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DIVE ACCIDENT MANAGEMENT IN CENTRAL NEW ZEALAND

Tony Hochberg

Preamble

This paper deals with the management of compressed air diving accidents in sport and commercial divers.[1,2]

Decompression illness (DCI) must be considered in the differential diagnosis of anyone becoming ill after a dive. The presentation of DCI may be obvious, delayed or unusual and present a diagnostic dilemma.

Advice and referral to a hyperbaric facility should be considered, even if there is a low probability of DCI, as frequently the severity is underestimated and the prevention of long term sequelae is of prime importance.

The key components of treatment are stabilisation, time to recompression and consideration of adjuvant therapy.

Assessment

The successful management of DCI involves effective communication between the referring agency (diver, dive shop, doctor, hospital etc.) and the physician trained in hyperbaric medicine.

Key questions in the assessment of any diver include the following:

1 Name and age of diver.
2 Status includes the level of consciousness, bleeding and visible injuries.
3 Dive profile, including any dives in the last 7 days, whether in fresh water or salt water, what dive tables or dive computer was used and the stage of the dive symptoms developed etc.
4 Symptoms.
5 Air travel and/or ascent to altitude over 300 m following the dive.
6 Relevant medical conditions, e.g. migraine, high blood pressure, asthma, epilepsy.
7 Medications.
8 Emergency treatment instituted.

Transportation

For referrals from a peripheral location, an intimate knowledge of the available emergency services and the level of skill of the operators is crucial to the successful evacuation of an acutely injured diver.

The modes of transportation for an injured diver include motor vehicle, train and air transport, either helicopter or fixed wing.

The first two modes of transportation are used if the probability of DCI is very low, the presentation is very late (with no serious complications such as neurological DCI that would necessitate the high cost of aeromedical evacuation) or there are adverse weather conditions.

By road the journey from Wellington to Devonport Naval Base, in Auckland. can be accomplished comfortably in 8 hours (a distance of 700 km).

Emergency air evacuation is not without its risks. Air ambulance standards are defined by the Civil Aviation Authority in an information circular Gen A dated July 1983.[3] Unfortunately deregulation of authorised air ambulances over the last few years has resulted in fatal aircraft accidents during aeromedical evacuation.

In New South Wales, Australia, Donaldson[4] provided some figures for comparison on helicopter aeromedical evacuation fatalities: a crude ambulance mortality rate of 3 deaths per 20,000 hours flown, which compares to a NSW road ambulance mortality of 0.015 deaths per 100,000 vehicle hours logged. In the USA the figure is under 6/ 100,000 hours for helicopter flights.

Contraindications to air travel in a diver include, shock, pneumothorax, myocardial infarction, vomiting and aerocele.

Equipment

Aeromedical equipment fits into two categories. The first is equipment integral to the aircraft e.g. stretcher, mountings, oxygen cylinders. The second is equipment carried onto the aircraft to accompany the diver.

The following are essential, intubation kit, chest drainage kit and medical kit. Table 1 lists a suitable medical kit.

Aircraft Type

The ideal aircraft is at least twin-engined, capable of being pressurised to sea level or greater, fast, long range, noise and vibration free with short take off and landing capability, large loading doors, adequate space, lighting and temperature and with toilet and hand washing facilities.

Helicopters can never meet all of these ideals and compromises therefore are made.

In Wellington there are two air ambulances dedicated to aeromedical work. These are a Piper Cheyenne II, a twin engined pressurised turbo-prop aircraft, and a BK-117 Messrschmitt Kawasaki twin turbine helicopter.

The Piper Cheyenne II (commissioned April 1994) is capable of being pressurised to sea level at an altitude of 10,000 feet. At an air speed of 230-240 knots the flight time from Wellington to Auckland International Airport is 70 to 75 minutes.

The Cheyenne is capable of carrying one stretcher patient or six seated patients in addition to two flight crew. It has a rate of climb of up to 4,000 ft/minute, which in turbulent weather is very important for patient comfort. Oxygen stores will typically last 3 hours at a flow rate of 10 litres/minute.

Standard equipment includes a Propak Life Monitor, Ivent ventilator, pulse oximeter, suction unit and a defibrillator with options for pacing when required. A unique stretcher bridge has been designed so that no equipment needs to be unplugged or transferred when moving the diver into or out of the aircraft.

The BK-117 Helicopter (commissioned April 1993) must be flown at an altitude not exceeding 300 m which is very fuel inefficient. At an airspeed of 120 Knots the journey from Wellington to Devonport Naval Base is two and a half hours. This includes two stops for fuel.

The BK-117 has the same equipment as the Piper Cheyenne with the added ability of being able to carry two stretcher patients or up to nine seated patients with the two pilots.

Cost

The Piper Cheyenne is billed, to Area Health Boards or the Accident Compensation Commission or the diver, at

TABLE 1
EQUIPMENT LIST
(TO BE CARRIED IN A CONVENIENT CASE).

