

Introduction To Hyperbaric Medicine

Hyperbaric medicine is the clinical specialty that uses elevated ambient pressure to enhance the delivery of oxygen to body tissues. The terminology in this field is extensive, and a solid grasp of the key words is essential for anyone studying Hyperbaric Oxygen Therapy Fundamentals. The following explanation presents the most important terms, organized by categories that reflect the physical environment, the equipment, the physiological processes, the clinical indications, and the safety considerations. Each term is defined, illustrated with an example, and linked to practical applications or challenges that learners may encounter in clinical practice.

Atmospheric pressure refers to the pressure exerted by the weight of the earth's atmosphere at sea level, commonly expressed as 1 atm, 1013 hPa, 760 mmHg, or 14.7 Psi. In hyperbaric therapy the environment is raised above this baseline. For instance, a treatment at 2.0 Atm absolute (ATA) means the patient is exposed to twice the pressure of sea-level air. Understanding atmospheric pressure is crucial because the calculation of gas partial pressures, which drive the therapeutic effect, depends directly on the baseline pressure.

Absolute pressure (also called total pressure) is the sum of atmospheric pressure plus any additional pressure applied by the hyperbaric system. When a chamber is pressurised to 2.5 ATA, the absolute pressure is 2.5 Times the pressure at sea level. This differs from gauge pressure, which measures only the pressure above atmospheric pressure. Gauge pressure is often displayed on the chamber's control panel, while absolute pressure is used in physiologic calculations.

Bar is a metric unit of pressure equal to 100 kPa, roughly equivalent to 0.9869 Atm. Many hyperbaric facilities use bar to describe treatment levels; a common protocol may be 2.0 Bar, which is essentially the same as 2.0 ATA. The term psi (pounds per square inch) is more common in the United States, where a typical outpatient protocol might be described as 2.0 Psi above atmospheric pressure, or 3.0 Psi absolute. Converting between these units is a routine skill for hyperbaric technicians.

Partial pressure of oxygen (pO_2) is the pressure contributed by oxygen in a gas mixture. In a normal breathing environment at sea level, the pO_2 is about 0.21 Atm (21% of atmospheric pressure). Inside a hyperbaric chamber breathing 100% oxygen at 2.0 ATA, the pO_2 becomes 2.0 Atm, dramatically increasing the amount of oxygen dissolved in plasma. This increase is the primary mechanism by which HBOT promotes healing in hypoxic tissues.

Dissolved oxygen is the fraction of oxygen that is physically dissolved in the plasma, independent of hemoglobin binding. At 1 ATA breathing ambient air, dissolved oxygen is roughly 0.3 ml O_2 per 100 ml of blood. At 2.0 ATA breathing 100% oxygen, dissolved oxygen can rise to more than 5 ml O_2 per 100 ml, enough to meet tissue metabolic demands even when hemoglobin function is impaired. Understanding the relationship between pO_2 and dissolved oxygen helps clinicians predict the effectiveness of HBOT in conditions such as carbon monoxide poisoning.

Hemoglobin saturation (SaO_2) describes the percentage of hemoglobin molecules bound to oxygen. In normal atmospheric conditions, SaO_2 is typically 95-98%. Hyperbaric exposure does not significantly increase SaO_2 because hemoglobin is already near its maximum binding capacity, but the increased dissolved oxygen compensates for any limitations in hemoglobin transport. This concept is vital when treating patients with severe anemia, where the dissolved oxygen component becomes the main source of tissue oxygenation.

Normobaric refers to conditions at normal atmospheric pressure (1 ATA). Normobaric oxygen therapy (NBOT) delivers high concentrations of oxygen without increasing pressure, such as a patient receiving 95% oxygen via a face mask. While NBOT can raise pO_2 , the increase is modest compared to hyperbaric therapy, which can achieve pO_2 values several times higher. Comparing normobaric and hyperbaric approaches helps trainees understand why certain injuries, like decompression sickness, require pressure elevation for resolution.

