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Review Article

HYPERBARIC OXYGEN THERAPY: A REVIEW

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ABSTRACT

Hyperbaric oxygen therapy (HBO) is an effective adjuvant therapy in conditions where normal healing is impaired. In HBO 100 per centoxygen at two to three times the atmospheric pressure at sea level is administered and this result in arterial oxygen tension in excess of 2000 mm Hg and oxygen tension in tissue of almost 400mmHg. Oxygen doses of such have many beneficial biochemical cellular and physiologic effects .In this article we review the mechanism of action, uses and risks of hyperbaric oxygen.

Keywords: Hyperbaric oxygen therapy, Wound healing, Decompression sickness, Gangrene.

INTRODUCTION

Hyperbaric oxygen has been described as "a therapy in search of disease" [1]. In the past it did not have much scientific support but it had evolved a lot and is of extensive use in the field of medicine. This concept historically can be traced back to 1600. The first hyperbaric chamber was constructed by British clergyman Henshaw [2]. He called the chamber *domicilium*. This chamber was pressurized and depressurized using bellows. Henshaw used his domicilium to facilitate digestion, to facilitate breathing, prevention of respiratory infections. This chamber provided only atmospheric air under high pressure as oxygen was not discovered till 1773 by Carl WilhemSheeley. The term oxygen was coined by Antoine Lavoiser only in 1777[2]. French surgeon Fontaine was the first to build a pressurized mobile operating room in 1879 [3]. He used Nitrous oxide as anesthetic agent and believed hyperbaric oxygen chambers helped in better patient anesthesia.Paul Bert (1878) demonstrated the physical and physiological principles, therapeutic applications and potential toxicity of oxygen. Then Bert (1878), Zuntz (1897) and Von Schrotter(1906) recommended the oxygen therapy for decompression sickness[4].Orwill Cunningham Professor of anesthesia (1928) ran a Hyperbaric oxygen hospital in Lawrence Kansas. He christened it as "Steel Ball Hospital". This so called hyperbaric oxygen hospital was six stories high and 64 feet in diameter. This hospital could achieve pressure levels of 3 atmospheres [3].From 1930 onwards oxygen supplementation was used to manage acute decompression sickness. Oxygen when respired at very high pressures manages to displace nitrogen accumulated from the tissue. Use of hyperbaric oxygen considerably helps to reduce the time taken to treat decompression sickness. In 1935, Behnke showed nitrogen to be the common cause of narcosis in humans during decompression sickness. Behnke and Shaw successfully used hyperbaric oxygen to treat decompression sickness. The first medical use of HBO(adjuvant treatment at 3ATA) for decompression was given by Boerema(1959) during an open heart surgery[4]. Brummelkamp(1961) incorporated HBO therapy in treatment protocolof gas gangrene[4]. After overcoming numerous problems like fires and explosions and the discovery of the cellular and biochemical effect of administering hyperbaric oxygen as primary therapy has increased in patients with severe carbon monoxide poisoning decompression sickness and arterial gas embolism, and as an adjunctive therapy for preventive and treatment of osteoradionecrosis, Clostridialmyonecrosis and comprised skin grafts flaps, promote healing by reducing edema and inflammation, augment microbial killing and involve cell mobilization [5], angiogenesis [6] and tissue repair[7].

PRINCIPLE [4]

Most applications of hyperbaric conditions and HBO therapy are derived directly from principles and laws of physics developed over centuries.

1. Boyle's law, the theory of compressibility states that at a constant temperature, the volume of gas is inversely proportional to pressure.
2. Dalton's law, the law of partial pressure states that pressure of a gaseous mixture can be considered as the sum of partial pressures of its constituent gases,
3. Henry's law, explains pathogenesis of decompression sickness and role of hyperbaric oxygen in its treatment.

EQUIPMENT [4, 8]

There are two types of hyperbaric chambers, monoplace and multiplace chambers (Table 1). Monoplace chambers have a small air tight cylinder for patient placement. The chamber is then filled with pressurised pure oxygen. Only auditory and visual communication is possible and patient cannot be physically examined. In multiplace chambers several patients can be treated at the same time and the patient jus breaths the hyperbaric oxygen through endotracheal tube or air tight mask and they can be clinically monitored by nurses or physicians throughout the procedure[4].