Airway equipment
Guedel airways
Laryngoscope and selection of blades
Spare laryngoscope batteries and bulbs
Endotracheal tubes
Cricothyroidotomy set
Suction catheters - endotracheal and oral

Breathing support
Stethoscope
Self-inflating bag and range of masks
Oxygen supply, portable and aircraft-mounted

Circulatory support
Aneroid sphygmomanometer
Intravenous cannulae
Fluids and giving set
Intravenous cutdown set
Central venous catheter

Specific Items
Intercostal drain set with Heimlich valve
Cervical support collars
Urinary catheters
Nasogastric tube
Thermometer, non-mercury
Drugs, needles, and syringes

General items
Scissors
Sticking plaster
Dressings and eye pads
Crepe bandages
Torch
String, plastic bags
Alcohol swabs
Sterile gloves
Tissues
Vomit containers

Separate items of equipment to be kept with above
Suction apparatus
Portable ventilator
Monitor/defibrillator
Syringe pump
Pulse oximeter
Vacuum mattress
Traction leg splint
General limb splints
Pillows and blankets
Urinal and bedpan - where to empty?

An end tidal CO_2 monitor and oesophageal stethoscope are optional.

$850 per hour (actual running costs are $1,400 /hour). The typical cost of evacuation is $3,400.

The BK-117 is charged at $1,600 per hour (actual running costs are $2,200/hour). Typical cost of evacuation is $8,000.

Geography

The importance of geography in the management of diving accidents includes the location of hazardous dive sites, the location of hyperbaric facilities and the peculiarities of the terrain in between

Peculiarities of the Terrain

The central volcanic plateau of the North Island is composed of 3 active volcanoes, Mount Ruapehu at 2,797 m (9,175 ft), Mount Ngauruhoe at 2,291 m (7,515 ft) and Mount Tongariro at 1,968 m (6,458 ft). State Highway One runs alongside and peaks at an altitude of 1,600 m.

Divers travelling to Devonport by train or car must therefore avoid this route and go the longer and more complicated way through New Plymouth. Two divers have reported an aggravation of symptoms while passing through the central volcanic plateau which was alleviated by descent.

For fixed wing evacuation across the central volcanic plateau icing on wings can be a problem along with cloud with a particularly high ceiling. A coastal route is often favoured by pilots.

Hazardous Dive Sites

It is very clear that certain dive sites pose a greater risk than others. The Mikhail Lermontov which sank in 1986 in the Marlborough Sounds is a prime example with 3 recent dive related deaths and probably as many as 20 cases of DCI.

Hyperbaric Facilities

New Zealand had three Hyperbaric Chambers in operation 3 years ago (Auckland, Wellington and Christchurch) but now (October 1994) we have only one based at the Naval Hospital in Devonport, Auckland.

This has significant and potentially serious implications given that a large amount of scientific and recreational diving is undertaken in Wellington, Marlborough Sounds, Fiordland and Foveaux Strait. Some of these locations are over 1,575 km (900 miles) from Auckland.

With a population base of 3.25 million there is reasonable justification for another hospital based chamber.

Commercial recompression chambers can be found at Maui Oil Rig near New Plymouth and on The Little Mermaid in Wellington.

The importance of an understanding of geography to dive accident management is well summarised by the following case:

A 20 year old experienced diver (550+ dives) presented with a paralysed left arm following a provocative dive profile (41.4 m for 23 minutes, surface interval of 3 hours then 28.2 m for 30 minutes) combined with heavy alcohol consumption after the dive. His symptoms were of progressive weakness and numbness of the left arm. He was evacuated to Auckland International Airport in the Piper Cheyenne pressurised to sea level while on 100% oxygen. The estimated time of arrival at Auckland Airport coincided with peak rush hour traffic (1700). This would have added at least 2 hours to his arrival at Devonport by road ambulance. A helicopter was therefore standing by and there was only a further 15 minute delay. Six and a half hours elapsed between assessment and treatment.

Differential Diagnosis

In the assessment of any symptoms following a dive one must consider non-diving related illness.

Rarely a combination of diving related pathology will co-exist with non-diving related pathology eg acute appendicitis.

A short list to consider includes the following:

Hypoglycaemia
Migraine
Multiple sclerosis
Epilepsy
Gastro-oesophageal reflux
Aerophagy
Myocardial infarction
Porphyria
Ciguatera poisoning
Shellfish poisoning
Round window rupture
Alternobaric vertigo
CO intoxication
Salt water aspiration
Shallow water blackout
Viral illness

Management

The initial management of DCI can be summarised as follows:

FIND THE DIVER

Ancillary aids such as safety sausage, flares, torches, fluorescent dyes, whistles and radio transmitters all have their respective merits.

REMOVE FROM DANGEROUS ENVIRONMENT

At depth

If unconscious:

Purge regulator before placing it in the diver's mouth.
Gas should not be purged into an unconscious diver.
Surface with the victim's neck extended to enhance upper airway patency.

If conscious:

Controlled ascent where possible.

