

THE ACCIDENTS IN HYPERBARIC CHAMBERS – RETROSPECTIVE ANALYSIS

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ABSTRACT

Introduction: Hyperbaric oxygen therapy (HBOT) is a well-established medical intervention with documented clinical benefits. Nevertheless, the operation of hyperbaric chambers involves significant safety risks, particularly the potential for fire and explosion in high-oxygen environments. This study provides a retrospective analysis of extraordinary incidents associated with hyperbaric chamber operation, with the objective of identifying primary causes, consequences, and effective preventive strategies.

Methods: This study was conducted as a narrative review of available scientific and grey literature. Eleven documented incidents meeting the specified inclusion criteria were evaluated. Data were organized by time and geographical location, aetiology, technical parameters of the equipment, consequences, and safety measures implemented. The data were then subjected to qualitative comparative analysis.

Result: Of the 11 events analyzed, 72.7% were attributed to fire or explosion resulting from sparks or non-compliance with oxygen safety protocols. Technical malfunctions accounted for 54.5% of cases, and human error contributed to 27.3%. These incidents resulted in 31 human fatalities and one animal fatality. The analysis identified the absence of a unified international incident reporting system as a barrier to effective prevention and knowledge dissemination.

Conclusion: Mitigation of safety risks associated with HBOT requires the implementation of a unified global incident reporting system, comprehensive technical inspections, mandatory staff training, and explicit standards for non-clinical facilities. Systematic risk management and international collaboration are essential to improve the safety of both patients and personnel.

Keywords: hyperbaric chamber; risk management; patient protection; emergencies; hyperbaric oxygen therapy; explosions; operational safety; healthcare facilities; preventive measures.

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INTRODUCTION

Hyperbaric chambers are used in specific healthcare facilities to deliver air with elevated oxygen content at increased pressure, which enhances tissue oxygenation and supports regenerative processes. In response to heightened patient safety requirements and the demand for advanced clinical skills, simulators and training environments have been implemented. These resources allow healthcare professionals and students to practice procedures involving hyperbaric chambers without risk to actual patients.

Although hyperbaric oxygen therapy is a recognised treatment for a number of acute and life-threatening conditions, its implementation requires strict adherence to safety rules, e.g., due to the increased risk of fire when working with pure oxygen or possible complications associated with transporting patients from intensive care units, and it also requires the presence of professionally trained personnel [1,2].

Despite strict safety measures, the hyperbaric chamber environment remains potentially dangerous. For example, there have been cases of sudden decompression that have led to injuries to personnel and equipment damage, highlighting the need for thorough planning, operator training, and technical reliability of the entire structure [3]. Hyperbaric oxygen therapy, when properly indicated, dosed, and supervised by professionals, is an effective and safe treatment method whose benefits are supported by decades of research and clinical practice. The current recommendations and standards published by the Undersea and Hyperbaric Medical Society thus serve as a fundamental support to ensure quality patient care [4, 5]. In the context of hyperbaric application, common workplace injuries can occur, potentially affecting the operation itself [2, 6].

METHODS

This paper is structured as a narrative review with the objective of systematically identifying, analyzing, and synthesizing available information on serious incidents related to hyperbaric chamber operation. The study focuses on the aetiology of events, their clinical and technical consequences, and the implementation of subsequent safety measures.

The purpose of this study is to characterize the causes of extraordinary events, evaluate their impact on health and life, identify changes in safety practices, and provide recommendations for preventing future incidents.

A targeted search of professional literature and other relevant sources was conducted on 30 November 2025. The search encompassed scientific databases (Web of Science, Scopus, PubMed), Google Scholar, and official web portals of professional and technical institutions, including the Undersea and Hyperbaric Medical Society (UHMS), Occupational Safety and Health Administration (OSHA), and American Veterinary Medical Association (AVMA). Grey literature sources such as accreditation manuals, internal reports, and news reports were also included. An artificial intelligence algorithm was used to search websites in multiple languages for grey literature. The keywords used were: “*hyperbaric safety, hyperbaric chamber incident, hyperbaric therapy explosion, safety failure, oxygen fire hazard,*” and their modified forms.

In addition to keywords, inclusion criteria were established for including extraordinary events in the study:

- a documented incident in a hyperbaric chamber with serious consequences (death, serious injury, fire, explosion),
- available information on the cause, course, and consequences of the event that is scientifically or professionally documented or verifiable from at least two independent sources,
- specified corrective measures or recommendations to increase safety.

Exclusion criteria were established for sources that provided only general overviews without specific case studies, articles focused solely on therapeutic aspects without reference to incidents, and unverifiable, speculative, or duplicate information.

Analytical framework. As part of the data processing for each extraordinary event, the following variables were extracted:

- time and geographical location of the event,
- technical parameters of the equipment (if available),
- aetiology of the incident,
- consequences (clinical, material, operational),
- system response – implemented safety measures, changes in protocols, recommendations.

