vital signs are rechecked and a post-dive exam is conducted by the physician.

Conclusion

Physicians are encouraged to consider HBOT for appropriate patients. In some cases this may be a life saving treatment, and in many other situations serious complications such as amputation and disfigurement can most definitely be avoided. HBOT is generally safe and well-tolerated.

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References

1. Sheffield, PJ, Desautels, DA. Hyperbaric and hypobaric chamber fires: a 73-year analysis. Undersea Hyper Med 1997;24(3):153-164.

2. Kindwall, EP. A History of Hyperbaric Medicine In: Hyperbaric Medicine Practice, 2nd Ed, Kindwall EP, editor, Flagstaff (AZ): Best Publishing Company; 1999. p. 1-20.

3. Feldmeier J: Hyperbaric Oxygen Committee Report 2003. Undersea and Hyperbaric Medical Society, Kensington, Maryland.

4. Marx, RE, 1983 Osteoradionecrosis: A New Concept in Pathophysiology. J Oral Maxillofacial Surgery 41;(5):283-288.

CME Questions 2a-c

Please select the best answer to each of the following:

2a. Which of the following is not a medicare approved diagnosis for HBOT?
   a. Radiation soft tissue injury
   b. Diabetic foot ulcers
   c. Vascular ulcers
   d. Refractory osteomyelitis

2b. Which of the following items are allowed in the monoplace chamber?
   a. Polyester clothing
   b. Adhesive bound magazines
   c. Cotton clothing
   d. A hearing aid

2c. A 51-year-old male presents for HBOT evaluation. What history would warrant further investigation?
   a. History of pneumothorax
   b. Diving instructor (former)
   c. History of three tympanic membrane surgeries
   d. Claustrophobic at last MRI