DMAC

The Diving Medical Advisory Committee

Training Objectives for a Diving Medicine Physician

This guidance includes all the training objectives agreed by the Diving Medical Advisory Committee, the European Diving Technology Committee and the European Committee for Hyperbaric Medicine in 2011.

Rev 1 - 2013

INTRODUCTION

The purpose of this document is to define more closely the training objectives in diving physiology and medicine that need to be met by doctors already fully accredited or board-certified in a clinical speciality to national standards.

It is based on topic headings that were originally prepared for a working group of European Diving Technology Committee (EDTC) and the European Committee of Hyperbaric Medicine (ECHM) as a guide for diving medicine some 20 years ago by J.Desola (Spain), T.Nome (Norway) & D.H.Elliott (U.K.).

The training now required for medical examiners of working divers and for specialist diving medicine physicians was based on a EDTC/ECHM standard 1999 and subsequently has been enhanced by the Diving Medical Advisory Committee (DMAC), revised and agreed in principle by DMAC, EDTC and ECHM in 2010 and then ratified by EDTC and ECHM in 2011. The requirements now relate to an assessment of competence, the need for some training in occupational medicine, the need for maintenance of those skills by individual 'refresher training'. Formal recognition of all this includes the need to involve a national authority for medical education.

These objectives have been applied internationally to doctors who provide medical support to working divers. (Most recreational instructors and dive guides are, by their employment, working divers and so the guidance includes the relevant aspects of recreational diving. Although the term "diver" refers to anyone who breathes at pressure from an underwater source of gas, the scope of training is in fact greater than that and includes those who work at pressure in a dry environment, such as compressed air workers, and those in deeper caissons and tunnels who use mixed gas and saturation techniques. (Though rare, the unique problems of professional and competitive breath-hold divers are also mentioned.) The training required for a hyperbaric oxygen physician is not covered here.

D.H.E. 2012

SCOPE OF DIVING

The term “working diver” is used **for all divers who dive for a reward.** This is a legal term that, in addition to working for money, includes those who dive in return for some non-monetary reward. Thus previously unregulated divers, such as some part-time fishermen, are now required to comply with their national diving regulations regardless of their principal employment and this appears to have led to a reduction of incidents.

The “Working diver” is the preferred term because, though the distinction is not essential, it covers all categories of commercial and professional divers. These terms are synonymous but sometimes imply a different working style, viz:

- **A commercial diver** tends to be employed full-time for diving duties, primarily by an offshore, inshore or inland diving company, port or other water-related authority:
  - **Offshore diver** (oil and gas industry, salvage, wind farms at sea**)**
  - **Inshore diver** (outfalls, harbours, marine buoys, most fish-farming, etc)
  - **Inland diver** (hydro-electric schemes, bridges, weirs, sewers etc)

- **A professional diver includes one who may not be working full-time as a diver, but who** is employed in another primary role that also requires diving tasks:
  - **Military divers** for ship husbandry, mine disposal, etc
  - **Public Service Divers** including Coastguard helicopter and Police divers for body recovery and SAR, divers in Fire & Rescue depts, City Hall etc
  - **Cameramen** for underwater photo shoots or filming,
  - **Diving instructors and guides** in the recreational diving industry. This covers all aspects of recreational diving. he diving doctor also needs to know about the special techniques of competitive breath-hold (apnoeic) divers.
  - **Marine and other scientists** (includes associated university students)
  - **Insurance assessors,**
  - **Aquarium and swimming pool attendants** (eg for helicopter dunker training)
  - **Open-sea harvesting** (of scallops etc) **and fish-farming**

TRAINING OBJECTIVES

The first edition of this revised guidance had paragraphs based on the structure and numbering of the Joint ECHM/EDTC Training Standards (1997) but, because of some differences of content between that, the original EDTC-ECHM document with its deeper scope (that led to DMAC Guidance 29) this further restructuring now seems practical for course providers and candidates. With the international growth of all diving, these new detailed training objectives are focussed primarily on international standards of competency in providing medical support for the working diver, thereby acknowledging that they include but must be broader than just the training objectives in diving needed for hyperbaric therapy. Medical cover for the working diver needs to include every category of diving.

Some doctors wish to become competent in both diving and hyperbaric medicine and so care has been taken to reduce duplication by the use of training objectives, where appropriate, that apply to both of these medical fields. For this reason HBO is addressed in this document only where it is relevant to diving.

Each training objective stands on its own and does not depend on others for interpretation. This means, theoretically, that the order in which they are presented is not significant but, for convenience, they have been placed in topic groups which should be a more practical format for training providers

Throughout this document, note also that the words of the training objectives that follow are each to be understood as beginning with this phrase:

"On completion of this training, the candidate is expected to - "

1 PHYSIOLOGY & PATHOLOGY OF DIVING AND HYPERBARIC EXPOSURE:

1.1 HYPERBARIC PHYSICS

- understand Archimedes‘ principle, including the differences between being negatively, neutrally and positively buoyant, and apply this to the underwater working environment,.
- understand atmospheric pressure, the universal gas law, general gas laws, other related gas laws (Boyle, Charles, Gay-Lussac) and be able to make all the relevant calculations, e.g. be able to calculate partial pressures, surface-equivalent values, pressure-volume and density changes at depth. Should be able to calculate the volume of compressed breathing gas needed for a given duration of specified activity at a specific pressure.
- understand Poisuelle's equation and be aware of the effects of changes in density and changes in diameter on air flow.
- calculate the effect upon the subsequent measurement of content per unit volume when samples taken at depth are decompressed to atmospheric pressure for analysis. Be aware that this expansion can reduce an unacceptable gas partial pressure or particulate count at depth to one that may be undetectable at the surface.
- convert between the different temperature units (degrees Centigrade, Fahrenheit, Kelvin and Rankin)
- understand Laplace's equation and its application to changes of bubble mechanics in the diving environment.
- understand Pascal's principle of pressure transmission in fluids and how this principle may affect a diver in the water.
- understand the significance of temperature changes with compression and decompression.
- be familiar with converting between imperial, metric and other units of pressure used
- be aware of the need to adjust for the difference between the concept of "gauge pressure“ (as still used by many engineers) and the absolute values of pressure.
- understand Henry's Law of gas equilibrium and the time dependence of gas equilibrium in fluid. (Review gas diffusion gradients in the tissues and pulmonary gas exchange .)
- understand the speed, transmission and reflections of sound waves in water, the units of sound pressure and energy underwater, and their attenuation by other factors. Apply this to various underwater sources: sonar, seismic etc.
- be familiar with the effect of various breathing gases on speech distortion at depth and the limitations of "helium unscramblers“.
- understand the influence of surface waves in various sea states upon transient changes of pressure on the diver at depth or on 'stops'
- understand the influence of a mask on the apparent displacement of perceived images and the effect of depth underwater on colour transmission and perception

1.2 DIVING RELATED PHYSIOLOGY
(FUNCTIONAL ANATOMY, RESPIRATION, HEARING AND EQUILIBRIUM CONTROL, THERMOREGULATION)

- understand the interactions upon underwater equilibrium of the loss of visual reference points in poor visibility and some loss of proprioception, especially if concurrent with ear-clearing difficulties
- understand the effect of lung volume on diver's in-water neutral buoyancy and the impact of increased rate of physical work and minute volume and hyperventilation

Respiratory

- explain the differences between normobaric and hyperbaric physiology (strong focus on gas physiology, gas transport, etc.)
- be aware of the special air-packing techniques of competitive apnoea divers that may change vital capacity and other parameters beyond physiological norms and of the complications of advanced breath-hold diving
- understand respiratory external dead space as influenced by various underwater breathing apparatus circuits and helmet designs
- understand the vertical pressure gradient over the immersed chest and the eupnoeic point in relation to counter-lung or demand-valve positioning
- understand the limitations imposed by increased density on ventilation and the external work of breathing
- understand the implications of underwater breathing apparatus (uba) on the work of breathing and how it changes with density and gas mix
- be able to understand technical reports on the adequacy of a uba (new design or in accident reports)
- understand the hazards of "Skip-breathing" to prolong scuba tank duration
- understand airway structure and hyperbaric gas flow in relation to diver velocity of ascent

Hearing

- understand the attenuation of sound at the ear when it is transmitted (i) through water only (ii) through water plus a neoprene hood (iii) through dry gas within a helmet

Thermal

- understand the physiology of thermoregulation and what determines human limits when exposed to sudden cold immersion (cold shock) or slow prolonged cooling.
- understand the responses to slow body cooling during immersion, and the relative roles of wet suits and dry suits.
- understand the advantages and disadvantages of providing thermal supplements (such as use of a surface-supplied hot-water suit) in relation to subsequent decompression safety.

