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A Concise Review on the Scope, Therapeutic and Cosmetic Applications and the Future of Hyperbaric Oxygen Therapy.

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ABSTRACT
Hyperbaric oxygen therapy (HBOT), a therapy in which patients breath pure oxygen in a pressurized chamber, has been long used as a treatment for conditions such as decompression sickness and carbon monoxide poisoning. Oxygen recently has been found to be an important component in skin rejuvenation, treatment of photoaging , and improvement in skin complexions. The interest in the use of HBOT for this purpose is continually growing and becoming more widespread. In addition to aging and genetic makeup, chronic UV radiation due to everyday exposure, especially UV-B, can greatly increase the rate of wrinkle formation through increasing skin angiogenesis and degradation of extracellular matrix molecules. The use of HBOT and hyperoxia conditions has been found to attenuate the formation of wrinkles from UV irradiation. However, this treatment for wrinkles is definitely growing due to recent studies showing the effectiveness of oxygen therapy on wrinkles. This review article will explore and summarize researches done on possible mechanisms dealing with the use of oxygen therapy for reduction of UVB-caused wrinkles, its side effects, and its possible future improvement and use in medicine .Also deals with scope, medical uses ,contraindications and hyperbaric chambers used.

What Is Hyperbaric Oxygen (HBO) Therapy?

HBO therapy involves breathing 100% oxygen intermittently in a chamber (either mono- or multiplace chamber) at a pressure greater than 1 atmosphere (1 ATA). The chamber pressurization should be at least 1.4 ATA according to the Undersea & Hyperbaric Medical Society (UHMS) . In clinical practice, patients breathe pure oxygen at 2.0 to 3.0 ATA, equivalent to 33 to 66 feet below seawater. Monoplace chambers are one-man chambers filled with pure oxygen at pressures up to 3 ATA. The walk-in or multiplace chambers are pressurized with compressed air and can accommodate more than two patients. The chamber capability varies from two to 14 patients and can take as many as 20 patients . Patients in multiplace chambers receive 100% oxygen via a plastic head hood, a tight fit mask, or endotracheal tube. Critically ill patients and patients on mechanical ventilation can also be treated in HBO facilities equipped with adequate critical care setups and experienced staff.[1]

SCOPE

Hyperbaric medicine includes hyperbaric oxygen treatment, which is the medical use of oxygen at greater than atmospheric pressure to increase the availability of oxygen in the body, and therapeutic recompression, which involves increasing the ambient pressure on a person, usually a diver, to treat decompression sickness or an air embolism by eliminating bubbles that haveformed within the body. Research found evidence that HBOT improves local tumour control, mortality, and local tumour recurrence for cancers of the head and neck[2].Research also found evidence of an increase in stem progenitor cells[3] and a decrease inflammation. [4]

MEDICAL USES

In the United States the Undersea and Hyperbaric Medical Society, known as UHMS, lists approvals for reimbursement for certain diagnoses in hospitals and clinics. The following indications are approved (for reimbursement) uses of hyperbaric oxygen therapy as defined by the UHMS Hyperbaric Oxygen Therapy Committee.[5]

- Air or gas embolism
- Carbon monoxide poisoning.
- Carbon monoxide poisoning complicated by cyanide poisoning
- Central retinal artery occlusion,
- Clostridal myositis and myonecrosis (gas gangrene)

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• Crush injury, compartment syndrome, and other acute traumatic ischemia
• Decompression sickness
• Enhancement of healing in selected problem wounds
• Diabetically derived illness, such as short-term relief of diabetic foot,diabetic retinopathy, diabetic nephropathy.
• Intracranial absces
• Osteomyelitis (refractory)
• Delayed radiation injury (soft tissue and bony necrosis)
• Skin grafts and flaps (compromised)
• Thermal burns

CONTRAINDICATIONS

An absolute contraindication to hyperbaric oxygen therapy is untreated pneumothorax. The reason is concern that it can progress to tension pneumothorax[6], especially during thedecompression phase of therapy, although treatment on oxygen-based tables may avoid that progression.[7]

