Decompression illness

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Scuba diving is a common leisure activity in Australia, with millions of dives taking place every year.

Diving may also be part of a job such as abalone harvesting or underwater cleaning services. Local and overseas dive holidays are increasingly popular, and divers may consult inland or rural GPs on their return, particularly as relatively late presentations are common in diving-related conditions.

Decompression illness may seem a mysterious condition to many medical practitioners but understanding the pathophysiology behind diving-related illness is relatively easy and treatment is usually highly successful.

All diving with compressed air is associated with some risk of decompression illness and the incidence rises steeply when the dive tables or computer algorithm limits are breeched.

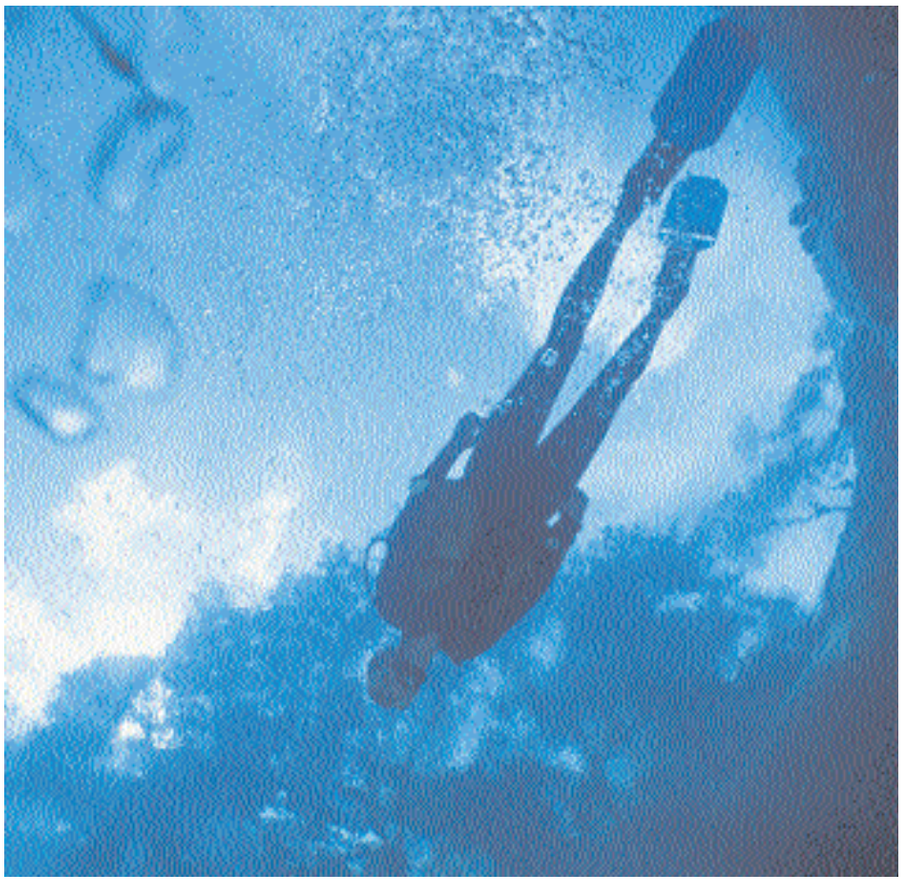
However, half of all divers diagnosed with decompression illness have not exceeded the limit of their dive table or computer.

Each year about 350 people in Australia are treated using recompression and there are 5-10 dive-related deaths. Many divers also present to medical practitioners for advice and treatment of other problems related to diving – such as disorders of the ear, lungs and respiratory sinuses.

Ill-effects associated with diving may be caused by:

- the generation of bubbles within the tissues or vasculature (decompression illness)
- changes in pressure at the tissue/gas interface (barotrauma)
- immersion in water (eg, near drowning, salt water aspiration syndrome).

This article deals specifically with decompression illness, but it is important to consider all of these mechanisms when considering a diagnosis.



Under pressure: all scuba diving carries some risk of decompression illness.

CASE HISTORY

Alex, age 38, presents three days after returning from his first diving holiday near Cairns.

He did 11 dives over three days without incident. Alex reported no episodes of rapid or panic ascent and did not miss any obligatory decompression stops.

But since about one hour after surfacing from the last dive, Alex has felt unwell and has had difficulty concentrating at work.

He feels weak and lethargic and complains of intermittent paraesthesia in both legs. Alex also noticed aches and pains in his limbs on the flight back from Cairns, which receded on landing.

Examination reveals little except weak deep tendon reflexes in both legs.

Case outcome, page 20

Making the diagnosis

HOME TRUTH

- All injured divers should be treated with the same standard first aid protocol in the emergency situation. The difference between decompression sickness and cerebral arterial gas embolism (AGE) can be subtle and has no clinical significance in the acute phase.

COMMON SYMPTOMS

Decompression illness can affect any system and symptoms are remarkably diverse. This table lists the commonly cited symptoms reported by divers suffering a decompression disorder from a recent case series of 76 patients.

SYMPTOMS	% OF PATIENTS
Pain	67
Fatigue	54
Tingling	46
Headache	46
Numbness	35
Weakness	26
Cognitive difficulty	25
Dizziness	20
Ataxia	17
Dyspnoea	13
Itch	10
Visual disturbance	8
Rash	7
Loss of consciousness	5
Cough	3
Urinary dysfunction	1
Other	13

Source:
Mitchell S. Diving Injuries 1: Decompression Illness. Australia and New Zealand Hyperbaric Medicine Group Introductory Course Notes. Sydney 2005

Decompression illness has many possible manifestations, ranging from mild and vague constitutional symptoms to sudden loss of consciousness, death or paralysis.