- understand the respiratory loss of heat at greater depths especially in relation to gas density and the need for routine inspiratory gas heating
- recognise the hazards of respiratory heat loss when breathing cold gas at depth
- understand the thermal properties of the respired inert gases in relation to the increase of thermal capacity with increased pressure

1.3 HYPERBARIC PATHOPHYSIOLOGY OF IMMERSION

- understand the physiological effects of head-out immersion and supine submersion on cardiac output and tissue perfusion
- understand the hazard of hypoxia in ascent from a breath-hold dive especially if pre-dive hyperventilation has reduced CO2 drive
- understand the synergistic effects of raised partial pressure of respiratory gases in the causation of “deep-water blackout“ in deep air diving with hard work.
- understand the concept of CO2 retainers
- understand the need of training to prepare the individual to have a resilient psychological response for stress, particularly when handling a life-threatening situation.

Endurance

- assess the maximum dive duration as predetermined by the required decompression
- consider the nature of the task, the muscular and respiratory work (as increased with greater gas density) and diver’s motivation
- ecognise that industry guidance provides maximum in-water durations of excursions from a bell by a sat diver, e.g. 4 h for each man in a 2-man 8-h bell run.

1.4 PATHOPHYSIOLOGY OF DECOMPRESSION

- be aware of the history of and development of decompression theory
- be aware of the evidence surrounding the many mathematical and other hypotheses that relate to decompression theory and calculation, and including
  - the uptake and distribution of the respiratory gases at depth
  - effects due to the inspiration of the other so-called inert gases
  - bubble nuclei and bubble formation, growth and distribution
  - the separate role of bubble emboli arising from the alveoli
  - the implications for bubble effects of potential right-to-left shunts
  - surface activity at the blood-gas interface and its systemic effects
  - role of endothelium, blood constituents and other tissues in sequelae
- understand the basis of contemporary decompression theories (e.g, deep stops, rate of ascent, gas switching) and the limitations of their validation by manned testing and other techniques

- be aware of the concepts of superficial and deep counter-diffusion, their potential consequences and methods of avoidance
- relate the type of decompression to nature of any subsequent manifestations (Section 4.4)

1.5 ACUTE DYSBARIC DISORDERS: A BRIEF INTRODUCTORY SECTION ONLY

- understand the consequences of pressure-induced volume changes (barotrauma) in the various gas-containing spaces of the body
- recognise the many factors that can influence individual susceptibility to decompression illness, both acquired and natural.
- understand the different pathologies of DCI associated with
  - dissolved gas (DCS)
  - embolic gas (AGE)
  - both concurrently ("Type III DCS")
- recognise localised bubble formation in areas of hypoperfusion
- understand the role of the cellular elements of blood and the endothelium in the development of DCI
- understand that the pathology of decompression illness progresses with time after its onset and the possible implications

1.6 CHRONIC DYSBARIC DISORDERS ("LONG-TERM HEALTH EFFECTS")

General

- understand the principles of recognizing the presence of an occupational condition in a particular population of workers such as divers, of avoiding or minimising any contributory factors, of accepting any residual risk, of monitoring the population for effectiveness of control and the surveillance of individuals at risk for early diagnosis and management

Dysbaric osteonecrosis (DON)

- know the history of this condition in compressed-air workers (caisson and tunnel workers) and is subsequent identification in divers
- understand the application of occupational health principles to the problems of bone necrosis in divers and other pressure exposed workers.
- understand that DON is currently a larger problem in developing countries than the industrial world.
- know the approximate/estimated prevalence, the prolonged natural history and the relatively benign prognosis in most of those found to have early lesions.
- understand the management of this condition and be aware of the relatively benign significance of shaft lesions in contrast to the surgical interventions needed in some for structural collapse of the humeral or femoral head.

- understand the limitations of diagnostic screening if using less-hazardous MRI., In particular the implications of identification of early lesions (FICAT Stage 1), the differing pathological prognosis between dysbaric osteonecrosis (DON) and idiopathic femoral head necrosis (FHN) of adult males and the implications for management

CNS long-term health effects

- be aware of the possible implications of the insidious and long-term neurological and psychological manifestations reported in compressed air workers and divers and of the evidence for these. Recognise the multiple dysbaric and environmental factors that may contribute to such findings and the need for maintaining continuing vigilance

Other LTHE

- be aware of other reported long-term health effects related to
  - pulmonary function
  - hearing impairment
  - retinal angiographic findings

1.7 HBO-BASICS - PHYSIOLOGY AND PATHOLOGY

NOTE: a diving doctor associated with any treatment chamber that also treats non-diving conditions, must also attend an HBO Level 2B course. Those diving doctors who have no HBO responsibilities must nevertheless be capable of managing patient care and safety at raised environmental pressure in a chamber and of using infusions and ventilators.

- understand the basic effects of HBO
- know the approved indications for HBO therapy and the basis on which HBO works
- apply that knowledge to the diving environment (e.g. a diver with a crush-injury of the hand) particularly in saturation.

1.8 OXYGEN TOXICITY

- understand that at increased partial pressure and in relation to duration of exposure, O2 is a general tissue toxin that has two principal manifestations (below) and also causes general vascular effects e.g. vasoconstriction at higher partial pressures
- understand that it also has important interactions with the effects with N2 and CO2

Pulmonary toxicity

- describe the pathophysiology of acute and chronic O2 pulmonary toxicity
- recognise the need to monitor symptoms and pulmonary function during long exposures to elevated partial pressures of oxygen and understand the potential for confusion with the manifestations of breathing a dry gas.

- calculate the CPTD (cumulative unit pulmonary toxic dose (UPTD) or Oxygen Toxicity Units (OTU) over time as a guide but also to recognise the limitations of that prediction
- understand the relevance and importance of “oxygen breaks“ (i.e. normoxic or less hyperoxic interludes during an oxygen exposure.
- understand methods of calculating CPTD for repetitive exposures (over many days) and their limitations.
- understand the long term pulmonary sequelae of hyperoxia
- be able to clinically manage a case of DCI already suffering oxygen toxicity

Neurotoxicity

- be aware of the various molecular and cellular mechanisms suggested to cause neurological oxygen toxicity
- understand the factors that may reduce or increase cerebral O2 toxicity
- understand the clinical presentation and appreciate the seriousness to the diver of an underwater oxygen seizure
- understand the unreliability of prodromal symptoms
- recognise the need to check the O2 content of breathing gas and the maximum safe depth for using it.
- review the different pO2 limits for depth exposure published by various authorities (understand the potential value of maximum durations for each exposure level) and understand the influence of nature of the dive and equipment used in estimating the residual risk
- understand the safety advantages when the depth of the working diver and the surface-supplied gas mixture are both continuously monitored
- consider the actions to be taken by the diver when another diver has a seizure and understand the potential risk of secondary pulmonary barotraumas during ascent of a diver with ongoing seizures
- recognise the importance of each diver at risk having a secure airway (not merely a mouth-piece with a strap but ideally a helmet) in order to avoid drowning during a seizure
- manage a case of CNS oxygen toxicity in the chamber and how to re-enter the treatment table protecting both patient and attendants)

1.9 GENERAL PRESSURE EFFECTS

- be aware of the direct effects of pressure on the physiology of man (e.g. neural transmission, HPNS, compression arthralgia).

