Chapter 16

DECOMPRESSION SICKNESS TREATMENT

FIRST AID

❑ Expert advice.

Expert advice from a diving physician, a diving medical organisation (such as DAN) or a hyperbaric facility, should be sought as soon as possible. **Appendices B and D** contain a list of sources for such expert advice. In the interim, first aid treatment must be applied

The principles of first aid management of decompression sickness (DCS) are:

- **basic life support (BLS)** (see Chapter 42).
- **100% oxygen (O_2)** (see Chapter 40).
- **positioning and rest**
- **fluid replacement**

❑ Oxygen therapy

If the diver breathes 100% oxygen (O_2), nitrogen (N_2) is removed from the lungs. The breathing apparatus must supply to the lungs as close to 100% O_2 as possible. This means an **anaesthetic type mask** or an O_2 diving regulator as used in technical and commercial diving. It is not the simple plastic hospital oxygen mask that does not produce an air tight seal. 100% O_2 in the lungs results in a high diffusion (pressure gradient) of N_2 from the blood to the lungs, causing the increased elimination of N_2 from the blood and tissues – and also from any bubbles there.

Unfortunately 100% O_2 can be toxic to the lungs if given for 18–24 hours on the surface. This may complicate the hyperbaric O_2 which is later given to the diver in a recompression chamber (RCC). Ideally O_2 therapy should be given under the supervision of a diving physician however, if expert advice is unavailable, then **all suspected case of DCS should be given 100% O_2** from the outset, before and during movement of the patient and transport to the recompression chamber.

Fig. 16.1
Photograph of diver with DCS breathing near 100% O_2 from a resuscitation bag. Note reservoir bag (lowermost) and high constant flow (>14 litres per minute) through an oxygen delivery tube.

Unconscious divers, if not breathing of their own accord, will require assisted ventilation (intermittent positive pressure respiration or I.P.P.R.). Conscious patients can be treated with continuous flow or demand type masks. In such cases, treating personnel must always check the breathing mask on themselves first in order to ensure the oxygen system is working, and that resistance to breathing is not excessive.

❑ Position and rest.

An unconscious diver should be placed on his side in the coma position, to protect the airway at all times (see Chapter 42). If there is any likelihood of air embolism, the diver is best placed horizontal - preferably on the left side, but this is not essential. Some clinicians recommend that cases of cerebral DCS should be managed with the patient on the side, without a pillow, to prevent buoyant gas bubbles reaching the brain through the circulation.

The Trendelenburg (30 degree head down, feet up) position is no longer recommended. Having the head lowered raises the pressure in the brain – and this can aggravate the brain injury.

Due to the buoyancy of bubbles, sitting or standing may be dangerous in patients with air embolism or cerebral decompression sickness where the bubbles are still in the blood stream. As a general rule, 100% O_2 should be given for at least an hour before allowing the patient to sit or stand. After this, the diver can be allowed to adopt any comfortable position but should be kept relatively still and on 100% O_2. A diver with "chokes" will be more comfortable sitting up.

❑ Fluid replacement.

Severe DCS results in loss of blood and fluids into the tissues. It may be valuable to replace this fluid orally or intravenously. Oral fluids may be given if the diver has no abdominal pain, nausea or vomiting. Water or electrolyte fluids (eg."Gastrolyte") may be given – with the type and volume recorded. Acidic (orange juice) and glucose dinks should be avoided. If there is no bladder involvement (i.e. the patient can urinate), a litre of clear fluid every 2-4 hours should suffice. This fluid intake should be modified by the patient's thirst.

Some authorities have recommended large volumes of oral fluids while the diver is being transported to a RCC in an attempt to replace this deficit. One problem with this (as any party goer will attest) is that the fluid load will promote a vigorous urine flow, so the diver arrives at the recompression facility with a stomach and bladder full of fluid. A patient with spinal DCS may be unable to empty the bladder and will therefore be in considerable pain.

The patient will usually be treated on a hyperbaric O_2 (HBO) treatment table. There is a very real risk of nausea, vomiting and convulsions as complications of this treatment. A full stomach can then possibly result in regurgitation of the stomach contents and aspiration into the lungs – further complicating treatment.

If the brain or spinal cord is involved and the patient has difficulty in voiding urine, an **in-dwelling urinary catheter** should be inserted whenever possible by a trained physician or nurse. If this is not feasible, care must be taken not to overload the patient with fluids.

Anyone who is trained to institute and monitor an intravenous infusion can be expected to be able to assess the state of hydration and determine the desirability and quantity of intravenous fluids, remembering that glucose fluids can aggravate cerebral oedema.