The COPD patient with a large bleb represents a relative contraindication for similar reasons.[8]Also, the treatment may raise the issue of Occupational health and safety(OHS), which has been encountered by the therapist.[9]

The following are relative contraindications - meaning that special consideration must be made by specialist physicians before HBO treatments begin:

- Cardiac disease
- COPD with air trapping - can lead to pneumothorax during treatment.
- Upper respiratory infections - These conditions can make it difficult for the patient to equalise their ears or sinuses, which can result in what is termed ear or sinus squeeze .
- High fevers - In most cases the fever should be lowered before HBO treatment begins. Fevers may predispose to convulsions.
- . Emphysema with CO_2 retention - This condition can lead to pneumothorax during HBO treatment due to rupture of an emphysematous bulla. This risk can be evaluated by x-ray.
- History of thoracic (chest) surgery - This is rarely a problem and usually not considered a contraindication. However, there is concern that air may be trapped in lesions that were created by surgical scarring. These conditions need to be evaluated prior to considering HBO therapy.[6]

THERAPEUTIC PRINCIPLES

- Clinical pressure (2.0-3.0 Bar)

The increased overall pressure is of therapeutic value in the treatment of decompression sickness and air embolism as it provides a physical means of reducing the volume of inert gas bubbles within the body[10]. Exposure to this increased pressure is maintained for a period long enough to ensure that most of the bubble gas is dissolved back into the tissues, removed by perfusion and eliminated in the lungs[11]. The improved concentration gradient for inert gas elimination (oxygen window) by using a high partial pressure of oxygen increases the rate of inert gas elimination in the treatment ofdecompression sickness[12].

For many other conditions, the therapeutic principle of HBOT lies in its ability to drastically increase partial pressure of oxygen in the tissues of the body. The oxygen partial pressures achievable using HBOT are much higher than those achievable while breathing pure oxygen under normobaric conditions (ie. at normal atmospheric pressure). This effect is achieved by an increase in the oxygen transport capacity of the blood. At normal atmospheric pressure, oxygen transport is limited by the oxygen binding capacity of haemoglobin in red blood cells and very little oxygen is transported by blood plasma, Because the haemoglobin of the red blood cells is almost saturated with oxygen at atmospheric pressure, this route of transport cannot be exploited any further. Oxygen transport by plasma, however, is significantly increased using HBOT because of the higher solubility of oxygen as pressure increases[11].

- Proangiogenic Stem Progenitor Cell Mobilization
- Low pressure hyperoxia, stem progenitor cell mobilization and inflammatory cytokine expression

HYPERBARIC CHAMBER

- Construction

The traditional type of hyperbaric chamber used for therapeutic recompression and HBOT is a rigid shelled pressure vessel. Such chambers can be run at absolute pressures typically about 6bars (87 psi), 600,000 Pa or more in special cases .

Professional diving organizations, hospitals, and dedicated recompression facilities typically operate these. They range in size from semi-portable, one-patient units to room-sized units that can treat eight or more patients. The larger units may be rated for lower pressures if they are not primarily intended for treatment of diving injuries.

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A rigid chamber may consist of:

• a pressure vessel with the view ports (windows) made of acrylic
• one or more human entry hatches - small and circular or wheel-in type hatches for patients on gurneysthe entry lock that allows human entry - a separate chamber with two hatches, one to the outside and one to the main chamber, which can be independently pressurized to allow patients to enter or exit the main chamber while it is still pressurized
• a low volume medical or service airlock for medicines, instruments, and food;
• transparent ports or closed-circuit television that allows technicians and medical staff outside the chamber to monitor the patient inside the chamber, an intercom system allowing two-way communication
• an optional carbon dioxide scrubber - consisting of a fan that passes the gas inside the chamber through a soda lime canister,181)
• a control panel outside the chamber to open and close valves that control air flow to and from the chamber, and regulate oxygen to hoods or masks;8]
• an over-pressure relief valve
• a built-in breathing system (BIBS) to supply and exhaust treatment gas
• a fire suppression system[13].

