Certificate in Hyperbaric Medicine (United Kingdom)

Hyperbaric Safety and Emergency Procedures

Air Dive – a dive using compressed air as the breathing gas. related: dive profile, decompression schedule Air dives are common in training and recreational settings. Practical application includes using air for shallow therapeutic dives (Barotrauma – tissue injury caused by pressure differentials between a gas-filled space and surrounding tissue. related: equalisation, sinus injury In hyperbaric chambers, barotrauma can affect ears, sinuses, lungs, and teeth. Example: a patient failing to equalise middle-ear pressure during pressurisation may develop pain and haemorrhage. Prevention requires thorough pre-dive assessment and training in equalisation techniques.

Boyle's Law – the principle that at constant temperature, the volume of a gas is inversely proportional to its pressure. related: gas law, pressure-volume relationship Understanding Boyle's Law is essential for predicting gas expansion during ascent and for calculating safe decompression stops. Practical use includes estimating the change in lung volume when a patient ascends from 2 ATA to surface pressure.

Cabin Pressure – the absolute pressure inside a hyperbaric chamber measured in atmospheres absolute (ATA). related: pressure monitoring, gauge calibration Maintaining accurate cabin pressure is critical for therapeutic efficacy and safety. Example: a pressure sensor drift of 0.1 ATA can lead to under-treatment or excessive oxygen exposure. Regular calibration and redundancy are required to mitigate this risk.

Chamber Certification – the process by which a hyperbaric chamber is inspected and approved by a recognized authority (e.g., UK Health and Safety Executive). related: conformity assessment, CE marking Certification ensures compliance with design, construction, and testing standards. Practical steps include documentation review, pressure-test verification, and safety-system inspection. Challenges include keeping records up-to-date and managing modifications without voiding the certificate.

Chamber Operator – a qualified individual responsible for the safe conduct of hyperbaric sessions. related: dive supervisor, medical officer Operators must understand pressure control, emergency procedures, and patient monitoring. Example duties: initiating pressurisation, monitoring oxygen toxicity limits, and executing emergency depressurisation. Challenges involve maintaining competency through regular refresher training and managing high-stress situations.

Closed-Circuit Rebreather (CCR) – a breathing apparatus that recirculates exhaled gas after scrubbing carbon dioxide and replenishing oxygen. related: oxygen sensor, loop integrity While CCRs are more common in diving, they are occasionally used in hyperbaric research. Practical application includes extending treatment time without increasing gas consumption. Challenges include sensor failure, hypoxia, and hyperoxia, requiring rigorous pre-dive checks.

Decompression Sickness (DCS) – a disorder caused by inert gas bubbles forming in tissues and blood during or after a reduction in ambient pressure. related: inert gas, bubble formation Symptoms range from joint pain to neurological deficits. In hyperbaric medicine, DCS is treated with immediate recompression using a

monoplace or multiplace chamber. Prevention relies on adherence to validated dive tables or computer-generated profiles and careful monitoring of ascent rates.

Decompression Schedule – a prescribed sequence of depth and time intervals designed to allow safe inert-gas elimination. related: dive table, ascent rate Schedules are derived from empirical data and may be adjusted for patient age, fitness, and medical conditions. Example: a 90-minute therapeutic dive at 2.5 ATA followed by a staged ascent with 5-minute stops at 2.0, 1.5, and 1.0 ATA. Challenges include patient non-compliance and equipment malfunction that could truncate planned stops.

Dive Computer – an electronic device that calculates real-time depth, elapsed time, and decompression status using algorithms such as Bühlmann or VPM. related: algorithm, surface interval In therapeutic settings, dive computers assist operators in monitoring treatment progress and ensuring safe ascent. Limitations include sensor drift, battery failure, and reliance on proprietary software, all of which must be accounted for in emergency planning.

Diving Mask – a sealed eyewear device that provides an air space for vision and equalisation. related: mask squeeze, nasal valve Proper mask fit prevents water ingress and facilitates equalisation of middle-ear pressure. Example: a poorly sealed mask can cause mask squeeze, leading to facial barotrauma. Training in mask fitting and checking for leaks before pressurisation are essential safety steps.