❑ Drugs.

Aspirin as a first aid measure has not been demonstrated to be of value in DCS. It may interfere with blood clotting and cause haemorrhage (bleeding) – especially in the stomach. Haemorrhage is already a major pathology in spinal cord and inner ear DCS.

The authors have seen one patient with severe DCS bleed to death from an internal haemorrhage just before he was to be given an "experimental last-ditch" anti-clotting agent. We are therefore reluctant to advocate the routine use of aspirin either for pain relief or to inhibit clotting in any DCS case.

Joint pains of DCS can be significantly eased without the risk of serious side effects by the administration of **paracetamol (acetaminophen) –** 1000 mg (or two tablets) 4 hourly. NSAID drugs may be requested by a diving physician, but are not routinely needed.

Other drugs such as steroids, diuretics and special intravenous fluids such as "Rheomacrodex" have been advocated but have not been proven to be beneficial. Anti-epileptics and other drugs such as diazepam ("Valium") may be needed to control fitting (convulsions), and for confusional states.

TRANSPORT OF PATIENT WITH DCS

With mild DCS, or if there has been a delay of 12-24 hours or more, and there is no progressive deterioration, local treatment with rest, monitoring and breathing 100% O_2 may be all that is necessary. This decision is best made by a diving physician.

With more severely affected divers, or those that are deteriorating or need medical attention, transport should be expedited. The diver should be transported with **minimum agitation** and as close as possible to sea level or at **1 ATA**. Mountainous roads should be avoided whenever an evacuation route by land is planned. 100% O_2. should be breathed before and during transport (see Chapter 40).

Transportation in aircraft presents problems. Apart from movement which aggravates DCS, environmental pressure decreases with altitude, causing DCS bubbles to expand (Boyle's Law) and more gas to pass from the tissues into any bubbles.

If the patient is evacuated by air, unpressurised aircraft should endeavor to fly at the lowest safe altitude. Even an altitude of 300 metres (1000 ft.) can make the symptoms of DCS worse. However, maintaining such an altitude can be alarming when flying over 297 metre terrain.

It should be remembered that most commercial "**pressurised**" aircraft normally maintain a cabin pressure of around 2000 metres (6000 ft.), which could seriously aggravate DCS.

Whenever possible the cabin altitude should be maintained at 1ATA. This is attainable by many modern commercial jet aircraft, executive aircraft such as the King Air and Lear Jet, and some military transport aircraft (Hercules C–130). This requirement is not popular with the commercial airlines since it necessitates the aircraft flying at lower than its most efficient altitude, resulting in excessive fuel consumption. This requirement may also limit the range of certain aircraft.

Breathing 100% Oxygen before and during the flight may be of value, especially from closed or semi-closed circuit equipment. There are risks to the aircraft and its inhabitants if open circuit O_2 is used as many airlines recirculate the cabin atmosphere and fire/explosion is possible.

Fig. 16.2

A portable patient treatment chamber connected to a second compartment for the exchange and transter of attendents and medics. The larger chamber also allows for transfer of patient to a larger recompression facility.

DEFINITIVE TREATMENT OF DCS

This is best controlled by diving physicians, hyperbaric facilities or specialised diving medical organisations, such as DAN.

❑ Therapeutic recompression.

This is the most effective treatment for DCS. Delay increases the likelihood of a poor final result. The diver is placed in a **recompression chamber (RCC)** and the pressure is increased according to a specified recompression treatment table.

The increase in pressure reduces the bubble size (Boyle's Law) and usually relieves the clinical features. It also increases the surface area to volume ratio of the bubble, which may collapse. The increased pressure in the bubble also enhances the diffusion gradient, encouraging nitrogen to leave the bubble.

The therapeutic recompression schedule determines the depth and duration of the treatment profile. The table selected may depend on factors such as the time elapsed since the onset of symptoms, the depth of the original dive and the type and severity of symptoms, as well as the capability of the treatment facility and the various breathing gases available. The treatment may be amended depending on the patient's response.

In recent years the **Oxygen Treatment Tables** are preferred because of their increased effectiveness. The injured diver is usually compressed to an equivalent depth of 18 metres (60 ft.) and is decompressed over 3–5 hours. He breathes oxygen from a mask while the rest of the chamber is filled with air. If the whole chamber is filled with oxygen, the **fire risk** increases dramatically.

Because the attendant breathes chamber air, great care must be taken to monitor his dive profile to avoid the embarrassing predicament of an attendant emerging from the RCC with DCS.

