ISSN 2249-4073

Received : March 18, 2012; Accepted : May 30, 2012

Hyperbaric Oxygen Therapy: An Overview

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Abstract

Hyperbaric oxygen therapy (HBO) is a form of treatment in which a patient breathes 100% oxygen at higher than normal atmospheric pressure that is greater than 1 atmosphere absolute (ATA). Higher barometric pressure is used for delivering increased concentration of oxygen dissolved in plasma. Therapy is administered by special therapeutic chambers, which may be rigid or flexible. The therapy has been used over the last four decades for several medical indications. The lack of adequate scientific validation regarding efficacy and safety of treatment led to the lack of interest of physicians in this modality of treatment. Although in the last two decades, experimental studies on animals and clinical trials have produced validated scientific evidence and this has led to a renaissance of HBO, and hyperbaric facilities now form an important part of many hospitals all over the world. The aim of this overview is to summarize the mechanism of action, indications, contraindications and possible complications of hyperbaric oxygen therapy.

Keywords: Hyperbaric oxygen therapy (HBO), Decompression sickness, hyperbaric medicine, oxygen toxicity, carbon monoxide poisoning

Introduction

Hyperbaric medicine is the use of high barometric pressure for delivering increased oxygen dissolved in plasma to body tissues The committee on hyperbaric medicine defines hyperbaric oxygen therapy as " A mode of medical treatment in which the patient is entirely enclosed in a pressure chamber and breathes 100% oxygen at a pressure greater than 1 atmosphere absolute (ATA) ". Hyperbaric oxygen was first used in 1930s by Behnke to recompress divers [1]. But it was later used in 1950s to complement the effects of radiation in cancer treatment by Churchill-Davidson [2]. Thereafter in a few years hyperbaric oxygen was being used to support patients undergoing cardiac surgery [3]. The therapy is also used to treat clostridial gas gangrene and carbon monoxide poisoning [4, 5]. Hyperbaric oxygen was first used to assist wound healing in 1965 as it was noted that burns of the victims of a coal mine explosion, treated with HBO for their CO poisoning, healed faster [6]. In spite of this long history of therapeutic use, the mechanisms of action of HBO are still being discovered. Recent researches have found the therapy effective for cerebral palsy and multiple sclerosis. Today the medical use of hyperbaric oxygen is an evolving specialty. With the continuing growth all over the world hyperbaric medicine has a distinct role in the current era of evidence based medicine.

Principle of hyperbaric oxygen therapy

Several therapeutic principles are used in HBOT. The increased pressure of oxygen is of therapeutic value when used in the treatment of decompression sickness and air embolism [7, 8]. Another therapeutic principle applied is by increasing transport capacity of blood. At atmospheric pressure the tissue needs of oxygen are met by oxygen combined to hemoglobin which is 95% saturated. Each 100 ml of blood carries 19 ml oxygen combined with haemoglobin and 0.32 ml dissolved in plasma. If a person inspires 100% oxygen at atmospheric pressure oxygen combined with hemoglobin can increase to a maximum of 20 ml and that dissolved in plasma to 2.09 ml, higher atmospheric pressure pushes more oxygen into solution forms. The amount of oxygen dissolved in plasma can be increased to a maximum of 4.4 ml/dl at a pressure twice that of atmospheric pressure and to 6.8 ml/dl at 3 atmospheric pressure. This additional increase of oxygen in solution meets tissue needs without contribution from oxygen bound to hemoglobin and this forms the basis of hyperbaric oxygen therapy [9-11]. Hyperoxygenation leads to vasoconstriction which reduces tissue edema and hence is beneficial in acute trauma, wounds and burn [12]. It has bactericidal effect on anaerobic organisms inhibits production of alpha toxin by *C.Welchi*. Hence it is life

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saving in gas gangrene. Recently it has been proved that hyperbaric oxygen mobilizes stem/progenitor cells from the bone marrow by a nitric oxide (NO) mediated mechanism [13].