Hyperoxia denotes an excess of oxygen in the tissues, typically resulting from high pO_2 environments. Short-term hyperoxia is therapeutic, but prolonged exposure can lead to oxidative stress and tissue damage. For example, a patient receiving 10 sessions of HBOT at 2.4 ATA may experience transient visual changes due to retinal oxygen toxicity, a known risk of hyperoxia. Recognising the signs of hyperoxia is an essential safety skill.

Oxygen toxicity is the adverse effect of high pO_2 on cells, manifesting as pulmonary or central nervous system (CNS) toxicity. Pulmonary toxicity develops gradually with repeated exposures, presenting as cough, chest discomfort, or reduced lung compliance. CNS toxicity can occur acutely during a single high-pressure exposure, leading to seizures, visual disturbances, or loss of consciousness. The risk of CNS toxicity rises sharply when pO_2 exceeds 1.6 Atm for periods longer than 30 minutes. Clinical protocols limit pO_2 and exposure time to keep toxicity risk within acceptable bounds.

Decompression sickness (DCS) is a condition caused by the formation of inert gas bubbles in tissues and blood when ambient pressure drops too quickly. Divers, astronauts, and patients undergoing rapid ascent from a hyperbaric chamber are at risk. Symptoms range from joint pain (the "bends") to neurological deficits. HBOT treats DCS by increasing ambient pressure, re-dissolving bubbles, and enhancing inert gas elimination. Understanding DCS is fundamental because it illustrates the core therapeutic principle of hyperbaric medicine: Pressure manipulation to control gas dynamics.

Barotrauma refers to tissue injury caused by pressure differentials across a body cavity. In hyperbaric settings, barotrauma can affect the ears, sinuses, lungs, or gastrointestinal tract. For instance, a patient who fails to equalise middle-ear pressure during compression may develop an acute tympanic membrane rupture. Preventive strategies include thorough pre-treatment screening, patient education on equalisation techniques, and gradual compression rates. Recognising barotrauma early prevents escalation to more serious complications.

Inert gas is any component of a breathing mixture that does not participate in oxygen exchange, most commonly nitrogen. In the context of HBOT, inert gas dynamics are crucial because nitrogen can form bubbles during decompression. Switching a patient from a nitrogen-containing mixture to 100% oxygen

reduces the nitrogen load, accelerating bubble resolution. The term “inert gas” also appears in discussions of dive medicine, where nitrogen narcosis and high-pressure nervous syndrome involve inert gas effects at depth.

Recompression is the process of increasing ambient pressure to treat or prevent bubble-related injuries. In clinical practice, recompression is performed in a hyperbaric chamber following a DCS event, or as a prophylactic measure after certain surgeries. The recompression schedule is often expressed in “tables,” such as the US Navy Table 6, which specifies pressure levels, duration at each level, and ascent rates. Mastery of recompression tables is a core competency for hyperbaric technicians and physicians.

Decompression is the controlled reduction of ambient pressure after a period of hyperbaric exposure. Proper decompression prevents the formation of new bubbles and allows existing bubbles to be eliminated safely. Decompression protocols may involve staged pressure reductions (e.g., 0.2 ATA per minute) with “air breaks” where the patient breathes air for a few minutes to reduce oxygen exposure and mitigate toxicity risk. The balance between decompression speed and oxygen toxicity risk is a frequent challenge in treatment planning.

Multiplace chamber is a large hyperbaric enclosure that can accommodate several patients, a medical team, and support equipment simultaneously. These chambers are typically pressurised with air, and patients breathe 100% oxygen through masks or hoods, reducing fire risk. A common example is a 20-person multiplace unit used in a hospital hyperbaric department for both emergency and elective treatments. Multiplace chambers require a dedicated “airlock” system for safe entry and exit, and they allow continuous monitoring of multiple patients by a single operator.

Monoplace chamber is a single-patient hyperbaric unit that is filled entirely with 100% oxygen. Because the entire environment is oxygen-rich, fire safety measures are stringent, and the patient must be free of any combustible materials. Monoplace chambers are often used for outpatient treatments such as chronic wound care, where a single patient can be treated without an attendant. The simplicity of a monoplace design reduces staffing needs but limits the ability to perform simultaneous interventions.

