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Hyperbaric Oxygen Therapy: A Comprehensive Literature Review Of Mechanisms, Clinical Indications, And Emerging Applications

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Abstract
Hyperbaric oxygen therapy (HBOT) delivers 100% oxygen at pressures above atmospheric level to enhance tissue oxygenation. It has established efficacy in specific conditions such as decompression sickness, carbon monoxide poisoning, and radiation-induced tissue injury. Increasing evidence suggests its potential benefits in neurological injuries and chronic wounds. This review summarises the physiological basis of HBOT, approved indications, emerging clinical uses, safety considerations and current challenges, providing an updated synthesis for clinicians and researchers involved in hyperbaric medicine.

Keywords: Hyperbaric oxygen therapy, decompression sickness, wound healing, neurological injury, chronic wounds, radiation induced soft tissue injuries, clinical indications, emerging applications.

Introduction

Hyperbaric oxygen therapy (HBOT) involves the administration of 100% oxygen at pressures greater than 1 atmosphere absolute (ATA), usually between 2 and 3 ATA, significantly increasing plasma oxygen concentration and tissue oxygen delivery[1]. Oxygen is essential for cellular metabolism and tissue repair and HBOT exploits these properties to treat hypoxic and ischemic conditions. Since its early use for decompression sickness, HBOT's scope has broadened to a variety of clinical applications[2]. This review explores the mechanisms of HBOT action, evidence-based clinical indications, emerging therapeutic areas and limitations with a focus on recent advances. This will help clinicians understand and treat the different conditions which are benefited by Hyperbaric Oxygen Therapy.

Mechanisms of Action

The therapeutic effects of HBOT are due to a combination of different pathways which primarily arise from hyperoxia, which increases dissolved oxygen in plasma, enhancing oxygen delivery to tissues where circulation may be compromised[3]. Elevated oxygen tension stimulates angiogenesis, modulates inflammatory pathways, and enhances leukocyte and fibroblast functions critical to wound healing[4]. HBOT also induces vasoconstriction thereby reducing tissue oedema without impairing oxygen supply[5]. The controlled generation of reactive oxygen and nitrogen species triggers cellular signalling cascades that promote repair and regeneration[6].

Approved Clinical Indications

Several authoritative bodies, including the Undersea and Hyperbaric Medical Society (UHMS), endorse HBOT for a range of indications supported by strong evidence[7]:

- Decompression sickness and arterial gas embolism
- Severe anemia
- Intracranial abscess
- Chronic refractory osteomyelitis
- Thermal burns
- Arterial Insufficiencies like Central Retinal Artery Occlusion
- Idiopathic Sudden Sensorineural Hearing Loss
- Avascular Necrosis
- Carbon monoxide poisoning and cyanide toxicity
- Radiation-induced injuries such as osteoradionecrosis and soft tissue radionecrosis
- Non-healing diabetic foot ulcers and compromised skin grafts/flaps
- Necrotising soft tissue infections, including clostridial myonecrosis
- Acute traumatic ischaemias, such as crush injuries[7 8]

In these conditions, HBOT enhances oxygen availability, decreases inflammation, and promotes tissue healing. UHMS indicates 15 conditions which are primarily benefited with Hyperbaric Oxygen Therapy.

Emerging and Investigational Applications

Emerging research explores HBOT's utility in neurological and chronic disorders with encouraging preliminary results[9]:

- Traumatic brain injury (TBI) and stroke rehabilitation: HBOT has shown to improve neurological recovery by mitigating hypoxia and inflammation in brain tissue[10 11].

- Chronic refractory osteomyelitis and non-diabetic wounds: HBOT has shown to enhance infection control and tissue repair[12].
- Autism spectrum disorders and cerebral palsy: Small clinical trials indicate potential functional improvements, although further studies are required[13].
- Fibromyalgia and chronic pain syndromes: HBOT might modulate central pain pathways and improve quality of life[14].

Robust randomised controlled trials are needed to validate these emerging indications and establish treatment protocols.

Limitations and Safety Considerations

While HBOT is generally safe, it is not devoid of risks. Common adverse effects include barotrauma (especially middle ear and sinus), oxygen toxicity seizures, and claustrophobia[15]. Contraindications include untreated pneumothorax and some chemotherapeutic agents[16]. The high cost and limited accessibility restrict wider application which seems to be the biggest disadvantage of clinicians not recommending HBOT. Furthermore, insufficient high-quality evidence for many off-label uses has led to ongoing debate about appropriate indications[17].

Conclusion

Hyperbaric oxygen therapy is a clinically valuable treatment for a spectrum of ischaemic and hypoxic conditions, supported by solid physiological rationale and clinical evidence. Although emerging applications show promise, further rigorous trials are essential for outweighing the benefits of HBOT. Careful patient selection and monitoring can optimise benefits while minimising risks to a greater extent. This review highlights the current state of HBOT and emphasises the need for continued research to expand its therapeutic potential and thus reaching to a larger crowd of clinicians.

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Conflicts of Interest

No conflicts of interest.

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