Table 1: Features of monoplace and multiplace chamber

	Monoplace	Multiplace
Patient	Claustrophobic environment limited access to patient.	More room assistance to deal with some acute problems.
Administration of HBO	Inhaled in the atmosphere or through an endotracheal tube in the monoplace chamber.	Inhaled through mask, tight fitting hoods or endotracheal tubes in a larger multi-occupant chamber.
Cost	Lower cost.	Higher cost.
Infection	Less spread of infection.	Risk of cross infections when used for ulcers.
Portability	Portable more common worldwide. (5-32)	Large device not portable.
Treatment on patient	Usually one patient at a time and is used to treat patients with chronic medical conditions.	Required for critically ill patients who require an attendant within the chamber and is usually used for acute problems.
Risk	Increased risk of fire.	Reduced risk of fire.

MECHANISM OF ACTION OF HBO [4, 8, 9]

Effect of pressure: Reduces volume of gas bubbles allows them to move freely through small blood vessels thereby reducing chances of infarction. This effect helps in gas embolism and decompression sickness.

Effect of increasing oxygen pressure: Administration of oxygen at high pressure helps in rapid elimination of toxic gases like carbon monoxide, hence used in treatment of carbon monoxide poisoning.

Effect of reactive vasoconstriction: HBO acts as an alpha-adrenergic agent this causes reactive vasoconstriction in small vessels thereby reducing vascularoedema without altering normal tissue oxygenation. This property helps in management of severe crush injuries and thermal burns.

Antibacterial effect: Most antibacterial defence mechanism are oxygen dependent, HBO optimizes anti-infective properties of polymorphonuclear neutrophil through formation of enzymes and superoxide ions.

Anti-ischemic effect: HBO therapy results in excess dissolved oxygen in blood also it increases deformability of red blood cells, which enable them to reach ischemic tissues.

Healing effect: HBO promotes osteoclast and osteoblast growth, facilitates collagen synthesis stimulates angiogenesis hence used in management of refractory lesions, osteoradionecrosis, extensive burns and compromised grafts.

INDICATIONS OF HBO [10, 11]

Non-healing ulcers, wounds, compromised skin grafts and flaps: Wounds have tissue hypoxia with oxygen tension below 20mmhg, hence prone for infection. HBO increases oxygen tension which enhances leukocyte bacterial activity and promotes neovascularisation. Hence used as an adjuvant in ischemic foot ulcers, dehiscent amputation site, post-radiation ulcers [7, 8, 12]. It increases graft and flap survival and is also beneficial in occlusive arterial diseases of extremities[13,14]

Acute traumatic ischemia (Crush injuries): These injuries may cause necrosis of a portion of the extremity or entire extremity which as a secondary complication can develop infection due to compromised circulation. HBO enhances oxygen tension, increases reperfusion by increasing oxygen delivery per unit of blood flow. Thus it acts as an effective adjuvant in managing these injuries[8,15].

Clostridialmyonecrosis (Gas gangrene): Clostridium cannot produce alpha-toxins when HBO is administered as it elevates the oxygen tension; they never kill the organism nor detoxify alpha-toxin but shuts off toxin production within 30minutes. It is synergistic with antibiotics like aminoglycosides, quinolones, sulpha and amphotericinB. Hence in conditions like gas gangrene the treatment protocol includes antibiotic, surgery, HBO therapy [8, 10,16].

Necrotising soft tissue infection: Soft tissue necrosis involves both aerobic and anaerobic organisms hence HBO acts as an adjuvant therapy. HBO enhances white cell killing of bacteria promotes inhibition of anaerobic organism growth [1, 8, 17].

Late radiation tissue damage: Above 5000rads healing of wound is difficult because of progressive endarteritis which results in hypoxia and tissue ischemia. HBO induces neovascularisation which result in healing [3, 18].

Thermal burns: They have zone of coagulation, surrounded by area of stasis, bound by hyperaemia. HBO reduces fluid retention, preserves marginal viable tissue, improves microvasculature, faster epithelialization, reduces inflammation, preserves tissue creatine phosphate and adenosine phosphate also decreases wound lactate thereby promoting healing[19].