Airlock is a compartment attached to a multiplace chamber that allows personnel and equipment to move in and out without depressurising the main chamber. The airlock cycles through pressurisation and depressurisation steps, maintaining the therapeutic pressure within the chamber. For example, a physician may enter the chamber via the airlock to perform a bedside procedure while the patient remains inside. Mastery of airlock operation is essential for maintaining safety and treatment integrity.

Control console is the central interface that monitors and regulates chamber pressure, temperature, humidity, and gas composition. Modern consoles display real-time pressure curves, alarm thresholds, and patient vital signs. The console also logs treatment data for documentation and quality assurance. Familiarity with the control console enables technicians to respond quickly to pressure deviations, equipment malfunctions, or emergent patient needs.

Patient monitoring during HBOT includes continuous observation of heart rate, blood pressure, oxygen saturation, and respiratory status. In many facilities, a dedicated monitor is attached to a peripheral sensor

that transmits data to the control console. Monitoring also extends to visual cues such as the patient's level of consciousness and ability to communicate. Effective monitoring helps detect early signs of oxygen toxicity, barotrauma, or other adverse events.

Therapeutic pressure is the specific pressure level prescribed for a given clinical indication. Typical therapeutic pressures range from 1.5 ATA for chronic wound healing to 2.8 ATA for acute carbon monoxide poisoning. The selection of therapeutic pressure balances the desired increase in pO_2 against the risk of toxicity and patient tolerance. For example, a diabetic foot ulcer may be treated at 2.0 ATA, while a severe crush injury with suspected compartment syndrome may require 2.4 ATA.

Treatment schedule or "protocol" describes the number of sessions, duration of each session, pressure level, and breathing gas composition. A common protocol for radiation-induced tissue injury is 20 sessions at 2.0 ATA, each lasting 60 minutes, with a 5-minute air break after the first 30 minutes. Understanding how to construct and adjust a treatment schedule is vital because patient response varies, and protocols often need individualisation based on comorbidities, age, and tolerance.

Air break is a short interval during a treatment session where the patient breathes air instead of 100% oxygen. Air breaks reduce the cumulative oxygen dose, lowering the risk of CNS toxicity while maintaining overall therapeutic efficacy. For instance, a 90-minute session at 2.4 ATA may include a 5-minute air break at the halfway point. Proper timing of air breaks requires coordination between the technician and the patient, and it is a frequent source of scheduling errors for novices.

Hyperbaric preconditioning (or "pre-HBOT") is the use of low-dose hyperbaric exposure before a planned injury or surgical procedure to induce protective physiological changes. Animal studies have shown that preconditioning can up-regulate antioxidant enzymes and reduce inflammatory responses. Clinically, preconditioning is being explored for patients undergoing high-risk cardiac surgery, where a series of low-pressure HBOT sessions may improve postoperative outcomes. The concept illustrates the expanding role of hyperbaric therapy beyond acute treatment.

Hyperbaric conditioning is similar to preconditioning but is applied as a chronic, ongoing regimen to enhance overall tissue resilience. Some athletes use periodic HBOT sessions to accelerate recovery from intense training, although the evidence remains mixed. The term "conditioning" signals the need for careful assessment of benefits versus risks, especially regarding long-term oxygen exposure and potential oxidative damage.

Reactive oxygen species (ROS) are chemically reactive molecules containing oxygen, such as superoxide, hydrogen peroxide, and hydroxyl radicals. While ROS are normal by-products of cellular metabolism, excessive ROS production during hyperoxia can overwhelm antioxidant defenses, leading to oxidative stress. Therapies that combine HBOT with antioxidants (e.g., Vitamin C or N-acetylcysteine) are under investigation to mitigate ROS-related damage. Understanding ROS dynamics is key for managing the fine line between therapeutic hyperoxia and toxicity.