Narcosis of inert gases

- understand the different theories of patho-physiological inert gas effects
- understand the difference in anaesthetic potency between different inert gases.
- understand the clinical presentation of inert gas narcosis

- be able to use objective measures to assess levels of narcosis in another individual
- be aware of the effects of nitrogen narcosis upon decision-making at depth and the claimed benefit of adaptation
- be aware of the equivalent narcotic levels of the other inert gases that may be breathed intentionally or unintentionally (e.g. argon breathed as a welding contaminant)
- be aware that helium is not significantly narcotic (and is not related to HPNS)
- be aware that hydrogen is not inert but has narcotic properties and is also biologically active. Be aware that H2, though explosive, has been used as a component of a breathing mixture with extensive safety precautions

HNPS

- be aware of the clinical manifestations and adverse effects of the high pressure nervous syndrome (HPNS) at depth.
- understand that HPNS is *not* a manifestation of inert gas narcosis
- review the hypothetical causative mechanisms of HPNS
- understand that HPNS can be exacerbated by faster rates of compression and at warmer temperatures during compression and understand that HPNS can be ameliorated when the rate of compression is slower and the chamber is kept cool
- understand that the demonstrated amelioration of HPNS by the addition of a narcotic agent (such as 5% nitrogen) to inspired oxy-helium, can create difficulties for subsequent gas reclamation and purification, is not a direct reversal of HPNS and so is not used routinely.

1.10 MEDICATION UNDER PRESSURE

- provide advice on non-prescribed medication commonly used by some divers
- recognise that insufficient is known about the effectiveness of conventional drugs and their side-effects when prescribed for use at deeper depths where.
- be aware that some drugs affecting CNS function may have unpredictably increased or reduced effect depending on the circumstances when taken (treatment for psychiatric disorder, long term prophylaxis after successful treatment, conventional drugs for self-medication, drug abuse).
- be able to guide and risk analysis the use of antimalarials weighing (neuropsychological) side effects to malaria protection.

1.11 NON-DYSBARIC DIVING PATHOLOGIES

Hypothermia

- recognise the insidious effects of immersed body cooling and know the importance of rewarming in relation to resuscitation
- be aware that greater body cooling occurs at depth where thermal capacity of respired gas is increased at its greater density.
- be familiar with supplementary body heating (usually by hot-water suits) and need for supplementary respiratory gas heating.
- understand the importance of breathing gas heating at great depth and the potential for rapid development of symptoms
- recognise hypothermia as potentially common to all diving injuries and manage it both alone and in conjunction with other problems (e.g. DCI)

Raised temperature and the risk of hyperthermia

- understand that the use of hot-water suits potentially may lead to greater gas uptake and thus exacerbate DCI in decompression, particularly with SurD O2 procedures
- recognise the adiabatic heat of compression can have serious effects that have been fatal, when compounded by high humidity and the inability to dump heat by sweating.
- understand the reduced thermal comfort and safety limits associated with a heliox environment.

Fauna and flora

- be aware that marine flora are not generally hazardous but kelp may result in entanglement and that marine algae may be toxic and can cause allergic and irritant reactions).
- be aware of the hazardous marine fauna in the area of diving operations, the recognition and management of the principle
- be able to advise on appropriate contents of diver first aid kits with respect to the management of these hazards

Some other injuries and accidents

- manage acute illness or trauma sustained in the water and when there may be an obligation for some decompression stops. (A similar event that occurs at depth in saturation diving will be discussed later.)
- understand the pathophysiology and clinical presentation of near-drowning as well as treatment and post recovery complications
- manage sequelae of oil-mist contamination of breathing gas
- recognize salt-water aspiration syndrome (SWAS) as a risk in: choppy waters, especially with leaky regulators etc, in a differential diagnosis of immersion accidents and manage appropriately

- be aware that marine pathogenic bacteria that may infect a diver’s wound are different from those at surface and, if culture and antibiotic sensitivities are necessary, the pathologist should be advised of the marine source
- be aware of the need for immunisation or other prophylaxis (e.g. for leptospirosis)
- manage suspected carbon monoxide poisoning sustained underwater from contaminated compressed air
- manage exposure to in-water chemical pollution with examples ranging from skin exposure, mucus membrane irritation, neurologic effects and carcinogens.
- manage exposure to contaminants in the chamber - manage sea-sickness and understand the impact of this and of its medications upon the diver and potential safety (e.g. how to vomit underwater?).

2 DIVING TECHNOLOGY AND SAFETY

2.1 BASIC SAFETY PLANNING:

- be aware that by working dive procedures are likely to be influenced by government rules that have significant variations between countries. Provided such rules are not broken, many diving companies will follow other industry guidance that often is more stringent.
- understand the greater constraints upon a working diver than on a recreational diver, including the need to
  - complete a specific task effectively
  - follow agreed procedures and emergency procedures
  - dive where and when required to do so.
- understand that the diver is responsible for aspects of his/her personal safety and for own physical fitness
- understand that after the working diver has passed the annual medical examination to confirm fitness to dive, he/she still has the responsibility to report via the local medic and/or supervisor any subsequent changes or illness
- be aware that the working diver is usually under the direct control of a surface supervisor and that line-management has responsibilities for health and safety
- understand the importance of formal pre-dive checks
- revise the basic principles of occupational medicine
- reinforce the need for workplace assessment (and not only when underwater).
  - hazard recognition
  - hazard assessment
  - risk avoidance
  - risk control.
  - acceptance of residual risk.
  - understand the importance of keeping permanent records.
- be aware of known hazards such as
  - physical: (noise, vibration etc)
  - biological: (bacteria, algae)
  - chemicals: (solvents, contaminant gases)
- implement the need for individual health surveillance following exposure.
- identify the role of safety awareness and safety manuals by the employers of divers and by the recreational diver training agencies. Evaluate the effectiveness of different requirements for health protection and monitoring.
- be knowledgeable about, and able to evaluate, the general administrative methods of safety management and monitoring used in industry.

- be able to implement a monitoring system to show continual improvement of safety indicators (with specific focus on medical consequences)
- be aware of the potential role of anonymous reporting
- check the availability and experience of medical advisory and emergency hotlines

2.2 COMPRESSED AIR

Compressed air work

- understand the nature of compressed air work in the dry without any immersion effects (Caisson work, Tunnelling etc)
- recognise the historic significance of early epidemiology of, for example, decompression sickness and bone necrosis because of the availability of large numbers of exposures
- understand the nature of hard physical work in regular shifts in a hot humid environment with possibility of a CO_2 build-up
- review the nature of their decompression procedures that include surface decompression and some differences from tables used by divers
- recognise the occasional need for mixed gas saturation techniques to service the drilling shield in deep tunnelling work

Air chambers

- review operational procedures for dry diving and therapeutic chambers
- review chamber safety, particularly fire risks and oxygen
- recognise that the dry chambers are largely associated with, but not confined to, surface decompression and recompression.
- be aware that breathing air in dry chambers as attendants with patients or for training is routine. Attendants may need to follow oxygen-breathing as prescribed for them in the Tables.
- the availability of medical equipment for an operational surface decompression chamber should be audited by a Level II diving doctor (see 2.8)..