Flexible Monoplace chambers are available ranging from collapsible flexible aramid fiber reinforced chambers which can be disassembled for transport via truck or SUV, with a maximum working pressure of 2 bar above ambient complete with BIBS allowing full oxygen treatment schedules. to portable, air inflated "soft" chambers that can operate at between 0.3 and 0.5 bars (4.4 and 7.3 psi) above atmospheric pressure with no supplement al oxygen, and longitudinal zipper closure[14].

Oxygen delivery

In the larger multiplace chambers, patients inside the chamber breathe from either "oxygen hoods" - flexible, transparent soft plastic hoods with a seal around the neck similar to a spacesuit helmet - or tightly fitting oxygen masks, which supply pure oxygen and may be designed to directly exhaust the exhaled gas from the chamber.

During treatment patients breathe 100% oxygen most of the time to maximise the effectiveness of their treatment, but have periodic "air breaks during which they breathe chamber air (21% oxygen) to reduce the risk of oxygen toxicity. The exhaled treatment gas must be removed from the chamber to prevent the build-up of oxygen, which could present a fire risk. Attendants may also breathe oxygen some of the time to reduce their risk of decompression sickness when they leave the chamber. The pressure inside the chamber is increased by opening valves allowing high-pressure air to enter from storage cylinders, which are filled by an air compressor. Chamber air oxygen content is kept between 19% and 23% to control fire risk (US Navy maximum 25%). If the chamber does not have a scrubber system to remove carbon dioxide from the chamber gas, the chamber must be isobarically ventilated to keep the CO_2 within acceptable limits[13].

- A soft chamber may be pressurised directly from a compressor or from storage cylinders .
- Smaller "monoplace" chambers can only accommodate the patient, and no medical staff can enter. The chamber may be pressurised with pure oxygen or compressed air. If pure oxygen is used, no oxygen breathing mask or helmet is needed, but the cost of using pure oxygen is much higher than that of using compressed air. If compressed air is used, thenan oxygen mask or hood is needed as in a multiplace chamber. Most monoplace chambers can be fitted with a demand breathing system for air breaks[15].In low pressure soft chambers, treatment schedules may not require air breaks, because the risk of oxygen toxicity is low due to the lower oxygen partial pressures used (usually 1.3 ATA), and short duration of treatment.
- For alert, cooperative patients, air breaks provided by mask are more effective than changing the chamber gas because they provide a quicker gas change and a more reliable gas composition both during the break and treatment periods[16].

S0FT CHAMBER

These are mild HBOT or mHBOT are portable chambers sealed with a zipper. It is pressurised directly from a compressor or from storage cylinders. They are originally designed for divers and mountain climbers until they could transport to a hard sided chamber. Not for the intention of treatment. They are bags made of polyurethane or canvas material .These chambers reach a much lower pressure and only compress room air, which contains about 21% oxygen vs. the 100% medical grade oxygen used in a traditional monoplace or multiplace hyperbaric chamber. Despite these key differences, "soft chambers" are often marketed as effective as the hard monoplace or multiplace chambers in a host of conditions, even if these claims have not been studied or proven. Users of in-home soft hyperbaric chambers

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are advised to take precautions, speak to an expert, and make sure they are supervised each time they get into the chamber[17].

APPLICATION IN SKIN REJUVENATION AND PHOTO AGING

Due to the reigning desire in today's society to maintain youthful appearance, development of minimally invasive dermatological procedures is progressing to rejuvenate aging face. Quite a few of these minimally invasive procedures have been effectively developed such as chemical peels, intradermal fillers, and botulinum toxins, but one not yet fully understood is HBOT .

HBOT as a therapy for aesthetic means is a relatively new use so there have not been a great number of researches done specifically on usage of oxygen therapy on reduction of wrinkles. However, from the few that has been done, positive outcomes were achieved and the use of oxygen therapy for treatment of wrinkles seems an attractive option . Receiving regular treatments of HBOT is thought to increase skin elasticity and stimulate collagen production, leading to reduction of wrinkles and fine lines and improvement in skin texture.