Emergency Evacuation – the rapid removal of patients and staff from a hyperbaric chamber to a safe environment. related: evacuation plan, rescue team Evacuations may be triggered by fire, gas leak, or medical emergency. Practical application includes rehearsed drill procedures, availability of a secondary power source, and clear communication channels. Challenges involve coordinating multiple personnel, managing patient positioning, and ensuring continuous oxygen supply during transfer.

Emergency Shut-Down – the immediate cessation of chamber pressurisation and power to all non-essential systems. related: kill switch, fire alarm A shut-down is initiated when a critical fault (e.g., over-pressure, gas contamination) is detected. Example: activation of the primary emergency stop button halts the compressor and vents excess pressure through safety valves. Maintaining redundancy and periodic testing of shut-down circuits are required to guarantee reliability.

Fire Suppression System – an installed network of detectors and extinguishing agents designed to control fire within the chamber environment. related: fire alarm, halon system Systems may use inert gases (e.g., FM-200) to avoid oxygen enrichment. Practical use includes automatic discharge upon detection of flame or smoke. Challenges involve ensuring the system does not compromise oxygen concentration or damage sensitive equipment during activation.

Gas Mix – the specific proportion of oxygen, nitrogen, and other gases used for breathing during hyperbaric therapy. related: FiO_2, therapeutic gas Common mixes include 100 % oxygen, 21 % oxygen (air), and enriched air nitrox (e.g., 36 % O_2). Selecting the appropriate mix depends on treatment indication, depth, and patient tolerance. Incorrect mix selection can precipitate oxygen toxicity or inadequate therapeutic effect.

Hyperbaric Oxygen Therapy (HBOT) – the clinical use of 100 % oxygen at pressures greater than ambient to

enhance tissue oxygenation. related: indication, treatment protocol HBOT is employed for conditions such as carbon-monoxide poisoning, chronic wounds, and radiation injury. Sessions typically last 60-90 minutes at 2.0–2.5 ATA. Challenges include monitoring for oxygen toxicity, managing claustrophobia, and ensuring equipment reliability throughout treatment.

Hyperbaric Chamber – a pressure-rated vessel designed to accommodate patients for therapeutic or research purposes. related: multiplace, monoplace Chambers can be monoplace (single-patient) or multiplace (multiple patients with attendant). Construction materials, seal integrity, and pressure-relief mechanisms are critical safety aspects. Regular inspection, pressure testing, and adherence to design standards are mandatory to prevent catastrophic failure.

Hyperoxia – a physiological condition where tissue oxygen levels exceed normal physiological ranges. related: oxygen toxicity, FiO_2 While hyperoxia is the therapeutic goal of HBOT, excessive exposure can lead to central nervous system (CNS) toxicity, pulmonary edema, or visual disturbances. Monitoring cumulative oxygen exposure (e.g., using the U.S. Navy tables) helps balance therapeutic benefit against risk.

Incidence of Ocular Toxicity – the frequency with which patients develop visual disturbances (e.g., myopia, cataract) due to oxygen exposure. related: lens opacity, visual acuity Prolonged or repeated HBOT sessions increase this incidence. Practical mitigation includes limiting total oxygen exposure, scheduling visual assessments, and adjusting treatment depth when possible. Data collection on ocular outcomes is essential for long-term safety monitoring.

Isobaric Counterdiffusion (ICD) – the diffusion of gases in opposite directions across a tissue interface under constant pressure, potentially causing bubble formation. related: gas switching, nitrogen supersaturation ICD can occur when a patient switches from a high-nitrogen to a high-helium mix without adequate wash-out time. Example: moving from air to heliox at depth may precipitate inner-ear barotrauma. Proper sequencing of gas changes and monitoring of tissue gas loads are required to avoid this phenomenon.

Leak Detection – the systematic identification of unintended gas escape from the chamber envelope or associated piping. related: pressure decay test, ultrasonic detector Detecting leaks early prevents loss of therapeutic pressure and reduces fire-hazard potential. Practical methods include pressure hold tests, soap-bubble inspections, and electronic leak detectors. Challenges include locating small leaks in complex joint assemblies and ensuring that detection equipment is calibrated.