2.3 WET BELLS AND STAGES

- understand that the use of an open stage or 'wet' bell, in which the diver is exposed to the ambient pressure of the sea, provides a transport system to safely get the diver(s) to the worksite and a site for conducting prolonged decompression stops by working divers.
- understand that, suspended from a surface boat, the vertical range of movement of the stage or bell through the water during stops may be greater than that experienced by a diver who hangs onto an adjacent shot rope in the water.

2.4 SCUBA DIVING (AIR AND MIXED GAS)

- understand the advantages and limitations of scuba techniques, particularly for working divers, including recreational instructors, of
  - being independent of surface control and reliable communications
  - having a finite gas supply (with/without a reserve bottle)
  - the 'buddy' principle that is usually adhered to *versus* solo diving
- be aware of the need to correlate gas capacity of tanks with minute-volume needs and predicted decompression times
- be aware of the many in-water procedures relating to
  - tables and personal decompression computers
  - rates of ascent and use of a safety stop
- be familiar with in-water emergency procedures (such as recovery of an unconscious diver with a decompression obligation) and with associated equipment and procedures (such as buoyancy aids, signalling)
- understand the rare but real hazard of carbon monoxide contamination of compressed air tanks, testing procedures for CO, its diagnosis and treatment
- understand the use of nitrogen mixtures with enriched oxygen in scuba and associated depth limits. Nitrox gas mixing and filling techniques.
- understand the use of special gas mixtures in separate cylinders for sequential use in deep self-contained diving is one of several "technical" procedures taught by recreational instructors.
- recognise that the term "Technical diving" is variably defined.
- be aware of other scuba diving procedures (used by some diving scientists and camera-men) such as
  - prior placement of reserve tanks for lengthy penetrations
  - availability of 'hanging tanks' for decompression stops
  - feasibility and hazards of 'drift decompression'

2.5 SURFACE-SUPPLIED HOSE DIVING.

This may be undertaken from the surface wholly in the water, or from a stage or a wet bell. (Deep short-duration "bounce" hose dives that begin from a closed-bell capable of transfer-under-pressure are considered later, with saturation diving.)

Note that for air or oxygen-rich Nitrox diving, hose diving possibly from a stage or wet-bell, is considered by most authorities as being much safer than using scuba. Some national regulations also permit oxy-helium hose procedures with a stage or wet bell to be used deeper than 50m but with some limits of duration. All hose divers need also to carry a reserve or 'bale-out' bottle.

- understand the safety advantages of a having
    - a hose as a strong tether
    - depth monitoring by the surface supervisor
    - an unlimited gas supply if trapped
    - continuously available communications
- understand the implications for decompression procedures

2.6 STANDARD DRESS DIVING

Note that this equipment is no longer permitted for working divers in most countries because there is no provision for a breathing reserve in case the surface gas supply fails. However it is still used in some countries (and also by some amateur historical enthusiasts).

- understand advantages and limitations of this equipment.
- be aware that the diver's gas supply pressure is determined at the surface and so specific risks include squeeze, should the dive fall uncontrolled through the water column.
- recognise that uncontrolled blow-up, feet first, has also been fatal.

2.7 REBREATHER DIVING (SEMI-CLOSED AND CLOSED CIRCUIT)

- understand the advantages and limitations of the different configurations of self-contained breathing apparatus.
- recognise the possible applications for rebreather use
- understand the principal differences between
    - closed circuit pure oxygen
    - constant-mass flow
    - tidal-volume proportionate replacement
    - constant pO2 electronically controlled
- understand the extensive training and maintenance requirements needed to use safely the electronic self-mix rebreathers
- recognise the difference between a rebreather and the gas reclaim system used for deep commercial diving.

2.8 OTHER DIVING PROCEDURES

Underwater habitats

- Although practical procedures have been established, particularly by NOAA scientists, this would deserve supplementary review if re-introduced.

Surface decompression

- understand the procedures based on the historic use of ‘crash surfacing’ for salvage where strong tides did not permit in-water stops but where a deck chamber was available for recompression within 5 min of surfacing. This procedure remains in use in both military and commercial diving.
- know the procedural constraints for enhanced safety and the HSE studies that explored its safety in comparison with in-water decompression.
- be aware that the use of ’hot-water suits’ at depth has been suggested to affect gas uptake and the safety of SurD chamber decompression
- be aware that the operational chambers that are used for this procedure require supplementary items of equipment for a medical emergency (see 2.2).

Nitrox and oxygen decompression stops

- be aware of the advantages and limitations of breathing oxygen-rich mixtures and/or oxygen during in-water decompression stops following air or heliox hose diving.

Scientific projects

- recognise that scientists who dive in their work usually do so within codes of practice that also outline the assessment of exceptional techniques (such as diving within trawl nets)

Deep bounce diving and TUP-diving

- introduce the students to these diving techniques (e.g. the use of a diving bell for short mixed-gas deep dives and the use of transfer under pressure bells) recognizing that these techniques are less used nowdays.

Saturation diving

Note - will be detailed in the next section but this stage

- understand the commercial advantages of saturation diving as the technique required by many jurisdictions for diving deeper than 50m but which, for technical reasons, may also be used at shallower depths.

2.9 CHARACTERISTICS OF VARIOUS DIVERS AND OTHERS WORKING UNDER PRESSURE

- understand the varying characteristics of various groups of divers and other who work at pressure
- e.g. **recreational** divers dive only for personal reasons and receive no payment or other reward for doing so. Understand that they can choose when and where to dive or, indeed, choose not to make a planned dive. Some recreational divers dive in caves, wrecks or deep water with advanced rebreathers and multiple gases, but at their own risk. Breath-hold/apneic diving falls within the same category.
- **working divers** are professional divers who may be employed either
  - full-time as divers or
  - primarily for other tasks, some of which include diving
- **caisson workers, tunnellers and others in compressed air** are not divers because they work at pressure in a dry environment. Thus they avoid the physiological problems associated with a hydrostatic pressure gradient over the body but they do have many medical problems that are similar to those of divers. Some deep bridge building and tunnelling has taken these workers to mixed-gas exposures as deep as 70m. Like those who have to enter very dense fluid (bentonite) to service a deep tunnel-cutting shield may have been recruited as saturation divers.

2.10 DIVING EQUIPMENT AS USED TO C.50M (SEE ALSO CHAMBERS, 2.2 & 2.8)

Breathing apparatus

- understand the physiological and respiratory acceptance criteria required for both laboratory and manned testing of new or modified underwater breathing apparatus before it is released as 'safe' for operational use
- understand how breathing resistance induces changes in respiratory pattern (e.g., diminished respiratory minute volume with increased dead space, increased gas density or increased work of breathing)
- become familiar with the general working principles of breathing apparatus as a minimum including demand regulators, rebreathers and free-flow systems and understand the nature and consequences of forseeable malfunctions

Diver monitoring

- be aware of various systems for on-line recording of diving data such as depth, inspired pO_2, water and gas temperature, video surveillance and voice communication and the benefit for the surveillance of the diver as well as post-incident investigation.
- Understand the practical use/safety benefit of monitoring divers breathing rate through communication during underwater work.

- in-chamber video recordings and the need for these to be retained for an agreed duration after safe completion.
- understand the need for continuous monitoring at depth of chamber, bell and welding habitat atmospheres with alarms for the early detection of contaminants

Tools

- understand the effect of neutral buoyancy on the safety of tool use and the problems of in-water ergonomics in tool design
- be aware of injury hazards due to High Pressure water-jetting, burning-torches, pressure differentials etc
- understand the implications of the isolation of an injured diver in relation to safety/risk assessments

Thermal

- understand the working of thermal protection and the need for heating inspired gas at depth
- understand the potential problems of scalding from hot-water suits, and the potential contamination carried by that hot-water supply.