The data were systematised into a summary table and then subjected to qualitative comparative analysis in the discussion section of the paper.

RESULTS

Analysis of eleven documented incidents related to hyperbaric chamber operation reveals several recurring patterns and causes of extraordinary events. In 8 of 11 cases (72.7%), fire or explosion resulted from the ignition of combustible material in a high-oxygen environment. The most common triggers were sparks, electrical discharges, or failure to follow safety protocols when handling electrical equipment.

In 6 cases (54.5%), technical malfunction was identified as the cause, including faults in electrical installations, defects in ventilation systems, or defective chamber structures. In 3 cases (27.3%), human error was identified, such as improper handling or insufficient operator training. Some incidents involved multiple contributing factors.

The consequences of these incidents were often fatal for individuals receiving treatment. In 9 of 11 cases (63.6%), patients or operating personnel died. Notable incidents occurred in Milan (1997), Cape Canaveral (1967), and Sunrise, Florida (2009). Across all documented cases, there were 31 human fatalities and one animal fatality.

One incident analyzed in 2012 involved a horse sports rehabilitation institute. A restless horse kicked the rear cover, exposing raw metal and generating sparks that triggered an explosion. Both the horse and the operator died at the scene, while a second individual was hospitalized in serious condition.

Based on these cases, several preventive measures have been gradually implemented. These include the introduction of mandatory cotton or antistatic clothing. Specifically, following an incident involving the

ignition of synthetic fabric, measures such as the installation of spark detectors, oxygen concentration monitoring, automatic fire extinguishing systems, and thorough checks of personal belongings were implemented [7].

The analysis also shows that there is still no uniform mandatory global system for reporting incidents in hyperbaric chambers. This deficiency complicates prevention, information sharing between facilities, and systematic improvement of safety protocols. In addition to national emergency reporting, the Undersea and Hyperbaric Medical Society maintains a database that allows for electronic incident reporting [8,9].

To identify key safety deficiencies and recurring risk factors, reports on serious incidents related to hyperbaric chamber operation were collected and analyzed. Table 1 summarizes eleven selected cases from various medical and veterinary facilities. Each case includes information on location, year, incident description, consequences, and corrective measures implemented.

This overview provides a foundation for further discussion on the effectiveness of current safety standards and serves as an analytical basis for designing systemic preventive measures.

OVERVIEW OF DOCUMENTED INCIDENTS IN HYPERBARIC CHAMBERS

Tab. 1

Extraordinary events related to death during the operation of a hyperbaric chamber.

Seznam mimořádných událostí spojených s barokomorou.

Year of the incident	Location	Number of fatalities	Cause	Consequences	References
1923	Kansas, USA	0	Fire caused by gas burners.	Damage to the Cunningham's chamber.	7, 10
1967	Cape Canaveral, USA	4	Explosion and fire in an oxygen environment during testing.	Complete destruction of the module, death of the astronauts, and two workers in the following days.	3, 10
1968	Louisville, Kentucky, USA	1	Explosive decompression caused by the rupture of the plastic cover.	Damage to the module and control room. The operators were injured.	3
1997	Milan, Italy	11	Explosion (the exact cause has not been specified).	Damage to the chamber and surrounding area.	11, 12, 13
1998	Turkey	3	A chemical reaction between incompatible substances led to the generation of a large amount of heat and subsequent spontaneous combustion.	Damage to the chamber.	14
2009	Fort Lauderdale, Florida, USA	2	The explosion was probably caused by static electricity; several factors were identified (dusty cables, other contaminants).	Both the woman and the child died in hospital. <i>The child died several months later as a result of his injuries.</i>	15, 16, 17
2012	Ocala, Florida, USA	1	The horse kicked the lid, which came loose and exposed the raw metal, which it also kicked, causing sparks and a subsequent fire.	Person operating the chamber and the horse died. Second person was taken to the hospital with serious injuries. The explosion destroyed the chamber.	18, 19
2012	Stavropol, Russia	1	Probable use of a lighter inside the hyperbaric chamber, resulting in a fire. A burnt lighter was found at the scene (on the patient's blanket).	The patient suffered extensive burns and was taken to the ICU in critical condition, where he died. The doctor who attempted to save the patient suffered burns to his hands. The chamber was damaged.	20, 21, 22
2016	Jakarta, Indonesia	4	Fire in the chamber, unsuccessful extinguishing.	Destruction of the chamber.	7, 14, 23
2019	San Borja, Peru	1	Oxygen leak or equipment malfunction.	An explosion or highly intense fire occurred in a single-person chamber, caused by an oxygen	24

				leak or technical failure in an oxygen environment.	
2021	Bogota, Columbia	1	Technical malfunction in the oxygen system.	A fatal fire broke out in a single-person hyperbaric chamber, killing one person.	24
2025	Troy, Michigan, USA	1	The explosion was probably caused by a spark or electrical discharge in the chamber. *	A five-year-old boy died in an explosion in a hyperbaric chamber during oxygen therapy; his mother suffered injuries to her hands.	25, 26
2025	Lake Havas City, Arizona, USA	1	Rapid ignition inside the chamber. *	The owner of the clinic (a physiotherapist) died; he was outside the chamber at the time of the fire.	27, 28

* at the time of submission, both extraordinary events were under investigation.

