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(Review Article)

Hyperbaric oxygen therapy on aging diseases

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Abstract

Aging happens in all creatures and is usually measured based on chronological age. Someone over 65 years of age is often referred to as an elderly person. This is also the age when biological degeneration usually occurs causing a decline in performance and having a major risk factor for aging diseases. Hyperbaric oxygen therapy (HBOT) is a therapeutic approach based on exposure to concentrations of pure oxygen (O2) and increased atmospheric pressure that could be performed based on the patient's conditions. HBOT has an approved indication and also some contraindication that needs to be looked up to. HBOT has proven to have positive effects on some aging diseases such as increasing VO2Max, decreasing neuronal degeneration in Alzheimers disease, and accelerating collagen synthesis in osteomyelitis. Literature reviews on HBOT's effects on elderly people who suffer from aging diseases are still quite limited. Although some cases of HBOT are still facing pros and contras on its effects, this literature review is expected to be useful in conducting HBOT effects on aging diseases. However, further research is needed related to HBOT on enhancing quality of life for elderly people who suffer from aging diseases.

Keywords: HBOT; Aging diseases; Elderly people; Alzheimer; Osteomyelitis

1. Introduction

Hyperbaric oxygen therapy (HBOT) is a medical treatment that involves breathing 100% oxygen in a chamber under increased atmospheric pressure. The session typically lasts between 60 to 90 minutes, depending on the specific medical indication (Ortega et al., 2021). According to the Undersea and Hyperbaric Medical Society (UHMS), the pressure in the chamber may equal or exceed 1.4 atmospheres (atm) (Rosyanti et al., 2020).

Hyperbaric oxygen therapy (HBOT) can be used to treat various medical conditions, including decompression sickness, air embolism, burns, and wound healing (Rosyanti et al., 2020). Additionally, several studies indicate that HBOT may enhance physical performance in older adults. Notably, improvements have been observed in important measures such as VO2Max and VO2VT1 (Amir et al., 2024).

Another study concluded that hyperbaric oxygen therapy (HBOT) could enhance neurological functions, including improvements in memory, cognition, and motor skills, as well as an overall increase in quality of life (Ficher et al., 2020). Additionally, HBOT has been shown to positively influence cerebrovascular health in the brain, including improving blood-brain barrier permeability, promoting angiogenesis, and reducing edema (Mensah-Kane et al., 2022).

Research on the effects of HBOT on elderly individuals suffering from aging-related diseases remains limited. As a result, researchers are interested in conducting a literature review on the impact of HBOT on these aging diseases.

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2. Aging

2.1. Definition

According to the World Health Organization (WHO), aging is typically measured by chronological age. Individuals over 65 years of age are often referred to as elderly persons or senior citizens. This age also coincides with retirement for many people, who then start receiving pension funds (Andrew, 2023). Aging is associated with a gradual decline in physical activity capacity, even among healthy individuals who exercise regularly and do not suffer from serious illnesses or musculoskeletal problems. Furthermore, the rate of performance decline increases significantly after age 70 (Amir et al., 2024). This biological decline may contribute to major risk factors for cancer, cardiovascular diseases, and Alzheimer's disease (Hachmo et al., 2020).

2.2. Physiological Change on Aging

In elderly individuals, several physiological declines in the body occur, including decreased muscle mass and strength, as well as an increased prevalence of cardiovascular diseases. The decline in muscle mass and strength typically begins in a person's fourth decade of life. By age 85, approximately 20% of people meet the criteria for sarcopenia, which is characterized by the loss of muscle mass and strength. Factors such as chronic inflammation, decreased hormone levels, impaired mitochondrial function in muscles, and compromised muscle stem cell function likely contribute to the development of sarcopenia (Jaul et al., 2017). Most of these changes are irreversible and generally take place during the fourth or fifth decade of life. The rate of degeneration varies among individuals, influenced by genetics, dietary habits, environmental factors, and occupational characteristics (Gupta et al., 2024).

One of the primary reasons for this decline is a reduction in maximum oxygen consumption (VO2Max), which declines by more than 1% per year. Decreased VO2Max is a significant cause of age-related frailty and loss of function, affecting 25–50% of individuals over the age of 85 (Amir et al., 2024).