Other equipment

- understand the hazards associated with compressors and gas mixing devices, gas storage and delivery, control and recovery in hose diving.
- understand the design and use of totally protective suits for diving in contaminated fluids.
- be aware that sat divers equipment should include
  - bail-out UBA that needs to be heated,
  - neutrally buoyant umbilical with pre-determined length.
  - helium unscrambler,
  - tools designed for wearing gloves etc,
  - harness with lifting ring for emergency recovery from the water

2.11 DIVING TABLES AND COMPUTERS

NOTE that a detailed mathematical knowledge of decompression theory, while of great interest, is not essential to the practice of diving medicine (other than in some medico-legal cases)

Decompression theory and tables

- be aware of complexity and limitations of decompression theory (section 1.4). Review the further development of mathematical modelling and the many associated theories, but in summary only. In this context consider the limited manned testing of new tables, the problems met when applying them as written and the *ad hoc* modifications made by diving companies, some navies and individual divers to improve safety.
- know that diving at altitude requires compliance with special decompression adjustments

- know the DAN, DMAC and other recommendations related to the interval needed before flying after commercial or recreational diving and the limitations of that data
- be aware of rules governing repetitive diving
- be aware of the rules regarding upward and downward excursions from saturation depths (*covered later*).
- be aware that over the years all commercial tables have tended to converge by trial and error towards pragmatic solutions that seem to work.
- while adherence to the given tables is appropriate decompression tables cannot eliminate the risk of decompression illness and that individual variation means some incidents will occur after apparently safe exposures while apparently unsafe exposures do not necessarily result in incidents.

Dive computers

- recognize the main algorithms used in the software of dive computers (decompression computers) and computer based decompression programs.
- understand that they are widely perceived as providing an acceptable level of safety and relatively safe decompression solutions but considered controversial for use in commercial and military diving.

Decompression risk

- understand the concept of risk in relation to computer and table usage
- realise that compliance with accepted tables does <u>not</u> always prevent DCI
- realise also that to go beyond the safe limit does <u>not</u> mean inevitable DCI.

2.12 REGULATIONS AND STANDARDS FOR DIVING

- be aware of the wide variety of national regulations that relate to working divers around the world (some have prescriptive rules on details whereas others ascribe management responsibility to all participants for their outcomes)
- identify regulations and Codes of Practice (COPs) and norms (ISO, CEN) that are relevant to the nationalities of course attendees and how these relate to international codes of practice and recognise the importance of these where there are no regulations
- be aware of international guidance that is related to recreational diving, it's possible lack of legal authority but its relevance to cases in the civil courts
- maintain expertise by maintaining familiarity with current research and recognize availability of valuable written information in technical reports, non-medline listed meeting abstracts and international series of underwater symposia.

3. SATURATION DIVING

3.1 SATURATION MODE

- be aware of the history of saturation development:
- US Navy research (George Bond) leading to seabed habitats of Man-in-Sea (Ed Link), Conshelf (Jaques Cousteau) and Sealab (US Navy). Shallow seabed habitats (mostly NOAA).
- be aware of the start of commercial saturation (Westinghouse: Smith Mountain Dam) and further development into the North Sea and worldwide. Commercial development to ca. 350 m.

3.2 PHYSIOLOGY OF DEEP EXPOSURE

- be aware of the study of the effects of pressure on aquatic animals living at depth and on diving animals normally at or near the surface.
- recognise the manifestations of HPNS, with its convulsive and other hazards.
- be aware of laboratory studies on man to as deep as 700 m and the possibility of long-term sequelae of deep exposure

3.3 COMPRESSION

- understand factors, such as a cool environment, that ameliorate HPNS during slow compression and rest periods
- understand that compression rate and absolute ambient pressure will affect the HPNS risk and that the risk may be reduced by slowing compression rate and introducing stops
- assess the use of added gaseous nitrogen to ameliorate HPNS and recognise that for the trivial fact that compression starts from a normobaric air environment a certain low persentage of N2 will be present even when using heliox for sat life support, decreasing with time by dilution.

3.4 AT DEPTH IN LIVING CHAMBER

- understand the challenge of maintaining O2 within narrow partial pressure limits at great depths.
- understand the various methods for intermittent and continuous measurement of chamber and bell atmosphere contaminants. Understand the challenge of using high sensitivity/high specificity equipment with low maintenance cost and robustness. Understand that the threshold limit value is related to the mass of the contaminant per volume unit of chamber

gas. Understand that unless the detector is placed within the chamber, the detection threshold must be lower as gas will expand during decompression to a sensor or instrument placed on the outside the chamber

- review the clinical management in saturation of coincidental illness or injury when arising at depth from
  - injury in the water (e.g., crushed chest / traumatic amputation)
  - illness in the chamber (e.g., acute abdomen, cerebrovascular accident)
  - injury in the chamber (e.g., evisceration over toilet seat)
- understand the contingency measures required for the management of an offshore diving accident, particularly serious illness or injury within a saturation chamber and the preparations needed in advance to provide prolonged medical and surgical support at depth
- the need for
  - a diver medic in each sat team;
  - reliable 24h communications ashore,
  - duty medical officer available to fly out.

3.5. BELL EXCURSIONS

- consider the clinical management of illness in the water (e.g., wrong gas)
- understand emergency procedures for ill or injured divers out of a bell:
- rescue by flooding plus man-lift or winch,
- resuscitation in the vertical or semi-recumbent mode;
- first aid by bellman;
- recognise need for a 'lost' bell to have through-water communications and tapping code, transponder, enough gas and water for > 24h,
- be aware of risks of using bell's weight release if fitted
- understand the urgency of heat conservation. Review passive insulation of bell and diver, plus respiratory heat exchange and limited active heating of bell by supplementary heat,
- if a 'lost' bell cannot be recovered easily expect to be asked for medical prediction on survivability prognosis and physiological aspects of rescue methods.
- understand emergency evacuation of a split-level sat system using a hyperbaric lifeboat (HRV) with atmosphere control. Serious hazards of seasickness, dehydration, gas contamination, secondary injury and, with supplementary heating and survival suits <u>or</u> cooling, some risks to thermal balance prior to onshore recovery (consider DMAC guidance note 31 as well).

4 FITNESS TO DIVE

4.1 FITNESS TO DIVE CRITERIA AND CONTRAINDICATIONS (FOR DIVERS, TUNNEL WORKERS AND HBOT CHAMBER PERSONNEL, BUT NOTE THAT HBOT-PATIENTS ARE NOT INCLUDED HERE)

- consider each organ system in relation to diving: cardiovascular, pulmonary, urogenital, neurological, skin, etc.
- be able to interpret and apply the published clinical recommendations in relation to the fitness assessment of an individual diver or pressure worker
- be able to incorporate recent risk-based assessment in medicine into fitness for diving work, e.g. cardiovascular risk scores
- understand the different needs of fitness assessments between those in long-term employment as divers or working at raised environmental pressure, and those who dive only for their own recreation
- be able to assess the effects of prescribed and self-administered medications upon diving
- consider underlying patho-physiology and side effects of the drugs (eg anti-malarials) when diving
- consider the effect of environmental pressure on pharmacological actions
- assess the hazards of substance abuse and illicit drugs (recognising that for many employees this means dismissal)
- assess the impact of HIV status on diving and lengthy stays in saturation
- be able to explain to the non-diving clinician the critical aspects of a diving or pressure-exposure that may be relevant to an individual being referred for consultant opinion.
- be able to assess fitness to return to diving or pressure exposure following an illness or injury for which there may be no specific guidance
- be aware of factors influencing personal DCI susceptibility (e.g.post-dive exercise)
- be aware of conditions in divers (recurrent urolithiasis, salmonella carrier state) that may allow surface oriented diving but preclude saturation diving
- conduct health surveillance as indicated by the nature of the diving history e.g. dysbaric osteonecrosis, where the condition may affect a future diving status
- be fully aware of the influence of immaturity, youth, disability or old age upon the safety factors that need to apply in diving, particularly in recreational diving.