Oxidative stress occurs when the balance between ROS production and antioxidant capacity is disrupted, resulting in cellular injury. In hyperbaric medicine, oxidative stress can manifest as pulmonary inflammation

or CNS disturbances. Monitoring biomarkers such as malondialdehyde or glutathione levels is an emerging practice to gauge oxidative stress during repeated HBOT courses. The challenge for clinicians is to optimise therapeutic benefit while minimising oxidative injury.

Carbon monoxide poisoning is a life-threatening condition in which carbon monoxide (CO) binds to hemoglobin, forming carboxyhemoglobin (COHb) and impairing oxygen delivery. HBOT accelerates CO elimination because the high pO₂ displaces CO from hemoglobin and increases the diffusion gradient for CO from tissues to blood. A standard protocol for severe CO poisoning is 2.8 ATA for 90 minutes, repeated if COHb levels remain above 5%. The rapid reduction of COHb demonstrates the unique advantage of hyperbaric therapy over normobaric oxygen.

Decompression illness encompasses both DCS and arterial gas embolism (AGE), conditions that arise from rapid pressure changes. AGE occurs when gas bubbles enter the arterial circulation, often during a dive accident or a faulty breathing apparatus. HBOT treats AGE by increasing pressure to reduce bubble size and by delivering high pO₂ to salvage ischemic tissue. The distinction between DCS and AGE is important because treatment urgency and pressure levels may differ.

Arterial gas embolism is a critical emergency in which gas bubbles obstruct arterial blood flow, leading to ischemia of the brain, spinal cord, or other organs. Prompt HBOT, ideally within six hours of symptom onset, is essential to improve neurological outcomes. The treatment may involve a high-pressure protocol (e.g., 3.0 ATA for 60 minutes) with rapid decompression to minimise bubble size while avoiding exacerbation of CNS toxicity. The time-sensitive nature of AGE underscores the need for rapid access to a hyperbaric facility.

Radiation injury refers to tissue damage caused by ionising radiation, which can result in chronic wounds, osteoradionecrosis, or soft-tissue necrosis. HBOT promotes angiogenesis, fibroblast proliferation, and collagen synthesis, thereby improving healing in irradiated tissues. A typical regimen for osteoradionecrosis of the mandible is 30-40 sessions at 2.4 ATA, each lasting 90 minutes, with periodic assessment of bone vitality. The term "radiation injury" signals a specific therapeutic niche where HBOT has demonstrated measurable benefit.

Chronic wound is a wound that fails to proceed through the normal phases of healing within an expected timeframe, often persisting for more than three months. Diabetic foot ulcers, pressure ulcers, and venous stasis ulcers fall into this category. HBOT improves chronic wound healing by increasing tissue oxygen tension, stimulating neovascularisation, and enhancing leukocyte bactericidal activity. Clinical studies report that HBOT can reduce amputation rates in diabetic foot ulcers by up to 30% when combined with standard wound care.

Necrotizing fasciitis is a rapidly progressing infection of the fascia and subcutaneous tissue, commonly caused by polymicrobial organisms. Hyperbaric oxygen is an adjunctive therapy that inhibits anaerobic bacterial growth, improves leukocyte function, and augments tissue oxygenation. The typical adjunctive protocol includes daily HBOT sessions at 2.5 ATA for 90 minutes until clinical improvement is observed. The inclusion of HBOT in necrotizing fasciitis management highlights its role as a supportive, rather than primary, therapy.

Clostridial myonecrosis (gas gangrene) is an infection caused by *Clostridium* species that thrive in low-oxygen environments. HBOT creates an oxygen-rich milieu that directly inhibits clostridial toxin production and spore germination. In severe cases, patients may receive multiple daily sessions at 2.8 ATA until the infection is controlled. The term “myonecrosis” reminds clinicians that hyperbaric therapy can be life-saving when combined with surgical debridement and antimicrobial therapy.

Hyperbaric oxygen toxicity seizure is a rare but serious complication of high-pressure HBOT, characterized by a generalized tonic-clonic seizure. The mechanism involves excessive neuronal excitability due to high pO_2 . The seizure is typically self-limiting, but immediate reduction of chamber pressure and administration of anticonvulsants are recommended. Preventive strategies include limiting pO_2 to ≤ 1.6 Atm for sessions longer than 30 minutes and ensuring adequate air breaks. Recognising the early signs of CNS toxicity, such as visual disturbances or tinnitus, allows timely intervention before a seizure occurs.