Light-Sensitive Equipment – devices within the chamber that may be affected by intense illumination, such as optical sensors or phototherapy units. related: photobleaching, sensor saturation Proper shielding and placement are required to maintain functionality. Example: an oxygen sensor positioned near a high-intensity lamp may give erroneous readings, leading to inappropriate oxygen delivery. Routine checks and clear labeling mitigate this risk.

Medical Clearance – the formal assessment by a qualified medical professional determining a patient's fitness for hyperbaric exposure. related: contraindication, pre-screening questionnaire Clearance includes evaluation of pulmonary function, cardiovascular status, and history of ear disease. Practical application involves completing a standardised form and documenting any required modifications to the treatment

protocol. Challenges arise when patients have ambiguous histories or when urgent treatment is needed before full clearance can be obtained.

Micronucleus Test – a laboratory assay used to assess DNA damage in peripheral blood lymphocytes after hyperbaric exposure. related: genotoxicity, biomarker Although not a routine safety procedure, the test can provide insight into long-term cellular effects of repeated HBOT. Example: a study showed increased micronuclei frequency after >30 HBOT sessions, prompting review of cumulative exposure limits. Integrating such tests into research protocols rather than clinical practice is advisable.

Nitrogen Narcosis – a reversible central nervous system impairment caused by high partial pressures of nitrogen, typically above 3.0 ATA. related: inert gas effect, depth limitation Narcosis manifests as euphoria, impaired judgement, or slowed reaction time. In therapeutic settings, it is avoided by limiting depth to ≤2.5 ATA and using enriched oxygen mixes. Monitoring patient cognition during treatment helps detect early signs.

Oxygen Toxicity – a condition resulting from excessive exposure to elevated partial pressures of oxygen, affecting the central nervous system or lungs. related: CNS toxicity, pulmonary toxicity CNS toxicity may present as seizures, while pulmonary toxicity can lead to cough and dyspnoea. Practical safeguards include adhering to maximum exposure limits (e.g., 1.4 ATA for 45 minutes), using treatment tables, and employing real-time oxygen monitoring. Challenges include patient variability and the need for rapid intervention if seizures occur.

Partial Pressure – the pressure exerted by an individual gas component within a mixture, calculated as the product of the total pressure and the gas fraction. related: Dalton's law, FiO_2 Partial pressure guides decisions on safe oxygen exposure. For example, at 2.0 ATA breathing 100 % oxygen, the oxygen partial pressure is 2.0 ATA, exceeding the CNS toxicity threshold. Accurate calculation is essential for treatment planning and emergency response.

Pressure Vessel – a container designed to hold gases at pressures significantly above atmospheric pressure, such as a hyperbaric chamber or compressor tank. related: ASME code, burst pressure Compliance with design codes (e.g., BS EN 14120) ensures structural integrity. Practical responsibilities include periodic hydrostatic testing, corrosion monitoring, and maintaining a log of pressure-cycle counts. Failure to adhere to these practices can result in catastrophic rupture.

Primary Rescue – the immediate response to a patient incident within the chamber, performed by the chamber operator or designated rescue personnel. related: rescue protocol, patient extraction Primary rescue may involve administering supplemental oxygen, initiating emergency decompression, or performing cardiopulmonary resuscitation (CPR). Example: a patient experiencing a seizure is placed in the supine position, given 100 % oxygen, and the chamber is depressurised to surface pressure while resuscitation continues. Training and equipment readiness are critical.

Pressure Relief Valve (PRV) – a safety device that automatically vents excess pressure to prevent chamber over-pressurisation. related: over-pressure, fail-safe PRVs are calibrated to open at a predetermined pressure (e.g., 2.6 ATA for a 2.5 ATA rated chamber). Practical checks include functional testing with a

calibrated pressure source. Challenges involve valve sticking due to corrosion or debris, which can compromise safety.

Recompression – the process of increasing ambient pressure to treat conditions such as DCS or arterial gas embolism. related: treatment table, monoplace chamber Recompression protocols are based on internationally accepted tables (e.g., US Navy Table 6). Example: a diver with DCS is placed in a multiplace chamber and treated according to Table 6, involving a pressure of 2.8 ATA with staged decompression. Timely recompression is essential; delays increase morbidity.

