

Review Article

Hyperbaric oxygen therapy

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Abstract Hyperbaric O₂ therapy (HBOT) or hyperoxygenation is a method of administering pure O₂ at a higher atmospheric pressure in a pressurized chamber in order to treat a medical condition. This review focuses on the mechanism of action, treatment protocol, indications and the contraindications of hyperbaric oxygen therapy.

Key words

Hyperbaric oxygen therapy.

Introduction

Hyperbaric oxygen therapy (HBOT) or hyperoxygenation is a method of administering pure oxygen (O₂) at a higher atmospheric pressure in a pressurized chamber in order to treat a medical condition. "Goodness of air" was known to mankind for long. Oxygen was discovered by Joseph Priestley in the late 17th century¹; however, it was Fontaine who first proved the medical benefits of hyperbaric O₂ when he performed 20 operations in a pressurized operation theatre and noted low incidence of post operative cyanosis.²

In 1918, Cunningham treated cases of 'Spanish flu' with HBO with remarkable success. About a decade later, Junods reported benefits of 2ATM O₂ in cardio-respiratory diseases.³ In 1955, Boerrna successfully treated fatally anemic pigs with hyperbaric O₂ and established the role of HBO in the surgery of cyanotic heart disease.⁴ The benefits of HBO in Carbon monoxide poisoning were reported by Smith in 1962.⁵

Types of HBO therapy

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HBO therapy can be of two major types:

1. Systemic HBOT where patient breathes HBO in a pressurized chamber and O₂ is delivered systemically.
2. Topical HBO where O₂ is delivered directly to the wound surface. However, according to U.S. Food and Drug Administration, topical HBOT does not constitute HBOT.

Systemic HBO which is more commonly known as HBOT can be delivered by different types of chambers after proper humidification of 100% pure O₂. Monoplace chambers accommodate only one patient with limited pressure capability. This type requires little space and treatment protocol can be specified according to the patient's need. In multiplace chambers, 2-10 patients can be accommodated, larger space is needed and greater working pressure can be generated. However, here all patients have to be treated in the same protocol. Risk of iatrogenic decompression sickness is more in multiplace chambers.⁶

Mechanism of action of HBO

Effects of HBO on body can be divided into primary or direct effects and secondary or immediate effects.

Table 1 Treatment protocol for hyperbaric O₂ in few selected conditions.

2ATA	O ₂ x 90 minutes	Wound healing Compromised skin graft Thermal burns Mucormycosis
2.5 ATA	O ₂ x 90 minutes	Non clostridial gas gangrene Necrotizing infections Radiation injury
3 ATA	O ₂ x 90 minutes	CO poisoning Clostridial gas gangrene

ATA=Atmospheric absolute, CO=carbon monoxide

Primary effects include hyperoxygenation of the tissue due to increased O₂ carrying capacity and O₂ diffusion in tissue fluid. These properties could be effectively used in cases of severe blood loss anemia, crush injury, compartment syndrome and graft or flap salvage. It could also be useful in cases of air embolism where HBO gradient favours gas leaving out and oxygen moving into the bubble leading to decrease in the size of the embolus.

Secondary effects of HBO include vasoconstriction, angiogenesis, fibroblast proliferation and increased leukocyte oxidative killing. Vasoconstriction leads to decrease in edema which is helpful in conditions like crush injury, compartment syndrome and acute burns. Angiogenesis is useful for graft salvage, osteoradionecrosis, radiation endarteritis obliterans and chronic wounds. Chronic osteomyelitis and necrotizing soft tissue infections improve by increased leukocyte oxidative killing mediated by HBO.^{7,8}

Clinical applications of HBO

Hyperbaric O₂ can be used as a primary mode of therapy in carbon monoxide poisoning, cerebral arterial gas syndrome, decompression sickness, osteoradionecrosis and clostridial gas gangrene. However, it is more commonly used as an adjunct therapy. It is also beneficial in radiation tissue damage, acute ischemia or crush injury, necrotizing infections, acute anemia, acute thermal burns, compromised

graft, problem wounds and refractory osteomyelitis.^{9,10} Treatment protocol in various conditions is shown in **Table 1**.