The age-related decline in VO2Max is primarily due to reduced cardiovascular efficiency, which results from a decrease in maximal cardiac output and its uneven distribution, as well as a decline in lung function. Additionally, aging leads to a reduction in muscle mass and a decrease in muscle oxidative capacity caused by mitochondrial dysfunction (Amir et al., 2024). This decline in cardiovascular health can lead to various diseases, including chronic ischemic heart disease, congestive heart failure, and arrhythmias. It's important to note that ischemic heart disease may often be underdiagnosed in the elderly. Normal aging also involves vascular remodeling and increased vascular stiffness (Jaul et al., 2017).

The production of cellular energy by neurons and glial cells, as well as the ongoing maintenance of brain activity, relies heavily on a high consumption of oxygen. When neurons experience hypoxia, it can lead to irreversible damage that disrupts their electrical communication and significantly affects glial cells. Hypoxia during developmental stages can impair brain development, potentially resulting in neurodevelopmental disorders (NDDs) (Fischer et al., 2020). Furthermore, NDDs can also arise in older age due to the continuous or progressive loss of specific vulnerable neuronal populations in the brain or spinal cord. This degeneration can lead to neurodegenerative diseases, such as Alzheimer's disease (Mensah-Kane et al., 2022).

3. Hyperbaric Oxygen Therapy (HBOT)

3.1. Definition

The term "hyper" refers to something that is increased, while "baric" pertains to pressure. Hyperbaric oxygen therapy (HBOT) involves a patient inhaling 100% pure oxygen at a pressure greater than normal atmospheric levels, within a specially designed chamber. The pressure inside this chamber is typically 1.5 to 3 times greater than that at sea level (Sen et al., 2021). The duration of the therapy can vary between 30 to 90 minutes and may be repeated several times (Rosyanti et al., 2020).

3.2. Indications and Contraindications

Some approved indications for HBOT can be categorized based on several main effects, including wound healing acceleration, enhanced angiogenesis, improved antimicrobial effects, and its use in medical emergencies (Ortega et al., 2021).

Table 1 Approved Uses of HBOT

Approved indications	Air or gas embolism
	Acute thermal burn injury
	Carbon monoxide poisoning
	Carbon monoxide poisoning complicated by cyanide poisoning
	Central retinal artery occlusion
	Clostridial myositis and myonecrosis (gas gangrene)
	Compromised grafts and Flaps
	Crush injury, Compartment Syndrome and other acute traumatic ischemia
	Decompression sickness
	Delayed radiation injury (soft tissue and bony necrosis)
	Enhancement of healing in selected problem wounds
	Idiopathic sudden sensorineural hearing loss
	Intracranial abscess
	Necrotizing soft tissue infections
	Refractory osteomyelitis
	Severe anaemia

(Ortega et al., 2021)

An absolute contraindication for hyperbaric treatment is untreated pneumothorax, which could worsen under chamber pressure. Relative contraindications include patients with febrile illnesses, as these may lower the seizure toxicity threshold of the central nervous system, as well as those with poorly controlled seizure disorders and hyperthyroidism. Congestive heart failure (CHF) may also serve as a relative contraindication, particularly in patients with reduced ejection fraction, since oxygen can increase cardiac overload due to vasoconstriction of blood vessels (Lam et al., 2017).

Additionally, patients using certain chemotherapy agents such as Adriamycin and Cisplatin, or those taking Antabuse, fall into the category of relative contraindications. Other concerns include ventilated patients, individuals with uncontrolled hypertension, and those with diabetes (Rosyanti et al., 2020).

Table 2 Contraindications of HBOT

Contraindications	Suspect lung collapse
	Ear injury and thoracic surgery
	Upper respiratory tract infection
	Pregnancy
	Pneumothorax
	Uncontrolled hypothermia
	Claustrophobia

(Sen et al., 2021)

4. HBOT on Aging Related Complications and Diseases

4.1. Cardiovascular

Research by Schipke et al. (2022) concludes that inhaling pure oxygen can lead to bradycardia. This phenomenon may occur because, after administering hyperbaric oxygen (HBO), the increased tone of blood vessels elevates blood pressure. The rise in blood pressure stimulates the baroreceptor reflex, which in turn reduces heart rate. This reduction can be attributed to several factors, including increased oxygen availability, vasodilation, modulation of the autonomic nervous system, and stimulation of hyperbaric reflex bradycardia (Fatoni et al., 2024).