4.2 FITNESS TO DIVE ASSESSMENT

- be competent to perform, apply and/or interpret the clinical and physiological investigations needed to assess fitness of the working diver and others, as defined in authorative guidance
- be able to perform and interpret lung function tests (pre- & post exercise; pre- & post bronchodilator)
- be able to perform and interpret exercise tests
- be able to evaluate an-ECG and audiometry
- be able to understand the use and limitation of echocardiography and other techniques for PFO screening
- have a clear understanding of the role and application of "functional assessments" as performed by occupational therapists and how these should be applied to divers.
- be able, if requested, to assess the fitness of a recreational diver, to use own clinical judgement and follow appropriate guidance to reach a justifiable conclusion

4.3 FITNESS TO DIVE STANDARDS (PROFESSIONAL AND RECREATIONAL)

Although the same at Levels 1 and 2D, in both basic teaching and periodic revision, teaching styles may differ

- be aware that employer organisations may require a higher pass standard than many national legal minimum requirements for working divers
- be aware that a CEN norm exists concerning fitness for recreational diving.
- be aware of specific legislation existing in many countries, where "disabled" persons should be accommodated in workplaces where it is safe to do so.
- be aware of the different legal requirements for fitness of working divers that are specified by various national authorities and ensure that all have been met or exceeded
- be aware that the physiological ranges for normal pulmonary function varies between ethnic groups
- be aware that recreational training agencies may be required to follow some local regulations but that many set their own criteria, some of which may be minimal.

5 DIVING ACCIDENTS

5.1 DIVING INCIDENTS AND ACCIDENTS

- understand that in recreational diving, accidents are usually triggered by diver error whereas in a working dive there are many additional contributory factors. The consequence of diving accidents may be trivial, cumulative or catastrophic.
- recognise that incidents may occur
  - on descent e.g. ear barotrauma;
  - at depth e.g. respiratory gas effects
  - on ascent e.g. pulmonary barotrauma, or
  - at any time e.g. equipment failure; coincidental injury
- understand that factors may include
  - environment (e.g. poor visibility or inadequate surface support)
  - the diver (e.g. CO_2 build-up or concealed medical problem)
  - equipment.
- understand the importance of familiarity with all emergency drills at depth
- identify emergency resources available. For diving work some authorities require a dedicated chamber on site or, for some activities, within two-hours travelling time. Prepare and rehearse emergency procedures that will follow triage principles 'emergency', 'urgent' or 'timely' et cetera.

5.2 EMERGENCY MEDICAL SUPPORT (WITH NO CHAMBER ON SITE)

Note that medical life support and trauma life support is covered by requirements outside this guidance, e.g. ILCOR guidelines for CPR,ATLS, ACLS-programmes etc, and so is not repeated here.

- assess a diver recovered from the water for omitted decompression and/or barotrauma and their implications. Also assess for hypothermia.
- recognise clinically that a number of serious accidents (e.g. propeller trauma) cannot be moved easily or may not be suitable for recompression,
- understand the need to plan for the logistics of emergency medical care before diving in remote locations. Consider contingency planning for evacuation, the local availability of treatment gases, life support equipment, medications etc and of a recompression chamber and other medical support – in advance of diving.

- recognise the need for complete and accurate communication between those present and a remote adviser or provider
- consider the earliest time for evacuation or travelling by air
- keep personal log of communications, assessment, treatment and outcome

5.3 BAROTRAUMA: ENT(OTORHINOLARYNGOLOGICAL), DENTAL, CUTANEOUS, CONJUNCTIVAL, ETC (PULMONARY DECOMPRESSION BAROTRAUMA IS CONSIDERED WITH DCI)

- understand the pathology of compression and decompression barotrauma in the head and neck region.
- recognise and treat ENT events in a chamber or at the surface
  - external ear and tympanic membrane injury due to ear-plugs or a hood
  - middle ear injury with poor equalisation
  - round window and inner ear injury
- recognise the effects of “squeeze”
  - of a mask upon the conjunctiva
  - of a dry suit on the skin
  - of an uncorrected descent on the chest of a Standard Diver
- recognise sore throat, change in voice or crepitus in the anterior triangle of the neck etc. as a sign of pulmonary decompression barotrauma *(reviewed elsewhere)*

5.4 PHYSICAL INJURIES

- recognise the very different injuries that can be inflicted by various marine animals and, for those that sting or are venomous, know the specific first aid and definitive treatments
- understand that marine pathogens have different characteristics from terrestrial ones
- be aware that injuries from underwater tools, especially of the hands, are not uncommon among working divers.
- be aware of hazards from electrical in-water field forces from impressed currents
- realise that significant underwater explosions can cause pulmonary barotrauma and other internal organ injury and manage accordingly
- know that an injury from a water-jetting gun may have only a small entry wound but that the damage may be extensive internally.
- be able, perhaps together with an experienced supervisor, to assess the ability of an injured diver after recovery to comply with all emergency procedures before a return to operational diving

5.5 ACCIDENT INVESTIGATION OF DIVING ILLNESS OR INJURY

- know the procedures that divers and diving doctors should follow to secure evidence on the causation of any diving accident or illness.
- be able to advise a pathologist involved particularly if interpreting the significance of bubbles at autopsy (see alo chapter 7)

6. DECOMPRESSION ILLNESSES

6.1 PATHOPHYSIOLOGICAL BASIS AND MECHANISMS OF DCI

"DCS" (Decompression sickness)

- understand the wide range of symptomatology which may arise in the course of decompression illness" e.g.
  - musculo-skeletal manifestations of DCS, and how the presentation can then guide management, e.g. joint pain that is deep and changes with movement *vs.* superficial pain and no change with movement.
  - cutaneous manifestations associated with decompression ("les puces"; rashes)
  - lymphatic disorders (local oedema)
  - fatigue and malaise
  - respiratory DCS ("chokes")
  - peripheral and central neurological deficits (including "staggers") and particularly the distinction between 'spinal' and 'cerebral' DCS and understand the different theories of neurological decompression illness (e.g. spinal cord DCS as embolic, venous stasis, autochthonous bubbles, watershed theory, etc),
  - - hypovolaemia

"PB" & "AGE" (pulmonary barotrauma and arterial gas embolism)

- understand the pulmonary, systemic and neurological pathophysiology and sequelae of decompression barotrauma

Other DCI presentations

- differentiate classic gas embolism and/or decompression sickness from less common biphasic presentations and/or PFO-associated manifestations
- recognise the importance of this assessment for determining DCI treatment
- be aware of the learning value of historic accounts of different presentations and of those cases following treatments that have since been abandoned

- know the range of symptoms, signs and the patterns of presentation of DCI characteristically arising from different types of diving or chamber exposures (for instance compressed air workers in contrast to divers)

Assessment

- be aware of the practical limitations of the on-site examination of divers, e.g. with possible vertigo
- know the timescales of DCI onset and understand the significance of subsequent deterioration
- know the natural history of untreated decompression illness
- understand the importance and the recognition of symptom denial
- have a basic understanding of superficial and deep counter-diffusion