Carbon monoxide poisoning: HBO reduces half-life of carbon monoxide from 4 to 5 hours to 20 minutes hence prevents neuronal injury [8, 10,17].

Refractory osteomyelitis: HBO increases oxygen tension which promotes angiogenesis, increasing leukocyte killing, aminoglycoside transport across bacterial cell wall and osteoclastic activity in removing necrotic bone [20, 21].

Air embolism/Decompression sickness: Air embolism is caused by trauma. Decompression sickness is caused by nitrogen bubble formation in blood vessels. HBO reduces the size of the bubble and prevents infarction [4, 22].

Severe blood loss anaemia: Patient who had severe blood loss and where blood transfusion is contraindicate intermittent HBO will help in oxygen supply for metabolic needs [23].

Sudden deafness: Cochlear activity is sensitive in constant supply of oxygen. Hence an acute deafness can be improved by HBO therapy along with hemodilution and vasoactive drugs[24].

Table 2: Therapeutic doses of HBO [4, 17]

Condition	Dosage	Duration
Carbon Monoxide Poisoning	2.1 – 3.0 atmospheres	4 – 6 hours
Decompression sickness	2.5 – 3.0 atmospheres	2 – 4 hours
Arterial Gas Embolism	2.5 – 3.0 atmospheres	2 – 4 hours
Radiation Induced Tissue Injury (ORN)	2.4 atmospheres	90 minutes (30 preoperative sessions)
ClostridialMyonecrosis	3 atmospheres	90 minutes (with antibiotics and surgery)
Necrotizing Fasciitis	3 atmospheres	90 minutes (with antibiotics and surgery)
Refractory Osteomyelitis	2.0 – 2.5 atmospheres	90 – 120 minutes (after debridement and antibiotic therapy)
Acute Traumatic Ischemic Injury	2.0 – 2.8 atmospheres	2 hours
Anemia due to Exceptional Blood Loss	Hyperbaric oxygen used successfully to treat hemorrhagic shock in patients who refused transfusion or for whom suitable blood was not available.	
Comprised skin grafts and Flaps	2.0 – 2.5 atmospheres	90 - 120 minutes
Thermal Burns	2.0 – 2.5 atmospheres	90 – 120 minutes

CONTRAINDICATIONS [4, 9]

Absolute contraindication:

- Pneumothorax

Relative contraindication:

- Upper respiratory tract infection
- Emphysema
- Seizure disorder
- Patients on high dose steroids
- Chronic obstruction pulmonary disorder
- Recent myocardial infraction
- History of recent ear or thoracic surgery
- Pregnancy
- Claustrophobia
- Uncontrolled hyperthermia.

DISADVANTAGES[4]

1. Higher capitalization requirements.
2. Major space requirements; basement and/or ground floor level limitations.
3. Higher operating costs.
4. Larger and experienced staffing requirements.
5. Risk of decompression sickness in internal personnel.
6. Facility fire-associated decompression requirements.
7. Significant equipment maintenance and system upkeep requirements.
8. Associated fire hazard with pure oxygen environment.
9. Risk of oxygen toxicity as well as increased risk of complications from pneumothorax and/or tension pneumothorax and arterial air embolism developing during decompression.
10. Permit requirements by FDA, local health department, and fire marshal.

RISKS IN HBO THERAPY[8]

1. Fire hazard which may be fatal.
2. Barotrauma can lead to ear, sinus and lung damage.
3. Oxygen toxicity brain and lung damage.

SAFETY MEASURES [4]

1. Should rule out contraindications.
2. Proper training to the doctor.
3. Minimum clinical monitoring should be provide.
4. Electric circuit and chamber components should be checked periodically.
5. Fire control system is required.

CONCLUSION

Though HBO therapy has lot of disadvantages and risks the benefits overweigh in using it. But clearer evidences are available for few diseases like decompression sickness and gas gangrene. Hence a lot of work is required to be done to establish the indication, dosage and duration of the therapy. Doctors need to be trained to administer this mode of management and more centres are required to make it a regular treatment modality as it has synergistic effects with the conventional treatment modalities.

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