Rescue Diver – a trained individual equipped to assist patients during an emergency within the hyperbaric environment. related: dive rescue, surface support Rescue divers must be proficient in underwater navigation, patient handling, and emergency medical procedures. Practical application includes performing underwater extraction if a patient loses consciousness during a therapeutic dive. Ongoing competency assessments are required to maintain readiness.

Safety Valve – a valve that opens to release pressure when it exceeds a safe limit, similar to a PRV but often manually actuated. related: emergency depressurisation, valve inspection Safety valves provide a secondary line of defence if automatic relief fails. Regular inspection for corrosion, seal integrity, and correct spring tension is mandated. Failure to maintain the valve can result in uncontrolled over-pressure events.

Saturation Dive – a diving technique where a diver remains under pressure for a period long enough for inert gases to equilibrate with body tissues, allowing extended work at depth. related: habitat, decompression In hyperbaric medicine, saturation concepts inform long-duration treatment protocols and research on gas kinetics. Practical considerations include monitoring of gas composition, ensuring adequate CO_2 scrubbing, and managing psychological stress. Challenges include increased risk of DCS upon exit and the need for specialised life-support systems.

Scrubber Failure – the malfunction of a CO_2 removal system within a closed-circuit or habitat environment. related: CO_2 buildup, alarm Failure leads to rapid rise of CO_2 levels, causing hypercapnia, headache, and loss of consciousness. Practical mitigation includes redundant scrubbers, continuous CO_2 monitoring, and immediate venting procedures. Regular replacement of absorbent material and verification of airflow are essential preventative steps.

Seizure Management – the protocol for handling a patient who experiences a seizure, most commonly due to CNS oxygen toxicity. related: emergency depressurisation, anticonvulsant Immediate actions include turning off the oxygen source, gently positioning the patient, and initiating emergency depressurisation to surface pressure. Supplemental oxygen at 21 % may be administered after the seizure subsides. Documentation of seizure timing, duration, and treatment adjustments is required for future risk assessment.

Shockwave – a rapid pressure change that can occur during sudden depressurisation or equipment failure, potentially causing barotrauma. related: rapid decompression, pressure gradient Shockwaves may damage delicate structures such as the inner ear or lungs. Practical safety measures involve controlled depressurisation rates (e.g., ≤ 0.1 ATA min^{-1}) and use of pressure-relief valves that open gradually. Training

on the physiological impact of shockwaves helps staff avoid inadvertent rapid decompression.

Side-Port – an auxiliary opening in a multiplace hyperbaric chamber used for gas entry, instrumentation, or patient access. related: manifold, access hatch Proper sealing of side-ports is essential to maintain pressure integrity. Example: a malfunctioning side-port gasket can cause a slow leak, detected by a gradual pressure drop during a treatment run. Routine inspection and replacement of sealing components are required.

Smoke Detector – a fire-sensing device installed inside the chamber to provide early warning of combustion. related: fire alarm, evacuation trigger Smoke detectors must be rated for high-oxygen environments to avoid false alarms caused by oxygen-enhanced combustion. Practical considerations include regular functional testing, battery replacement, and ensuring detector placement does not interfere with patient positioning. Challenges involve balancing sensitivity with the risk of nuisance alarms.

Standard Operating Procedure (SOP) – a documented set of step-by-step instructions that describe routine operations and emergency actions. related: protocol, checklist SOPs for hyperbaric safety cover pressurisation, depressurisation, fire response, and patient monitoring. Example: an SOP may specify “If pressure exceeds 2.55 ATA, activate PRV and notify the medical officer within 30 seconds.” Maintaining current SOPs and training staff to follow them reduces human error.

Supplemental Oxygen – the provision of oxygen at a concentration higher than ambient air, typically used during emergencies or as part of therapeutic protocols. related: flow rate, delivery mask In emergencies, 100 % oxygen is administered via a non-rebreather mask while the chamber is depressurised. Practical issues include ensuring adequate oxygen supply, preventing enrichment of the chamber atmosphere, and monitoring for signs of toxicity. Stock management and regular checks of delivery equipment are essential.

Surface Support – the team and equipment located outside the chamber that provide logistical, medical, and technical assistance. related: control room, emergency trolley Surface support includes monitoring systems, communication links, and emergency medical kits. Example: during a treatment, the surface team observes a rise in chamber temperature and initiates cooling procedures. Coordination between surface and inside personnel is critical for rapid response.