Pulmonary oxygen toxicity manifests as irritation of the airway, cough, and decreased lung compliance after prolonged exposure to high pO_2 . The “U-shaped” dose-response curve indicates that toxicity risk rises with cumulative oxygen exposure. Clinicians track the “oxygen clock” by adding the product of pO_2 (in atmospheres) and exposure time (in minutes) for each session; values exceeding 2,000 ATA-minutes are associated with increased pulmonary risk. Adjusting treatment schedules to stay below this threshold is a common challenge in long-term HBOT programs.

Fire hazard is a paramount safety concern in hyperbaric facilities because oxygen-rich environments dramatically lower the ignition temperature of many materials. In a monoplace chamber, any spark can ignite a fire, so all equipment inside must be oxygen-compatible, and patients must be free of oil-based skin products, cigarettes, or electronic devices. Multiplace chambers mitigate fire risk by using air as the pressurising gas and providing a separate oxygen delivery system. Rigorous fire-prevention protocols, including regular inspection of seals, hoses, and electrical components, are mandatory.

Oxygen fire occurs when a combustible material ignites in an oxygen-enriched atmosphere. The flame can spread rapidly and become difficult to extinguish due to the high oxygen concentration. In hyperbaric settings, fire suppression systems often use inert gases such as carbon dioxide or halon, but the primary defense is prevention. Training staff to recognise and remove potential ignition sources before chamber pressurisation is essential to avoid catastrophic incidents.

Compression rate is the speed at which chamber pressure is increased, typically measured in ATA per minute. A common compression rate for elective treatments is 0.1 ATA per minute, allowing patients to equalise pressure in the ears and sinuses comfortably. Faster compression rates may be employed in emergency recompression for DCS, but they increase the risk of barotrauma and CNS toxicity. Selecting an appropriate compression rate requires balancing urgency with patient tolerance.

Decompression rate mirrors the compression rate, describing how quickly pressure is reduced. A standard decompression rate for therapeutic sessions is 0.05 ATA per minute, often interspersed with air breaks. Rapid decompression can precipitate bubble formation, while overly slow decompression prolongs treatment duration and may increase oxygen exposure. Mastery of decompression rate adjustments is a frequent source of learning curves for new hyperbaric technicians.

Equalisation is the process by which a patient balances the pressure in air-filled cavities (e.G., Middle ear, sinuses) with the external pressure. Common techniques include the Valsalva manoeuvre, swallowing, and yawning. Inadequate equalisation leads to barotrauma. Training patients in equalisation before entering the chamber reduces the incidence of ear pain and tympanic membrane rupture. In pediatric patients, caregivers often assist with equalisation techniques.

Pressure-controlled ventilation (PCV) is a mode of mechanical ventilation used in some hyperbaric intensive-care settings, where the ventilator delivers breaths at a set pressure rather than a set volume. PCV helps avoid excessive alveolar pressure during HBOT, reducing the risk of pulmonary barotrauma. Understanding PCV settings is crucial for managing intubated patients who require hyperbaric therapy for severe infections or carbon monoxide poisoning.

Inert gas elimination describes the process by which dissolved nitrogen is removed from the body during decompression. The rate of elimination depends on ambient pressure, ventilation, and tissue perfusion. Hyperbaric protocols often incorporate "air breaks" to promote nitrogen wash-out while limiting oxygen exposure. Monitoring inert gas elimination through serial blood nitrogen levels is not routine but can be useful in research settings.

Partial pressure of nitrogen (pN_2) is the pressure contributed by nitrogen in a gas mixture. At sea level, pN_2 is about 0.79 Atm. During HBOT with 100% oxygen, pN_2 drops to essentially zero, accelerating nitrogen elimination. Understanding pN_2 dynamics is essential for treating divers with DCS, as the reduction of pN_2 is the primary driver of bubble resolution.