DISCUSSION

The operation of hyperbaric chambers is inextricably linked to certain risks, with some incidents potentially having fatal consequences. In the professional literature, hyperbaric oxygen therapy is traditionally described primarily in the context of its positive effects on healing and treatment [29]. However, in comparison, there are relatively few systematically processed data on incidents that have occurred during the operation of these facilities. This study focused on analyzing serious accidents, their causes, and the specific safety measures subsequently implemented in practice.

Table 1 shows that the most common causes include fires and subsequent explosions, resulting mainly from sparks in environments with high oxygen concentrations or from the presence of unsuitable equipment and personal items [1,30]. Serious cases such as the explosions in Milan (1997), Cape Canaveral (1962), and Sunrise (Florida, 2009) had common factors, namely technical failure, non-compliance with operating regulations, or human error [3,10,11,15].

Following an incident where a spark caused an explosion in an oxygen-rich environment, stricter controls were introduced on materials and clothing, with particular emphasis on using cotton or antistatic variants to reduce the risk of ignition and melting of synthetic fibers that can stick to the skin [7,12]. General safety guidelines from institutions such as the UIHC state: „patients and staff are required to wear 100% cotton garments since these minimize the chance of static spark and they aren't subject to releasing toxic fumes or melting onto skin if exposed to fire.“ [31].

Current safety measures include spark detectors, oxygen concentration monitoring systems, automatic fire extinguishing systems, and strict rules regarding operator training and personal item checks. In addition, the chambers are manufactured from certified fire-resistant materials and subject to regular inspections in accordance with technical standards [9,31].

From a safety perspective, the professional community has long pointed to the need for systematic monitoring and analysis of incidents in hyperbaric chambers. One of the recommended measures is the introduction of a unified incident reporting system that would allow the categorisation of causes, type of equipment, personnel involved, and follow-up measures taken. These data would form the basis for a centralised database that could be used to prevent, train, and review existing safety protocols [9].

Professional institutions are already partially implementing this approach. For example, the Undersea and Hyperbaric Medical Society operates the Global Hyperbaric Incident Reporting System (GHIRS), which serves as an international platform for electronic incident reporting and safety trend analysis [9]. Similarly, the European Code of Good Practice explicitly recommends the introduction of incident reporting and monitoring of operational procedures as part of a comprehensive risk management system [32].

Effective information sharing among operators, technical specialists, and medical personnel is essential for improving safety while maintaining the therapeutic efficacy of hyperbaric treatment.

Given the documented fatalities and health impacts, adoption and compliance with safety standards are necessary for both human and animal treatments in hyperbaric environments. This situation raises concerns regarding wellness hyperbaric oxygen therapy, which is often provided by non-medical facilities and is not classified as a therapeutic measure. As a result, these facilities may not be required to comply with strict safety measures such as fire safety standards.

CONCLUSION

Retrospective analysis of serious incidents in hyperbaric chambers confirms that operation of these facilities is associated with significant safety risks, primarily the risk of fire and explosion in high-oxygen environments.

Most recorded events resulted from a combination of technical failure, non-compliance with operating regulations, and human error. Despite significant improvements in design and organizational safety measures in recent decades, a global mandatory system for reporting and sharing incident data remains absent. Implementing a standardized international incident reporting system, along with mandatory staff training, regular technical equipment inspections, and thorough checks of personal items, is essential for further risk reduction.

Special attention is required for wellness applications of hyperbaric oxygen therapy, which frequently occur outside healthcare facilities and may not be subject to strict safety standards. The study emphasizes the necessity of systematic risk management, technical equipment reliability, and international cooperation for incident data sharing to enhance the safety of patients and staff during hyperbaric oxygen therapy.

LIST OF ABBREVIATIONS

ECHM: European Committee for Hyperbaric Medicine
 GHIRS: Global Hyperbaric Incident Reporting System
 UHMS: Undersea and Hyperbaric Medical Society
 UIHC: University of Iowa Health Care

AVAILABILITY OF DATA AND MATERIALS

The data file used comes from professional sources and publicly available data.

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ETHICAL COMMITTEE

The study was conducted according to the principles of ethical research. Since only publicly available data without personal information were used, ethical approval was not required. The investigation did not interfere with the rights of individuals or institutions.

CONSENT FOR PUBLICATION

Not applicable. This manuscript does not include personal data, and all information has been fully anonymised in accordance with GDPR regulations.

CONFLICT OF INTEREST STATEMENT

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

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