On surface

Unconscious or conscious:

Remove weight belt.
Inflate buoyancy compensating device (BCD) for positive buoyancy and ensure that the diver does not float face down.
Maintain an open airway.
Expired air resuscitation (EAR) only if immediate exit from the water is not possible.
In water external cardiac compression (ECC) is ineffective and should not be used.
Avoid obstacles such as kelp, rips and jagged rocks.

RESUSCITATION

EAR and ECC where necessary
Control bleeding and seek assistance

POSTURE

Horizontal for most divers
Left lateral position if unconscious or vomiting
30° head down for cerebral arterial gas embolism (CAGE). Conventional wisdom suggests that a short period, less than 10 minutes, of head down may result in enhanced clearance of bubbles from the cerebral circulation followed by a horizontal position.[5,6]

The value of posture is well demonstrated by the following case. A call was received from the skipper of a dive boat concerning a 28 year old untrained but experienced diver who was dizzy and vomiting after a provocative series of dives. The skipper was advised to place the diver horizontal and on the left side. This resulted in a marked resolution of symptoms. The eventual diagnosis was vestibular, cerebellar, cerebral and musculoskeletal DCI.

Divers with neurological symptoms must not be allowed to sit up until inside a recompression chamber.

The sitting position may be adopted for isolated inner ear barotrauma as this may reduce perilymph leakage.

100% OXYGEN

Device

Close fitting oronasal mask, or mouthpiece and nose clip, supplied by demand valve or oxygen reservoir bag.
Standard disposable medical oxygen masks or nasal prongs are unsuitable for treating diving accidents.

Stores

Calculate sufficient oxygen stores to retrieve at least two injured divers to a recompression facility at a flow rate of 20 litres/minute.

Air breaks

For the first 4 hours on oxygen no air breaks are required.
From 4-12 hours on oxygen 5 minutes on air every 25 minutes and after 24 hours on oxygen alternate hours air and oxygen.
Record and observe for symptoms of oxygen toxicity e.g. central chest pain, dyspnoea, hiccups, tinnitus, tunnel vision.
Calculate the risk of oxygen toxicity e.g. by units of pulmonary toxicity dose (UPTD).

FLUID BALANCE

Dehydration is known to aggravate DCI through influences on blood rheology and compromise of the microcirculation by haemoconcentration. Therefore liberal oral or intravenous fluids are encouraged and an accurate record should be kept. Colloid or crystalloid IV fluids may be used.

Oliguria or anuria despite liberal fluid administration may indicate bladder paralysis due to spinal cord DCI. Urinary catheterisation is mandatory in this setting.

Contraindications to aggressive fluid management are brain oedema secondary to brain injury, pulmonary oedema secondary to near drowning, valvular or ischaemic heart disease and renal failure secondary

to pre-existing renal disease eg IgA glomerulonephritis.

URINARY CATHERISATION

Essential in spinal cord DCI with bladder dysfunction.

HYPOTHERMIA

Hypothermia is classified as mild when the rectal temperature is between 35-32°C, moderate between 32-28°C and severe below 28°C.

Treatment modes include, passive e.g. space blanket, active e.g. heated blanket or warming in a bath and central e.g. warmed IV fluids, perhaps warmed peritoneal fluids, humidified oxygen at 40-42°C via an endotracheal tube.

ADJUVANT TREATMENT

There are no drugs of proven benefit in the treatment of DCI (this includes aspirin, corticosteroids and alcohol).

Lignocaine may hold promise for peripheral centres referring divers and warrants urgent consideration by researchers.

Diazepam is effective in controlling or preventing oxygen toxic convulsions and also in controlling vestibular symptoms. Diazepam should only be used to control vestibular symptoms on the advice of a Hyperbaric Physician as it may make titration of treatment in recompression chambers difficult.

RECOMPRESS AS SOON AS POSSIBLE.

Perhaps one should use a transportable chamber e.g. Duocom.

Air or road transport at an altitude of less than 300 m.

Care by trained personnel.

I see no role for in-water oxygen therapy.

At the moment you are aware that an injured diver is on his way to you for assessment you must begin the process of evaluating the availability of your emergency services and be prepared to meet the diver at the local airport, time permitting, or if they require stabilisation at the local hospital.

Not infrequently the BK-117 Helicopter is in Nelson and the Cheyenne is in Palmerston North and one must therefore calculate and co-ordinate with ambulance control priorities. For example one routine transfer of a ventilated paraplegic patient to Christchurch Spinal Unit was delayed, after discussion with the Intensive Care Consultant, to enable urgent transport to Devonport of a seriously ill diver.

Contact Numbers

New Zealand Diver Emergency Service	09-445-8454
Australia Diver Emergency Service	
within Australia	1-800 088 200
from outside Australia	61-8-373-5312
USA Diver Alert Network (DAN)	1-919-684-8111

Conclusion

Effective and well rehearsed communication between the referring agency, the hyperbaric physician or doctor in a peripheral centre and the specialist hyperbaric unit are crucial to successful management of an ill diver.

Time is of the essence.

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