Therapeutic window in hyperbaric medicine refers to the range of pressure and oxygen exposure that yields clinical benefit without unacceptable toxicity. For most indications, the therapeutic window lies between 1.5 And 2.8 ATA with pO_2 values below 2.0 Atm for sessions longer than 60 minutes. Outside this window, the risk of CNS toxicity, pulmonary toxicity, or fire hazards outweighs the benefits. Determining the therapeutic window for each patient involves assessing comorbidities, age, and prior exposure history.

Contraindication denotes a condition or factor that makes a specific medical intervention inadvisable. Absolute contraindications for HBOT include untreated pneumothorax, certain chemotherapy agents (e.G., Doxorubicin) that sensitize lung tissue, and uncontrolled seizure disorders. Relative contraindications may include recent ear surgery, severe chronic obstructive pulmonary disease (COPD), and pregnancy. Recognising contraindications prevents iatrogenic harm and guides alternative treatment pathways.

Relative contraindication is a condition that does not automatically preclude HBOT but requires careful risk-benefit analysis. For example, a patient with mild COPD may tolerate HBOT if the therapeutic benefit outweighs the risk of barotrauma. In such cases, a lower therapeutic pressure or modified protocol may be employed. The distinction between absolute and relative contraindications is a core decision-making component for hyperbaric physicians.

Absolute contraindication is a situation in which HBOT must not be performed because the potential for severe harm is overwhelming. Untreated pneumothorax is a classic absolute contraindication; the presence of free air in the pleural space can expand dramatically under pressure, leading to tension pneumothorax

and cardiovascular collapse. The policy is to resolve the pneumothorax with chest tube drainage before considering hyperbaric treatment.

Adjunctive therapy refers to additional treatments used alongside HBOT to enhance outcomes. In chronic wound management, adjunctive therapies may include negative-pressure wound therapy, debridement, and antimicrobial dressings. For carbon monoxide poisoning, adjunctive therapy includes hyperventilation and administration of 100% normobaric oxygen before HBOT. Understanding how HBOT integrates with other modalities is essential for comprehensive patient care.

Compliance in the hyperbaric context describes the degree to which a patient follows the prescribed treatment schedule. High compliance is associated with better clinical outcomes, particularly in chronic wound healing where multiple sessions over weeks are required. Barriers to compliance include transportation difficulties, claustrophobia, and work commitments. Strategies to improve compliance involve flexible scheduling, patient education, and addressing psychological concerns.

Claustrophobia is a common psychological barrier to successful HBOT, especially in monoplace chambers where the patient is enclosed in a small space. Symptoms can range from mild anxiety to full panic attacks. Techniques to mitigate claustrophobia include patient orientation tours, use of visual or auditory distractions, and, in severe cases, mild anxiolytic medication administered under physician supervision. Overcoming claustrophobia improves treatment adherence and reduces session cancellations.

Hyperbaric nursing is a specialised field of nursing that focuses on the care of patients receiving HBOT. Responsibilities include patient assessment, monitoring vital signs, managing airway equipment, documenting treatment parameters, and responding to emergencies such as seizures or barotrauma. Hyperbaric nurses also educate patients on pre-treatment preparation, post-treatment care, and lifestyle modifications that support healing. Certification programmes often require both theoretical knowledge and hands-on clinical experience.

Hyperbaric technician is a professional who operates and maintains the hyperbaric chamber, ensures safety protocols are followed, and assists with patient positioning and monitoring. Technicians must be proficient in chamber operation, emergency procedures, and equipment maintenance. They also coordinate with physicians to adjust treatment parameters based on patient response. The role demands meticulous attention to detail, as small errors in pressure settings or gas delivery can have significant clinical consequences.

Quality assurance in hyperbaric medicine involves systematic processes to ensure that treatments are delivered safely, effectively, and consistently. QA activities include regular calibration of pressure gauges, verification of oxygen purity, documentation audits, and staff competency assessments. Implementing a robust QA program reduces the incidence of adverse events, improves patient outcomes, and supports compliance with regulatory standards.