Many dermatology clinics and even spas have utilized machines that deliver concentrated oxygen to the patient or client to treat age related skin problems. Oxygen is used in skin care because it is thought that delivery of natural oxygen increases cell metabolism. The use of oxygen therapy as a process of skin rejuvenation and reduction of loss of elasticity leading to formation of lines and wrinkles are becoming increasingly widespread in skin care clinics because of increasing successful results of their usage due to developing technologies. However, scientific evidences for those claims are waiting to be provided[18].

OXYGEN FACIAL

- It is mainly done to reduce wrinkles and fine lines.
- Improve blood circulation
- Promote collagen for younger looking skin.

Every spa has it's own process of administering oxygen facial by delivering stream of high pressure oxygen to skin surface

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BENEFITS

- Added radiance
- Hydrated skin
- Even skin tone
- Reduction in fine lines
- Calming of acne

POTENTIAL SIDE EFFECTS

- Temporary redness
- Puffiness or facial swelling
- Allergic reactions to serum.[19]

HYPERBARIC OXYGEN TREATMENT IN AUTISM SPECTRUM DISORDERS

However some investigators have used HBOT to treat individuals with autism spectrum disorders(ASD). A number of individuals with ASD posses certain physiological abnormalities that HBOT might ameliorate ,including cerebral hypo perfusion ,inflammation, mitochondrial dysfunction and oxidative stress. Studies of children with ASD have found positive changes in physiology and/or behaviour from HBOT.It is possible that HBOT could improve cerebral perfusion in ASD.Several studies has reported significant improvements in cerebral perfusion with the use of HBOT at low pressure (i.e., 1.3 to 1.5atm) ,as measured as measured by pre and post –HBOT SPECT scans in several neurological conditions, including TBI and brain injury . In addition cerebral perfusion has been shown to change in children with ASD after treating with HBOT.[20]

HYPERBARIC OXYGEN THERAPY AS TREATMENT OPTION IN ALZHEIMERS DISEASE (AD)

AD is characterized by extra cellular sensile plaques, formed by deposits of beta – amyloid and intracellular neurofibrillary tangles formed by the accumulation of abnormally phosphorylated tau protein, which ultimately lead to loss of synapse and degeneration of neurons, while reduced level of oxygen lead to pathological complications, higher oxygen level can improve or boost brain function[21]. Studies have shown that elderly healthy subject oxygen supplementation improve the subject performance in cognitive tasks and change in the EEG pattern of brain activity, indicating that oxygen is rate limiting factor in normal and disease associated cognitive function. IndeedHBOT improved the performance of healthy subjects in both motor and cognitive single task or in multitasking compared to subjects under normobaric conditions.[22]

IMPACT OF HYPERBARIC OXYGEN THERAPY ON ERECTILE FUNCTION

Recent clinical studies showed that HBOT improved the erectile functions in non surgical patients and this effect was linked to angiogenesis. The studies aimed to evaluate the effects of hyperbaric oxygen therapy (HBOT) on erectile function in patients who had no cavernosal or urethral injury by using International Index of Erectile Function (IIEF) questionnaire.

Materials and Methods:

The male patients who were treated by HBOT for several diseases between July 2017 and September 2017 were examined. All patients filled the IIEF questionnaire form before the first day and after the last day of HBOT and a questionnaire including demographic characteristics and medical history. The effects of demographic characteristics and risk factors on erectile function were evaluated, and the IIEF domain scores of patients in first day and last day of HBOT were compared.

Results:

Totally, 50 patients were included in the study between July 2017 and September 2017 and the mean age was 59.38+13.77. The mean post-HBOT IIEF-EF score of patients was significantly higher than the mean pre-HBOT IIEF-EF score of patients(15.74±10.52 vs. 19.50±10.91; $p< 0.001$). The mean post-HBOT IIEF scores of other domains including intercourse satisfaction, orgasmic function, sexual desire, and overall satisfaction were also significantly higher than pre-HBOT scores.

Conclusions:

HBOT may be a good alternative treatment or adjunctive treatment for erectile dysfunction[23].