The diver breathes oxygen for the duration of the treatment except for 5 minute periods of air – or sometimes heliox ($He\text{-}O_2$) breathing – every 25 minutes, to minimise oxygen toxicity to the **lungs**. The regimen is not without hazard as there is a significant risk of **cerebral oxygen toxicity** causing convulsions in such persons.

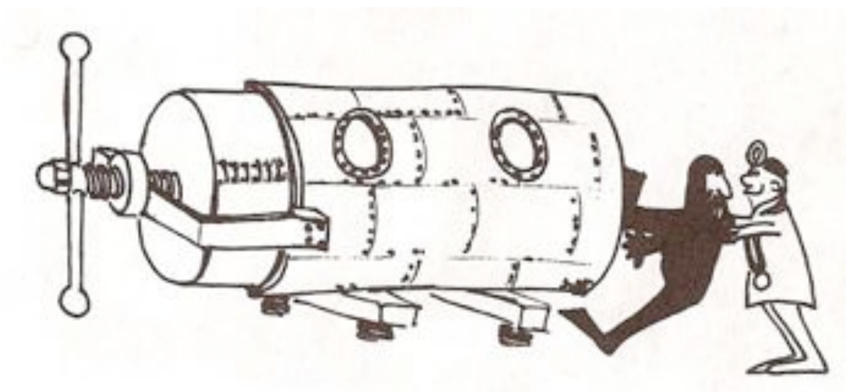

Fig. 16.3

Other tables are available which involve compressing the diver to a depth equivalent of 30–50 metres sea-water (100–165 ft.) in **air**, **heliox** and **nitrox** mixtures and then decompressing over periods ranging from several hours to several days depending on the severity of the symptoms.

Many other investigations and treatment modalities will be employed by experienced physicians in the RCC, including fluid balance, medications, etc, which need not concern the average diver.

A further emergency procedure, **Underwater Oxygen Treatment,** has been devised for use under expert supervision in remote localities. The diver is **recompressed in the water** to a maximum of 9 metres while breathing 100% O_2. Details of this procedure are outlined in Appendix C.

Treatment in water with the diver **breathing air** has been used in many parts of the world and water treatment tables are contained in some Navy diving manuals. While success has often been reported and delay in treatment can be avoided, this form of treatment has serious theoretical and practical difficulties which can result in worsening of the diver's condition.

The deep water air requirements (30 metres initially, and decompression for many hours)) renders the patient and accompanying divers prone to cold (hypothermia), narcosis, gas exhaustion, tide and other current changes. Attending divers may well develop DCS from extra exposures. This form of treatment is not generally recommended, unless other options (RCC, underwater oxygen treatment, etc.) are unavailable.

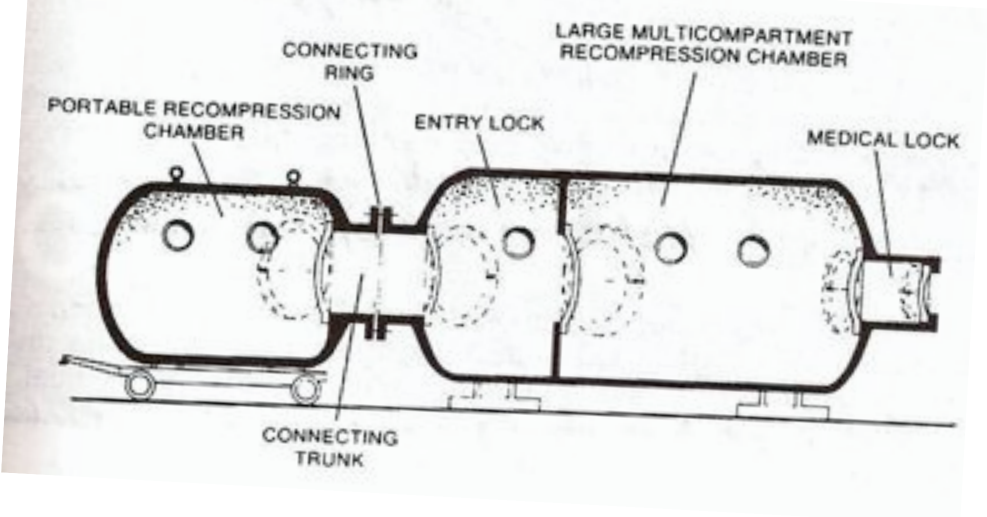

Fig. 16.4

Schematic outline of large static RCC treatment facility showing linking of a small portable chamber to the larger fixed unit. Both chambers are pressurised to identical pressures for a "transfer-under-pressure" (TUP).