Regulatory standards are guidelines established by governmental or professional bodies that govern the design, operation, and maintenance of hyperbaric facilities. In the United States, the Undersea and Hyperbaric Medical Society (UHMS) provides practice guidelines, while the Occupational Safety and Health

Administration (OSHA) sets workplace safety standards. Internationally, the European Committee for Hyperbaric Medicine (ECHM) offers similar recommendations. Adherence to these standards is mandatory for accreditation and reimbursement.

Undersea and Hyperbaric Medical Society (UHMS) is a leading professional organization that publishes clinical practice guidelines, maintains a registry of hyperbaric facilities, and promotes research in hyperbaric medicine. The UHMS guidelines define the approved indications for HBOT, outline safety protocols, and provide evidence-based recommendations for treatment parameters. Familiarity with UHMS publications is essential for clinicians seeking to align their practice with accepted standards.

Evidence-based indication is a clinical condition for which robust scientific data support the use of HBOT. Examples include chronic refractory osteomyelitis, radiation-induced tissue injury, and acute carbon monoxide poisoning. For each indication, the UHMS publishes a level of evidence rating (e.G., Level I, II, III) based on the quality of research. Understanding the evidence hierarchy helps clinicians justify HBOT to insurers and to patients.

Off-label use describes the application of HBOT for conditions not formally approved by regulatory agencies or not listed in the UHMS guidelines. While many clinicians employ HBOT for off-label indications such as traumatic brain injury or autism spectrum disorders, reimbursement may be limited, and the evidence base may be weaker. Practitioners must obtain informed consent, document the rationale, and monitor outcomes closely when pursuing off-label therapies.

Insurance reimbursement policies vary widely and often depend on whether an indication is listed as “approved” by the UHMS. For approved indications, insurers typically cover a predetermined number of sessions, while off-label uses may require pre-authorization or be denied outright. Accurate documentation of diagnosis codes, treatment parameters, and clinical response is essential to secure reimbursement. Navigating insurance requirements is a frequent administrative challenge for hyperbaric centers.

Clinical outcome refers to the measurable result of a treatment, such as wound closure, reduction in amputation rate, or improvement in neurological function. In HBOT research, outcomes are often assessed using standardized scales (e.G., The Wagner classification for diabetic foot ulcers) or objective measures (e.G., Tissue oxygen tension). Tracking clinical outcomes over time allows facilities to evaluate the effectiveness of their protocols and to refine treatment algorithms.

Side effect is any undesirable effect that occurs during or after HBOT. Common side effects include ear discomfort, sinus pressure, transient visual changes, and mild fatigue. More serious side effects, such as seizures or pulmonary toxicity, are rare but require immediate intervention. Recording side effects in a systematic manner aids in risk assessment and contributes to the overall safety database for hyperbaric therapy.

Patient education is a cornerstone of successful hyperbaric treatment. Education topics include pre-treatment fasting, clothing requirements (e.G., Cotton garments, avoidance of synthetic fabrics), medication adjustments (e.G., Withholding nicotine patches), and post-treatment care (e.G., Wound dressing changes). Effective education reduces anxiety, improves compliance, and minimises the incidence

of preventable complications.

Pre-treatment assessment is the systematic evaluation performed before a patient enters the chamber. It includes medical history review, physical examination focusing on ears, lungs, and sinuses, vital sign measurement, and verification of contraindications. The assessment may also involve laboratory tests such as arterial blood gases for patients with respiratory disease. A thorough pre-treatment assessment identifies potential risks and informs the selection of appropriate pressure and duration.

Post-treatment care involves monitoring the patient for delayed side effects, providing instructions on activity restrictions, and scheduling follow-up appointments. For example, after a session for radiation-induced osteoradionecrosis, the patient may be advised to avoid smoking and to maintain a high-protein diet to support bone healing. Documentation of post-treatment observations supports continuity of care and quality improvement.