System Failure – any loss of function of a critical component of the hyperbaric environment, such as power loss, compressor malfunction, or sensor error. related: fault diagnosis, redundancy A systematic approach to failure includes immediate risk assessment, activation of backup systems, and documentation. Practical example: loss of main power triggers an automatic transfer to an uninterruptible power supply (UPS) that maintains pressure control for at least 30 minutes. Challenges involve ensuring that all subsystems have adequate redundancy and that staff are trained to manage cascading failures.

Thermal Stress – physiological strain caused by temperature extremes within the chamber, potentially leading to heat exhaustion or hypothermia. related: HVAC, patient comfort Hyperbaric chambers can experience temperature rise due to compressor heat or cooling loss during depressurisation. Practical mitigation includes climate control systems, patient monitoring of core temperature, and provision of blankets or cooling packs. Failure to manage thermal stress may compromise treatment outcomes.

Training Record – a documented log of an individual’s participation in hyperbaric safety and emergency

procedure training. related: competency, refresher course Records must include dates, content covered, assessment results, and signatures of qualified instructors. Example: a chamber operator's record shows completion of a 12-hour emergency response course within the past 12 months. Maintaining accurate records ensures compliance with regulatory requirements and supports audit processes.

Transport – the movement of patients, equipment, or gases to and from the hyperbaric facility. related: logistics, chain of custody Safe transport of compressed gas cylinders requires adherence to the Carriage of Dangerous Goods regulations. Patient transport must consider medical stability, need for supplemental oxygen, and positioning to avoid pressure-related injury. Challenges include coordinating with emergency services and ensuring that transport containers are inspected for damage.

Valve Failure – the malfunction of any pressure-controlling valve, including PRVs, safety valves, or gas-delivery valves. related: stuck valve, leakage Failure may result in uncontrolled pressure rise, inability to depressurise, or gas contamination. Practical detection involves routine functional testing, visual inspection for corrosion, and verification of spring tension. Redundant valve designs and immediate availability of manual override tools mitigate the risks.

Ventilation – the process of supplying fresh air and removing stale or contaminated gas within the chamber environment. related: airflow, CO_2 scrubber Adequate ventilation prevents accumulation of CO_2 and maintains oxygen levels within safe limits. Example: a ventilated multiplace chamber uses a blower system delivering 15 L min^{-1} of fresh air to each occupant. Challenges include balancing ventilation rate with temperature control and ensuring that airflow does not create drafts that cause patient discomfort.

Vibration – mechanical oscillations transmitted through the chamber structure, often caused by compressors or external construction activity. related: equipment fatigue, patient comfort Excessive vibration can lead to equipment loosening, sensor drift, and patient anxiety. Practical measures include installing vibration isolators, regular tightening of fasteners, and monitoring vibration levels with accelerometers. Failure to control vibration may reduce the lifespan of critical components.

Water Intrusion – the unwanted entry of water into the chamber envelope, gas lines, or control electronics. related: seal integrity, corrosion Water intrusion can cause electrical short circuits, corrosion of pressure vessels, and loss of pressure control. Practical prevention involves regular inspection of seals, proper drainage of condensate, and use of waterproof connectors. In the event of intrusion, immediate shutdown of electrical systems and thorough drying are required.

Wound Healing – the physiological process accelerated by HBOT, especially in chronic or radiation-induced wounds. related: angiogenesis, fibroblast activity Hyperbaric treatment increases tissue oxygen tension, promoting neovascularisation and collagen synthesis. Practical application includes scheduling multiple daily HBOT sessions for refractory ulcers. Monitoring wound size, depth, and infection status provides objective measures of therapeutic efficacy. Challenges involve patient adherence to adjunctive wound-care protocols.

Zero-O_2 Alarm – a safety alarm triggered when the oxygen concentration in the chamber falls below a critical threshold (typically 19.5 %). related: hypoxia, gas monitoring The alarm prompts immediate

investigation for leaks, gas-mix errors, or equipment malfunction. Practical response includes checking oxygen supply lines, verifying gas-mix settings, and, if necessary, evacuating the chamber. Regular calibration of oxygen sensors is essential to avoid false alarms.