Mode and duration of administration

The hyperbaric oxygen chambers can be divided according to size into: monoplace, dualplace and multiplace chambers. These traditional chambers used for HBO therapy were hard shelled pressure vessel. Hyperbaric oxygen may be administered in a monoplace chamber wherein a single patient is placed in a chamber which is then pressurized with 100% oxygen. Monoplace chambers are used to treat stable patients with chronic medical conditions. Dual place chambers can accommodate two patients one may be an attendant. These chambers are usually used for pediatric patients. Multiplace chamber are used to treat many patients at the same time and when treating critically ill patients who require a medical attendant within the chamber. Both dual place and multiplace camber are pressured with air and patients use oxygen using hood or mask [14]. The treatment control panel controls the therapy and monitors the patient during the treatment. Most therapy is given at 2 or 3 ATA and the average duration of therapy is 60 to 90 minutes. Number of therapies may vary from 3-5 for acute conditions and to a maximum of 50-60 for radiation illnesses [12]. Recently due to advances in materials technology portable chambers have been introduced also known as soft chambers [14]. Hard chambers and soft chambers differ in efficacy and safety as they are different in many aspects. A hard chamber consists of a pressure vessel that is made of steel, aluminium with the view ports made of acrylic. A soft chamber may consist of a urethane-coated, nylon-bonded flexible acrylic pressure vessel with steel-weld technology; a full-length dual zipper-sealed opening and an over-pressure valve.

Indications

Undersea and hyperbaric medicine society (UHMS), in United States of America approves a list of indications for reimbursement in hospitals and clinics. The indications are approved (for reimbursement) by the UHMS are mentioned in the Table 1 [15].

Table1. Indications approved by the UHMS for Hyperbaric Oxygen therapy

1.	Air or gas embolism
2.	Carbon monoxide poisoning
3.	Clostridal myositis and myonecrosis (gas gangrene)
4.	Crush injury, compartment syndrome, and other acute traumatic ischemia
5.	Decompression sickness
6.	Enhancement of healing in selected problem wounds
7.	Diabetically derived illness, such as diabetic foot, diabetic retinopathy, diabetic nephropathy
8.	Exceptional blood loss (anemia)
9.	Intracranial abscess
10.	Necrotizing soft tissue infections (necrotizing fasciitis)
11.	Osteomyelitis (refractory)
12.	Delayed radiation injury (soft tissue and bony necrosis)
13.	Skin grafts and flaps (compromised)

Beneficial effects of HBOT are seen in following conditions

Wound healing

Hyperbaric oxygen therapy is indicated in non -healing or problem wounds eg diabetic wounds and vascular insufficiency ulcers [16-18]. It is used for preparation of a bed for skin grafting in areas with poor circulation. Hyperbaric oxygen therapy is used in the treatment of infected wounds especially clostridial myositis and myonecrosis (gas gangrene) [19]. The addition of hyperbaric oxygen in these gravely ill patients is life saving and possibly decreases chances of limb amputation [19]. Osteomyelitis causes low oxygen tension in infected bones. Studies show that elevating the oxygen tensions in affected bones and the surrounding tissues helps speed healing and prevents polymorphonuclear leukocytes from adhering to damaged blood vessel linings [20]. Addition of hyperbaric oxygen therapy in acute traumatic ischemia, crush injuries, compartment syndromes and thermal burns significantly decreases costs and complications. Compromised skin grafts and flaps can be salvaged by addition of hyperbaric therapy [21].

First aid therapy or primary therapy

HBOT is used as a primary line of treatment in air embolism, decompression sickness and carbon monoxide poisoning. In air embolism and decompression sickness, hyperbaric oxygen therapy helps by compressing bubbles by increased pressure and removing nitrogen from tissues. High oxygen counteracts the ischemic and hypoxic effects produced by vascular obstruction. It also reduces blood sludging and improves immune function [22, 23]. In cases of carbon monoxide (CO) poisoning hyperbaric oxygen causes immediate saturation of plasma with oxygen to sustain life and to tissue hypoxia is counteracted in spite of high levels of CO hemoglobin. It causes a rapid reduction of CO in the blood and also reduces cerebral edema and brain lipid peroxidation caused by CO [24].