Documentation is the written record of all aspects of a hyperbaric session, including patient identification, indication, pressure level, duration, gas composition, air break timing, vital signs, and any adverse events. Accurate documentation is required for legal protection, quality assurance, and reimbursement. Electronic health record (EHR) systems often include hyperbaric modules that streamline data entry and facilitate audit trails.

Audit trail is a chronological record of all actions taken within the hyperbaric system, from pressure changes to alarm activations. Audits enable facilities to investigate incidents, identify patterns of non-compliance, and implement corrective actions. Regular review of audit trails is an integral part of the quality assurance program and helps maintain accreditation status.

Alarm system is an essential safety feature that alerts staff to deviations from preset pressure, temperature, or gas composition limits. Alarms may be audible, visual, or both, and are typically tiered into warning and critical levels. For example, a gradual pressure drop below the set point may trigger a warning alarm, while a rapid loss of pressure would activate a critical alarm, prompting immediate evacuation. Understanding alarm hierarchies and response protocols is vital for safe chamber operation.

Evacuation procedure outlines the steps to safely remove patients from the chamber in the event of an emergency such as fire, loss of pressure, or severe medical distress. The procedure includes rapid depressurisation, patient extraction via the airlock (if applicable), and immediate medical assessment. Drills are conducted regularly to ensure staff proficiency. Efficient evacuation minimizes the risk of injury and demonstrates compliance with safety regulations.

Fire drill is a scheduled practice of the fire evacuation protocol, often performed quarterly. During a fire drill, the chamber is pressurised to a safe level, and staff simulate a fire scenario, practicing rapid depressurisation, opening the chamber door, and accounting for all occupants. Successful drills are documented and used to identify areas for improvement. Regular fire drills reinforce the importance of fire safety in hyperbaric environments.

Oxygen system maintenance involves routine inspection, cleaning, and testing of the oxygen delivery infrastructure, including cylinders, regulators, tubing, and masks. Contamination of oxygen lines with oil or

grease can create a fire risk. Maintenance schedules typically require monthly leak checks and annual certification of oxygen purity. Proper maintenance ensures reliable oxygen delivery and reduces the likelihood of equipment-related incidents.

Chamber certification is the formal verification that a hyperbaric chamber meets design, safety, and performance standards. Certification may be performed by the manufacturer, a third-party inspection agency, or a regulatory body such as the Food and Drug Administration (FDA) for medical devices. The certification process includes pressure testing, leak detection, and verification of alarm functionality. Re-certification is required at regular intervals (often annually) to maintain operational status.

Patient positioning is the arrangement of the patient's body within the chamber to optimise comfort, safety, and therapeutic effect. For wound healing, the affected limb may be elevated on a pillow to promote venous return. In cases of neurological injury, the patient may be positioned supine with the head slightly elevated to facilitate cerebral perfusion. Proper positioning also ensures that monitoring equipment remains accessible and that the patient can communicate with staff.

Monitoring equipment includes devices such as pulse oximeters, capnographs, and non-invasive blood pressure cuffs that provide real-time data during HBOT. These devices must be compatible with the hyperbaric environment, meaning they are either placed outside the chamber with leads extending inside or are specially designed for use inside the chamber. Calibration of monitoring equipment before each session is a routine part of the pre-treatment checklist.

Capnography measures the partial pressure of carbon dioxide ($p\text{CO}_2$) in exhaled breath and provides an indirect assessment of ventilation. In hyperbaric settings, capnography can detect hypoventilation or hyperventilation, which may affect oxygen and nitrogen elimination. For intubated patients, capnography is essential to verify tube placement and to monitor respiratory status throughout the treatment.

Blood gas analysis (ABG) may be performed before, during, or after HBOT to assess oxygenation, ventilation, and acid-base status. An ABG can reveal improvements in PaO_2 after a treatment session, confirming the physiologic impact of HBOT. In patients with severe respiratory disease, serial ABGs help guide adjustments to pressure level or session duration to avoid worsening hypercapnia.

Hydration status is an often-overlooked factor in hyperbaric therapy. Dehydration can increase blood viscosity, potentially impairing microcirculatory flow and reducing the efficacy of hyperbaric oxygen delivery.