Examination

- understand the detail medical history to be obtained from the diver, buddy, supervisor etc.
- be able to balance the need for rapid recompression and the time needed to take the history and examination. Consider completion of this in the chamber at pressure.
- be able to conduct a full but rapid general clinical (inc neurological) examination at the surface and understand the need to complete the examination on arrival at treatment depth to identify the residual manifestations.
- understand the physical limitations imposed on examination when breathing air at 50m, particularly those related to auscultation and percussion,
- understand the limitations imposed upon a basic assessment when the chamber is too small to permit standing.
- maintain a fluid balance chart

6.2 DIFFERENTIAL DIAGNOSIS OF DECOMPRESSION ILLNESS

- understand that different reasons for divers failing to report - recognise that a person recovered from the seabed unconscious has a wide differential diagnosis which may include DCI
- be aware of different skin disorders (e.g. suit squeeze, urticaria, marine pathogens) that may mimic decompression illnesses -*vs*-. superficial inert diffusion -*vs*- cutis marmorata
- be aware of the difficulties of assessing subjective paraesthesia, dizziness, drowsiness and headache
- be able to evaluate other possible differential diagnoses
- be aware of immersion pulmonary oedema and the usual benign development when surfaced and oxygen breathing
- be aware of the differential diagnosis of loss of consciousness on the surface

6.3 MANAGEMENT OF DECOMPRESSION INCIDENTS AT THE SURFACE

- understand the value of 100% O2 administration for suspected DCI and the need for oral or intravenous rehydration
- know that nitrous oxide / oxygen (e.g. “entonox”) used for analgesia is a probable bubble amplifier
- recognise that 100% O2 may not be available in all emergency rooms or ambulances. Be aware of the different oxygen delivery systems which can provide high concentrations of oxygen (closed system may be available for cpap and is appropriate)
- be aware that decompression paraplegia on surfacing has been clinically reversed almost immediately by recompression where onset has occurred right next to a diving chamber
- understand that DCS is a rare diagnosis in working divers, even though depth/time exposures are generally greater than recreational, and that in surface-supplied hose diving, AGE is rare
- be aware of the various national, military and diving-company networks providing medical support in emergency for recreational, military and working diving accidents
- be aware that the emergency rooms of the hospital may not have any checklists for or experience of DCI management
- be aware of the special role of agencies such as DAN to educate recreational divers about the medical problems of recreational diving and provide an international network to facilitate the medical treatment of emergencies.
- be able to advise on adjunctive medical therapy, including bladder management, pressure points, etc
- understand the need for rapid transfer, especially urgent if there is continuing deterioration.
- in some urgent cases, recompression has been first and detailed examination at depth to assess residua has followed, but recent studies suggest that initial severity is a better predictor of outcome than delay to treatment.
- always conduct a medical assessment at the treatment depth as the baseline for any subsequent deterioration
- ensure the collection of relevant data for the purpose of immediate management and future follow-up

6.4 MEDICAL MANAGEMENT, RECOMPRESSION TABLES AND STRATEGIES

If multiplace chamber is on site

- understand the value of rapid recompression
- consider whether recompression should be done first, and then an examination at depth for residua before deciding on the subsequent course.
- if distant, recognise the importance of doctor travelling to the chamber if feasible and be competent to judge when this is important.

If a one-man chamber is on site

- make a full assessment before compression
- know the limitations of access during treatment and the hazards that can be met
- understand the pressure and time limits of the tables used in these circumstances

In-water recompression (IWR)

- know that unplanned IWR can exacerbate DCI pathology
- be aware of successful protocols (shallow O2) and how these are to be implemented, which pre-conditions should be met, etc.
- be fully aware of the limitations and hazards of this treatment and of the equipment preparation, planning and training needed *before* any dive begins. When previously planned, IWR is used by some dive teams in remote locations
- consider the case for IWR (e.g. deep technical diver on a rebreather with no chamber in a remote area) and the associated risks.

If evacuation is needed from the dive location to a recompression centre

- understand the problems of transfer ("Medevac") especially with altitude exposure and duration whether by plane or by road
- ensure full consultation with the evacuation team before transfer and with the receiving unit
- provide continuous oxygen, i-v fluids and other treatment as discussed with receiving unit

Table selection

- be familiar with the many treatment algorithms available, including those for cases that arise during planned decompression, those that arise after surfacing and those used in difficult cases, especially when deep or saturation chambers are available. Understand their relative merits and application of different tables.
- understand the widely-accepted algorithms available for cases arising in saturation diving and the use of oxygen-enriched mixtures at depth.
- be aware that historical empirically-derived treatment algorithms for compressed air workers are different from treatment tables for divers.
- be able to advise on alterations to recompressions, including adding extensions, and also changing from one table to another

Decompression on completion of treatment

- recognise the importance to the working diver of achieving a full recovery without residua, the possible advantages of achieving this during the initial recompression treatment and the implications in relation to returning to dive. if he/she is to be able to return to work. Understand the options of extending the initial recompression to achieve this.
- understand the advantages and disadvantages of a prolonged initial recompression treatment compared to a shorter treatment followed by an interval then subsequent recompression such as repeated HBO
- be able to assess the decompression obligation of the chamber attendant

Air-range recompression

- be aware of the need to achieve the maximum benefit at an early stage in management and that residua will compromise diver's future employability.
- understand that an on-site chamber is an essential component of surface decompression and is an operational chamber that can be used for emergency treatment of working divers. If none available on site, pre-dive planning should identify availability of transport and suitable chamber.
- understand the legislative industrial standards for proximity of recompression chambers.
- be able to produce a contingency plan for recompression after surface decompression diving taking account of th use of the chamber for subsequent divers decompression
- become familiar with the wide variety of treatment protocols for decompression injuries around the world that use different pressure and oxygen algorithms supplemented by a variety of fluids and drugs. Most are usually successful but all are liable to encounter seemingly difficult cases with relapse or deterioration.
- know that the major failures of treatment include
  - failure to recognise the seriousness of post-dive symptoms
  - failure to recompress promptly
  - failure to recompress for an adequate depth and/or duration
  - failure to deliver adequate oxygen concentration (poor compliance with BIBS use
  - failure to get an early second opinion for an inadequate response
- be aware of the opportunities to delay decompression until the treatment at depth has achieved its maximum benefit and the potential hazards
- be aware of the delayed dysexecutive syndrome which may occur in association with cerebral DCI
- include basic ancillary care in severe neurological cases (urinary catheterisation, pressure points, passive range of movement, anti-thrombotic treatment).

Tables for air-range DCI

- in selecting an appropriate procedure accept that there is insufficient case information for the use of evidence-based analysis
- recognise that each treatment centre will be familiar with its own algorithm and protocols and may prefer them (there are recognised risks associated with use of new procedures).
- monitor recovery with regular checks and, if relapse occurs, modify the treatment procedure
- know that the therapeutic tables being used around the world within treatment algorithms identified by name may have significant local variations and the depth time profile should be considered in detail.

  Note that some algorithms are based on military needs (eg USN Diving Manual) and some alternative procedures have been adopted from Canadian, British, French and other military sources. These may not have the flexibility of alternative procedures that have been found by experience to be useful in other diving environments.

- know that in emergency, almost any air chamber can be converted into saturation with an O2 analyser, sufficient inert gas plus O2 supplies, with an improvised CO2 scrubber and the availability of additional watch-keepers. Understand the risks of engaging a saturation treatment in a chamber not prepared for this.

Treatment of DCI from deeper surface-orientated bounce dives
(i.e. not in saturation systems - see later)

- know that there is limited experience in treating DCS from deep surface-orientated mixed gas diving.
- experience in this area has demonstrated the importance of having a chamber on site.