Additionally, Rosyanti et al. (2020) noted that the primary physiological effect of oxygen is related to vasoconstriction. Elevated oxygen levels lead to a decrease in local nitric oxide (NO) production by endothelial cells, resulting in vasoconstriction. Conversely, increased levels of carbon dioxide, a byproduct of respiration, enhance NO production, promoting vascular vasodilation.

Furthermore, hyperbaric oxygen therapy may improve dyslipidemia, which is associated with an increased risk of accelerating atherosclerosis and cardiovascular disease in patients with diabetes mellitus (Resanović et al., 2020).

Aging can lead to a decline in VO2Max, primarily due to reduced cardiovascular efficiency that results from a decrease in maximal cardiac output (Amir et al., 2024). Prolonged hyperbaric oxygen therapy (HBOT) has the potential to enhance cardiac perfusion. This improvement may either contribute to better cardiac function or be a result of it, as evidenced by increased left and right ventricular systolic function, ultimately leading to enhanced myocardial performance.

However, due to the potential for hyperbaric oxygen therapy (HBOT) to increase afterload, Schiavo et al. (2024) conducted research on heart failure (HF) patients undergoing HBOT. The results indicated that some HF patients, regardless of whether they had preserved or reduced ejection fractions, might develop pulmonary congestion and pulmonary edema, particularly those with reduced cardiac ejection fractions (Ortega et al., 2021). Nevertheless, all patients were able to complete the therapy with close monitoring for any clinical or pharmacological changes during the treatment.

4.2. Neurology

Maroon et al. (2022) concluded that neurocognitive assessments conducted three weeks after hyperbaric oxygen therapy (HBOT) demonstrated improvements of 3.1% to 3.8% in global cognitive function, as well as in specific cognitive domains such as memory, attention, information processing speed, and executive function. Although the underlying mechanisms remain unclear, research by Xu et al. (2019) suggests that HBOT can enhance cognitive function in individuals with vascular dementia. Increased oxygen levels may boost brain function, and some studies have indicated that oxygen supplementation improves cognitive task performance in elderly subjects and can also alter the electroencephalogram (EEG) patterns of brain activity (Ashery et al., 2018). Additionally, a review by Marcinkowska et al. (2021) on Jacobs et al. (1969) found that 13 elderly patients with chronic organic brain syndrome showed improved cognitive functioning following exposure to HBOT.

Ashery et al. (2018) concluded that hyperbaric oxygen therapy (HBOT) could have neuroprotective effects for Alzheimer's disease by increasing the activity of antioxidant enzymes. This increase may lead to a reduction in oxidative damage and decreased neuronal degeneration. Additionally, Marcinkowska et al. (2021) reviewed research by Saphira et al. (2018), which also supports the notion that HBOT can improve cognitive functions in Alzheimer's disease by reducing neuroinflammation in a mouse model. However, the clinical application of HBOT requires further research to determine whether these effects can be replicated in humans (Ashery et al., 2018).

4.3. Musculoskeletal

The normal aging process is characterized by a loss of bone and muscle mass, which can increase the risk of fractures and decrease quality of life. Hyperbaric oxygen therapy (HBOT) may accelerate collagen synthesis, as collagen is a key component of these tissues, providing strength and flexibility. The increased oxygen supply aids in the repair process and may help slow down aging (Gupta et al., 2024). Additionally, HBOT supports osteogenesis and neovascularization, factors that contribute to healing in osteomyelitis (Sen et al., 2021).

One of the mechanisms of hyperbaric oxygen therapy (HBOT) is its ability to deliver higher concentrations of oxygen to tissues and cells. This increased availability of oxygen can enhance both aerobic and anaerobic energy production during physical activities. The greater oxygen supply to muscles may help delay the onset of fatigue and improve endurance (Goran et al., 2024). In a study conducted by Izquierdo-Alventosa et al. (2020) involving 49 women with fibromyalgia, with a mean age of 53.3 years, it was concluded that low-pressure HBOT significantly reduced fatigue and resulted in notable improvements in perceived pain at rest and the pressure pain threshold.

5. Conclusion

In conclusion, this paper explores the affects of HBOT on aging diseases. There are abundance of positive affects of HBOT on some of the aging diseases such as decrease of VO2Max, NDD, and osteomyelitis. Despite that, there are still unclear explanations about mechanism on some cases for HBOT. Therefore, further research is needed related to HBOT on enhancing quality of life for eldery people who suffers aging diseases.

Compliance with ethical standards

Disclosure of Conflict of interest

The authors declare that they do not have any conflict of interest.

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