❑ Hazards of therapeutic recompression.

While therapeutic recompression generally produces a dramatic relief of symptoms, it has several serious hazards. These include **oxygen toxicity** in the patient, the risk of **fire** and the risk of producing **DCS** i**n the attendant.** It should only be used under the close supervision of a medical officer experienced in its use.

PREVENTION OF DCS

There are a number of factors which predispose to DCS. These are described in Chapter 13. Obviously these should be avoided wherever possible but some are unavoidable. Apart from falsifying a birth certificate there is little an individual can do about the predisposing factor of age.

Because of the unreliability of the currently available dive tables and DCs, and the unpredictability of the development of DCS, it is possible for even the most careful, well trained and conscientious diver to develop this condition. The following suggestions will help reduce the risks.

It is important that the diver never exceeds the no-decompression limits and ascent rates. In spite of this, all the dive tables, and especially the dive computers so far devised, have a significant failure rate.

❑ "Fudge factors".

The rate of development of DCS varies from less than 1% to as much as 5% depending on the table or computer algorithm used, the depth and the duration of the dive, and if these are pushed to their limits. The apparent safety of tables and algorithms are probably improved by intelligent divers incorporating "fudge factors" of their own. This is especially required for older, fatter, less fit divers. Also for more important people, such as your children, spouses, best friends etc. Fudge factors imply ascending slowly before it is theoretically necessary – reducing bottom times and depths.

Some fudge factors may be incorporated into the dive as follows:

- For decompression tables; decompress assuming that the dive was carried out at a greater depth and/or duration than was the case. Ascend earlier and at a slower rate than required.
- For dive computers; ascend well before required to do so according to the display. Select the most conservative mode permitted by the computer or chose an altitude based decompression whilst diving at sea level

❑ Accurate depth & time.

It is essential that the diver knows accurately the depths and durations of his diving. A depth gauge which indicates the maximum depth attained is useful, because it is common for divers to descend deeper than they realise. An underwater **watch** or, better, a **bottom timer** is valuable, as is a D.C.

❑ No-decompression diving.

Although the tables and computers are not totally reliable, they are less reliable for deep diving (greater than 30 metres). It is advisable to avoid pushing the dive to the limits when a no-decompression schedule is followed and to avoid dives requiring decompression.

❑ Slow ascent rates.

A slow ascent is prudent and the diver should certainly not ascend faster than the rate recommended by the tables. Preferably a slower ascent rate should be employed (8–10 metres or 25–33 ft. per minute is an acceptable safe rate) and the extra time taken is deleted from the bottom time. i.e. ascend earlier than permitted by the tables.

❑ Routine decompression stops.

Most authorities recommend a routine minimum safety ("decompression") stop at **3-5 metres for 3-5 minutes**, after a no-decompression dive greater than 15 metres, to allow partial nitrogen elimination and trapping of venous emboli in the lung vessels.

❑ Exercise

Avoid strong exertion as far as possible during the dive and decompression staging. Gentle exercise may assist in de-gassing during the ascent, staging and post dive, although some would advise no exercise at all post-dive. The latter would be applicable if bubble formation had occurred.

❑ Dive planning.

When repeated dives or multi-level dives are planned, the **deeper dives** should always be **performed first.** Recreational repetitive dives on the same day should have long surface intervals between dives, preferably 4 or more hours if possible, and a maximum of 3 dives per day..

With multi-day diving, a rest day is included after each 3 continuous diving days.

With **deep diving**, gradual build up (**acclimatisation**) is achieved by progressively deeper exposures.

❑ Post-dive restrictions.

It is advisable to **rest** for an hour or more after a deep or long dive to ensure elimination of nitrogen from the fast tissues. Surface intervals should be > 2-4 hours.

Flying and significant altitude exposures within 24 hours of diving is not recommended. The DCIEM recommendation is "whenever possible it is inadvisable to fly above 600 metres in any aircraft within 48 hours of completing any dive. Travelling by vehicle over mountain ranges or hills can expose divers to the same dangers as flying and should be avoided in the same way for 24 hours. If flying after diving is considered essential, flying may be carried out after 24 hours but the increased risk of DCS must be borne in mind."

❑ **Dive computers** (See Chapter 14)**.**

.A healthy scepticism towards reliance on any mechanical equipment, especially if promoted by a glossy brochure or a dive computer salesman, also has good survival value.In addition to the above precautions, the diver is advised to buy a good quality waterproof rabbit's foot.