Heliox bounce diving (in-water, or from an open bell)

- be aware of the various treatment options available and their advantages and disadvantages in relation to the type of diving undertaken and the time of onset of symptoms. Recognise the potential value of being able to recompress in a heliox environment although an air recompression may provide adequate treatment in some circumstances.

DCI in saturation diving

- understand the differences between incidents occurring after excursion from storage and those occurring during a saturation decompression and the implications for recompression, enriched oxygen mixture breathing and stabilisation period after resolution before further decompression
- understand the problems associated with delivery of treatment gas mixture at great depth

Ancillary treatment

- understand importance of fluid balance (but avoid exacerbation of pulmonary DCS)
- be familiar with the guidance and developments in drug and other ancillary treatments
- be competent at depth and during pressure changes with limitations and modification of interventions, such as ventilatory support, pleurocentesis, catheterisation, i/v cannulation, catheter and other cuffs, of i.v. infusions

In all cases

- remember the value of an early telephone discussion with another doctor experienced in this field
- know the importance of regular re-assessment at depth to detect any early deterioration.
- continue assessment for any relapse after surfacing and treat as appropriate
- for persistent residua consider repetitive HBO therapy during recovery period
- after maximal recovery, assess when the patient may travel safely by air but be aware of the hazards of hypoxia at altitude.
- arrange appropriate follow-up for the individual (and for statistical review)

6.5 REHABILITATION OF DISABLED DIVERS

After decompression injury

- understand that this task of rehabilitation usually applies to diving accidents after neurological deficit. When recommended, implementation of a rehab programme is not usually the direct responsibility of the diving doctor.
- recognize the need to start rehabilitation processes early, especially for bladder and spinal cord DCS
- recognise the importance of referral to a specialist spinal injury unit
- recognise that any residua in a working diver may prevent a return to diving employment

After other accidents

- recognise that personal follow-up procedure may be crucial for avoiding posttraumatic stress disorder (PTSD) or somatoform reactions.
- understand that commercial divers tend to sustain hand and finger injuries and that a return to diving is dependent on confirming their ability to perform all emergency procedures.
- a little-known feature of such injuries is a painful intolerance of cold in the distribution of the cutaneous nerves and some have been solved by directing the flow from the hot-water suit through gloves to exit at finger-tips.
- be able to apply the concepts of impairments, disabilities and incapacities to the workplace environment and advise management on policies.
- try to convince the diving companies' clients that a prophylactic recompression for omitted decompression or some doubtful symptom should not be discouraged due to classification as a "Lost Time Injury" but rather promoted as a means to avoid medical injury.

7. DIVING ACCIDENT INVESTIGATION

Recreational accidents

- consider dives beyond the diver's competence, an error of judgement, violation of accepted procedures, an unforeseeable equipment failure, environmental factor or coincidental medical events
- ensure personal statements, obtain photos, recover and seal equipment, and ensure that dive records are collected
- get samples of cylinder gas and, in rebreathers, from counterlung
- obtain / retain / check medical records
- specify time of collection of samples of blood, urine or other specimens with a witnessed chain of custody
- photograph wounds, bites, envenomation, areas of subcutaneous emphysema
- provide specialist advice at autopsy, particularly the value of a whole CT-scan but also on the limitation of interpretation of any bubbles and their distribution; Advise pathologists as requested with different autopsy protocols and know how these are implemented and interpreted. Check for bullae, blebs, haemorrhages of lungs and any PFO

Commercial accidents

- similar but be aware that commercial divers also sustain underwater industrial injuries (e.g. crane driver sheds load; a ship moves off station etc) *see also accident management*
- be aware that decompression illness or drowning are not the usual modes of death in commercial diving fatalities
- know that diving companies follow similar established protocols under official supervision that include retention of audio and video records. Interact as appropriate with government inspectors.
- know how to manage fatalities offshore, especially if deceased is in saturation

Accident assessment and reports

- consider medical involvement in civil litigation, third party responsibility and insurance reports
- know the principles of expert evidence and the hazards of interpretation and report writing
- be able to provide objective analysis of relevant scientific publications
- be able to review experience gained from accident investigation and civil litigation proceedings arising from previous diving incidents and the relevant sources of published information
- be aware of the differencies in national legislations concerning the interpretation of diving emergencies as "accident" and the according consequences for insurance coverage

8 RECOMPRESSION CHAMBERS

Distribution and purpose

- recognise that most recreational diving is relatively remote from recompression facilities. The use of chambers located in hospitals or other medical facilities follows established procedures and recompression tables appropriate for cases after an inevitable delay.
- understand that, in contrast, many working divers are required to be provided with recompression facilities on site or, if at less decompression risk, within short travelling time. Also understand that chambers for many commercial air-diving locations are primarily for surface decompression
- recognise that an air chamber is not appropriate for deeper mixed-gas diving because, if not responsive to shallow recompression, gases other than air may be needed at deeper depths, preferably with atmosphere monitoring and control.
- Saturation divers may require recompression after a downward excursion conducted in one of the saturation chamber system compartments.
- note that operational diving facilities may not be recognised as equipment for medical use and that nevertheless the standard of medical care in diving chambers needs to approach that available in a hospital HBO unit.

Chamber design and procedures

- recognise the purposes of different chamber designs (multiplace, monoplace, and chambers designed for transporting divers at pressure), their components and safe operating procedures.
- be aware of safety regulations and Codes of Practice
- be aware of mandatory and recommended HBO indications.
- understand the constraints of using of various items of medical, diagnostic, monitoring and therapeutic equipment and of ensuring good nursing care of a sick or injured diver in a chamber

9 MISCELLANEOUS

- recognise the importance of data collection / statistics / evaluation / reports
- be aware of the hazards of compression chambers with particular reference to fire
- be aware of current trends in research related to diving
- understand the role, limitations and capabilities of paramedics in this field
- understand that the management and organisation of a diving chamber is not a diving doctor’s responsibility but awareness of this is needed by doctors who advise on the treatment of divers remotely

10 ASPECTS OF PRACTICAL TRAINING:

10.1 FITNESS OF THE COURSE PARTICIPANTS

- The requirement to assess the fitness of the course participants for a chamber dive: if temporarily unfit the candidate can complete the rest of course but if permanently unfit, the student will not be able to accept relevant clinical responsibilities within a compression chamber. Depending on job-description, a doctor's fitness to dive will need to be maintained in-date as long as has 'on-call' responsibilities

10.2 PRACTICAL REVISION OF EXAMINATION SKILLS

- Useful practical skills include e.g.: Neurological, pulmonary function, ENT examination, audiology, anthropometry, exercise testing.

10.3 EXPERIENCE NITROGEN NARCOSIS

- Compression to depth with demonstration of the minor difficulties of mental arithmetic and communication and to provide familiarity with medical work in a chamber environment

10.4 SIMULATED CASES IN CHAMBER

- For skills in medical management: treat a number of simulated diving casualties (probably at lesser depths) with the emphasis on the practical difficulties of a unit in a remote location.

10.5 SKILLS REVISION

- attendees are to gain appropriate life-support certificates elsewhere because in date advanced life support training is a continuing requirement
- must be familiar with the range of oxygen provision units

10.6 UNDERWATER EXPERIENCE

- induce a greater respect for the working diver (cumbersome clothing, heavy gear, water entry and exit, uncomfortable breathing, poor communication, cold water and leaks)
- possibly try to use a hammer and nails underwater to make a wooden frame.

10.7 DEMONSTRATIONS

- visit diving contractors base or on location to learn from senior divers about their work.
- visit a saturation system (rarely possible, but a Q&A session with experienced sat diver can be invaluable).

*NOTE: Practice in **paramedic teaching** is no longer part of this course when this teaching is completed in a nationally-approved training centre.*

D.H.E. 2012