Cancer therapy

In oncology hyperbaric oxygen is indicated in radiation induced tissue damge or as an adjunct to therapeutic radiation. It also acts as a radio sensitizer in certain head neck tumors. Patients, who have received 2,000 to 5,000 radiation or more have difficulties with subsequent of healing surgical wounds. The primary mechanism of late radiation tissue complications is endarteritis (progressive loss of the microvasculature) resulting in tissue hypoxia, death and necrosis. Hyperbaric oxygen is the only treatment available for these conditions and helps reduce morbidity, disfiguring sequelae and further need for corrective surgery. Common indications for HBO in radiation induced tissue damage are osteoradionecrosis, soft tissue necrosis, radiation cystitis, proctitis, enteritis, vesicocutaneous fistula, radiation induced optic neuropathy, retinopathy and brain damage [25-27]. Hyperbaric oxygen is also being evaluated for its role in enhancing radiosenstivity of cancer tissue. The oxygen tension inside a tumor can be as low as 8 mmHg. It drops lower as the tumor enlarges and may drop to zero in the necrotic center of the tumor. Hypoxia increases the resistance of cancer to radiotherapy. With oxygen tension at zero, the amount of radiation required to be effective is three times that required with normal oxygen tension. When irradiation is done immediately after HBO therapy, the well- oxygenated cells will be damaged lethally. The effect of HBO in enhancing radiosensitivity is most pronounced in head and neck tumors [28]. Pre and post operative HBO enhances the quality of irradiated tissues to allow them to better withstand surgical insults.

Miscellaneous

The therapy can be used in refractory anemia, acute sensorineural hearing loss and bells palsy. Recently a small double-blind study of autistic children found that 40 hourly treatments of 24% oxygen at 1.3 atmospheric pressure provided significant improvement in the children's behavior immediately after treatment sessions [29]. Research conducted by the center for autism and related disorders (CARD) found that hyperbaric oxygen therapy does not have a significant effect on symptoms of autism [30].Other indications include epidural abscesses, multiple sclerosis inflammatory bowel disease and psoriasis [31-33].

Contraindications

Contraindications to hyperbaric oxygen therapy can be divided into absolute and relative contraindications. Untreated tension pneumothorax is the only absolute contraindication to hyperbaric oxygen therapy [34]. Patients should not undergo HBO therapy if they are on therapy of doxorubicin, cisplatin, dilsulfiram and mafenide acetate. The relative contraindications where special consideration must be taken by the therapist include cardiac disease, upper respiratory infections, high fever, emphysema, prior thoracic (chest) surgery, malignant diseases, middle ear barotrauma and pregnancy [35].

Complications

Air filled tissues such as lungs, paranasal sinuses, back of eardrum and space underneath dental fillings in the body are at a risk of barotrauma [36-39]. Breathing high-

pressure oxygen may cause oxygen toxicity [40]. Temporarily blurred vision can be caused by swelling of the crystalline lens of the eye, it usually resolves in two to four weeks. Reports are available suggestive of progression of cataract following HBO therapy [41-43]. Rarely sight threatening complications like optic neuritis (inflammation of the optic nerve) have been reported. Psychological complications like claustrophobia or confinement anxiety due to isolation and dependency neurosis can also occur.

Conclusion

The therapy is safe and effective with very few minor side effects. Addition of hyperbaric oxygen therapy in certain condition obviates the need for frequent surgery, promotes wound healing and leads to early mobilization of the patient. It is the only primary treatment available in certain indications. The therapy has an emerging role in patients with life time disabilities. Hyperbaric oxygen therapy is an upcoming treatment for a wide array of diseases. A few more interesting indications include restoration of sexual vitality, restoration of hair colour, removal of skin wrinkles. Looking at the global perspective and if India is to remain at the forefront, we need to invest more in setting such clinics .

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