Role of HBO in chronic non-healing wounds

Hyperbaric O₂ therapy improves host immune response by increasing leukocyte oxidative killing of bacteria. It is cytotoxic to anaerobes and, therefore, decreases morbidity and mortality in various necrotizing infections. Hyperbaric O₂ therapy enhances the transport of aminoglycosides across the cell wall increasing the efficacy of these antibiotics. It also reduces local tissue edema by arterial vasoconstriction while maintaining higher than normal local oxygen tissue delivery. Decreased edema ensures better penetration of O₂ and nutrients to injured tissue.

Hyperbaric oxygen therapy has long been known to enhance collagen deposition in hypoxic tissues as well as in increasing angiogenesis. At the cellular level, these benefits must be mediated by cytokines. Recent data by Mustoe *et al.* demonstrate that HBOT modulates the signal transduction pathway that regulates the gene expression for PDGF β receptor.¹¹ HBOT enhances angiogenesis in ischemic irradiated tissue as reported by Marx *et al.*¹² Kang *et al.* proved experimentally *in vitro* that HBO increases fibroblast formation¹³ and Thom *et al.* showed that HBO causes mobilization of stem cells which is crucial for injury repair.¹⁴ All these

studies further compound the role of HBO in wound healing.

HBO has been used with varying degrees of success in leg ulcers caused by diabetes and venous, arterial insufficiency, burn wounds, crush injury, marginal flap and skin grafts and non healing trophic ulcers. However, the role of HBO in wound healing is controversial.

Complications of HBO therapy [15]

Complications of HBO can be due to either O₂ toxicity or barotrauma. O₂ toxicity is due to formation of superoxide, OH⁻ and H₂O₂. Signs and symptoms of O₂ toxicity mainly involve respiratory system and central nervous system. CNS symptoms include anxiety, nausea, vomiting, seizures, vertigo and decreased level of consciousness. Seizures in HBOT are due to formation of free radicals and decreased level of gamma aminobutyric acid (GABA); widely known as Paul Bert effect. Patients also show respiratory discomfort ranging from dry cough and substernal pain to pulmonary edema and fibrosis. HBO has minimal effects on cardiovascular system which include mild bradycardia and minimal elevation of blood pressure.

Decreased vital capacity, sternal chest pain and partial atelectasis of lungs in a patient treated with HBO is known as Loraine Smith syndrome.

Barotrauma is another major complication of HBOT. Organs affected by barotrauma include paranasal sinuses, middle ear and inner ear. Rarely gas embolism can cause sudden unconsciousness and hemiplegia.

Contraindications of HBO

HBO is contraindicated in a patient with pneumothorax due to increased risk of gas embolism. It is also contraindicated in

epileptics, hyperthermia and acidosis due to increased risk of seizures. Chronic obstructive pulmonary disease, malignant tumours, pregnancy, claustrophobia, hereditary spherocytosis and optic neuritis are the other relative contraindications for the use of HBO therapy.

Interactions

Careful administrative of HBO is needed with cytotoxic drugs e.g. cisplatin, doxorubicin and bleomycin. Steroids and nicotine may increase HBO-induced seizure incidence in alcoholics. Dehydration increases the risk of decompression syndrome.

Topical HBO

This is an innovative approach to deliver O₂ directly to the wound surface in order to minimise the systemic side effects of HBO. Moreover, in systemic HBO therapy though the O₂ level of blood increases, actual O₂ delivery at the wound site is limited due to poor vascularization. Topical HBO provides O₂ directly to wound surface; so delivery is ensured. In order to receive topical HBO, a patient must have an open wound. In topical HBO 1.03 ATA pure O₂ is given for 90 m/day for 4 consecutive days per week followed by three non treatment days which constitutes as one cycle. In order to achieve good results one cycle is repeated for 8-10 times.

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