COVID -19,ACUTE RESPIRATORY DISTRESS SYNDROME (ARDS),AND HYPERBARIC OXYGEN THERAPY

The current corona virus disease 2019 (covid 19) pandemic has become an unprecedented challenge for health care system world wide ,with an overwhelming number of patients requiring clinical attention and an unacceptably high mortality rate within critical care facilities .If we extrapolate theobservations to the COVID-19 situation, an early intervention before the need for mechanical ventilation could be of extraordinary utility for saving lives. In this regard, hyperbaric oxygen therapy (HBOT) that consists of exposure to 100% oxygen under in- creased atmospheric pressure up to 2.4 atm could be a great resource to improve the outcome from the infection when it is administered at early stages as soon as a reduction

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of arterial oxygen concentration is detected. Indeed, experimental animal studies have shown that an initial HBOT improved dramatically the outcome from sepsis, which was correlated with a reduction of the inflammatory response triggered by the initial insult (Halbach et al. 2019). The great advantage of HBOT is that it delivers oxygen at elevated partial pressure allowing this gas to penetrate tissues very rapidly and in higher concentration, which is more effective than hemoglobin oxygen delivery. Both mechanical ventilators, the current treatment for severely ill hypoxic COVID-19 patients in critical care, and HBOT are able to elevate the levels of arterial O, but in addition, HBOT provides a crucial function that ventilators lack. Therefore, HBOT could be a potential intervention to improve the outcome of COVID-19 patients. It has been shown to be safe during the use of mechanical ventilation.[24]

TREATMENT OF MIGRAINE WITH HYPERBARIC OXYGEN THERAPY

Migraines involve intense head pain, which severely affects the activities of daily living, and is the is the third most common disease in theworld. By using monoplace chamber, an individual patient breathes in directly pressurised 100% oxygen and in the multiplace chambers with more than one patient, the patients will be pressurised with air and breathe 100% oxygen indirectly via a head hood, mask, or endotracheal tube[25] HBOT is approved for several indications.However, besides these standard indications, several studies have demonstrated many other benefits of HBOT, including the management of migraines.There have been several published studies regarding the use of HBOT to treat migraine.

HYPERBARIC EFFECT ON ANGIOGENESIS

Studies regarding hyperbaric oxygen therapy (HBOT) on angiogenesis demonstrate an increased rate of blood vessel formation. As such, HBOT is a potent, though underutilized therapeutic tool capable of augmenting conventional treatment for problematic wounds and grafts[26]. HBOT is an effective means of promoting angiogenesis. Via its ability to increase the oxygen partial pressure gradient and its induction of VEGF, HBOT is an invaluable tool in a physician's armamentarium when confronted with compromised skin grafts and problem wounds. In conclusion, consider HBOT for osteoradionecrosis and soft-tissue radionecrosis as well. Both of these conditions are produced by radiation-induced small vessel loss and would benefit from angiogenesis aided by HBOT.[27]

HYPERBARIC OXYGEN THERAPY IN SPORTS

Football is frequently associated with minor injuries, involving joints, muscle, ligaments and tendons. A variety of therapies have been developed to reduce tissue swelling and preserve mobility. Hyperbaric oxygen therapy has been used to determine whether the expected duration of injuries can bereduced. The patients studied were all professional footballers, injured either during matches or duringtraining. The injuries were assessed by the club physiotherapist and an estimate made of the expected timebefore the players could be expected to resume full training. The chamber (Hyox HTU) was pressurised on air and oxygen. Supplied via a Scott demand-valve system with overboard dumping of exhaust gas at 2 atm[28].

CONCLUSION

HBOTas a natural healing process that infuses your body tissues with oxygen and naturally release your body stem cells by breathing purified oxygen under elevated pressure. It has been approved for treatment of various disease conditions like cognition, autism, erectile dysfunction, Alzheimer disease. It is being used for anti aging process, skin rejuvenation and oxygen facial .it has a major role in angiogenesis and also being used by various athletes and players .this is useful in staying strong ,sharp, and for being youthful. This article also deals with the construction of hard chamber and also with the aspects of soft chamber hyperbaric oxygen therapy.

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