It's important to seek advice from a recompression facility for any medical problem arising within 24 hours of diving (for which there is no probable alternative cause).

The most important affected tissues are the central nervous system and musculoskeletal system. Single or multiple limb pains are common but general, constitutional symptoms (similar to those experienced during viral illness) have been recognised as a primary manifestation in up to 40% of cases.

Severe illness is now uncommon in the developed world, but severe decompression illness leading to permanent disability or death remains a significant problem in poorly trained indigenous commercial divers in the developing world.

History

The diagnosis of decompression illness rests almost entirely on taking a careful history. The temporal relationship between symptoms and diving is particularly important. Typically, symptoms begin within minutes or a few hours after surfacing.

Although new symptoms (that start more than 12 hours after emergence from the water) are unlikely to be related to decompression illness, it is important to remember that divers with diving-related symptoms often present late for assessment.

For example, the average time to first presentation in a series of cases at the Prince of Wales Hospital in Sydney was more than 24 hours, yet the interval from the end of a dive to the first symptom in these patients was less than two hours.

In deep now: nitrogen gas bubbles forming in the tissues causes most cases of decompression illness.

Important elements of the history in a suspected case of decompression illness are listed in the table at right.

In a case of early presenting, serious or rapidly progressive symptoms of dive compression illness, the history should be significantly truncated in order to recompress the patient as quickly as possible.

Pathophysiology

During diving, air is breathed at greater pressures than normal, causing an increase in the quantity of nitrogen dissolved in tissues of the body. The longer and deeper the dive, the greater the amount of nitrogen to be dissolved until all tissues are saturated.

During ascent, nitrogen must be eliminated as the ambient pressure decreases. Ideally, during a planned ascent with a controlled reduction in ambient pressure, the nitrogen diffuses down a pressure gradient from the tissues to the venous blood and into the alveoli to be exhaled.

However, if the rate of ascent is too great, gas may come out of solution and form bubbles in the tissues, much like a bottle of carbonated water bubbles when the pressure is acutely reduced after opening the cap. Nitrogen gas bubbles forming in the tissues, sometimes called 'decompression sickness', is the mechanism responsible for most cases of decompression illness.

Bubbles may cause harm through mechanical distortion of tissues, vascular obstruction or stimulation of immune mechanisms that lead to tissue oedema, haemoconcentration and hypoxia.

The other, much less common, form of decompression illness occurs when discreet gas bubbles pass to the arterial circulation, either through pulmonary damage or across a (right to left) intracardiac shunt and is known as arterial gas embolism (AGE).

The central nervous system is particularly susceptible to this type of injury (cerebral AGE or CAGE).

The passage of bubbles along the vascular endothelium is damaging due to surface tension effects: it removes the protective surfactant layers and whole endothelial cells.

The damaged endothelium is a powerful stimulus to leucocyte adhesion and platelet aggregation, and restricts flow in small vessels. This secondary injury may explain the later deterioration after early recovery seen in many cases of suspected cerebral AGE.

IMPORTANT ELEMENTS TO CONSIDER IN TAKING A DIVING HISTORY

ELEMENT OF HISTORY	NOTES
Demographic data	Decompression illness is more common in older divers, as are many other possible diagnoses such as angina or diabetes.
Method used to control decompression status: table or computer	May help decide the gas burden and likelihood of decompression illness.
Number of dives and surface intervals	May help decide the gas burden.
Dive history – maximum depth, duration, number and speed of ascents to surface, violation of tables, level of activity	Divers are generally able to tell us if the dive was 'outside the tables' – that is the depth and duration were longer than recommended. Such violations are not required to make the diagnosis, but make the diagnosis more likely.
Any problem with ears?	May help differentiate barotraumas from decompression illness.
Temporal account of symptoms and signs	Related to the diving as discussed in the text.
Past diving history	Experience level may assist diagnosis.
Past medical history, medications and allergies	Includes any reason for illness and whether diving has previously resulted in illness.
Response to first aid	Did the symptoms improve with the administration of oxygen? How much oxygen was given and for how long?

In practice, pulmonary disruption or intracardiac shunt is rarely proved and the distinction between cerebral AGE and decompression sickness is often difficult to make.

It is now accepted practice to define the whole group of related conditions under the heading decompression illness and to characterise the type of illness by outlining the manifestation, evolution, time of onset, estimation of gas burden and presence or absence of evidence of barotrauma.

Manifestations: these cover signs and symptoms, as well as organs affected. For example, neurological decompression illness with headache, nausea and bilateral lower limb parasthesia.

Evolution: the chronology and intensity of symptoms over time in relation to the time of the dive.

Gas burden: an estimate of nitrogen still left in body. It is highest with increasing dive depth and duration, and if decompression stops are missed.

Barotrauma: if present, look especially for indications of lung injury. Also, chest pain, dyspnoea, cough or surgical emphysema (with or without clear cerebral injury) all suggest serious illness that may deteriorate quickly.

Examination and investigations

There are no reliable haematological or biochemical markers of decompression illness.

Supposedly sensitive radiological investigations, such as MRI, may fail to show an abnormality even when florid neurological signs are present.

Therefore, clinical history and examination are the most sensitive indicators for diagnosing decompression illness and assessing progress during treatment.

When performing an examination, the priority of the elements to consider will depend on the history.

Chest: Particularly if there are any respiratory symptoms. Look for surgical emphysema, pneumothorax.

Neurological: It is important to perform a thorough examination of higher functions, cranial nerves and peripheral nerves.

The most commonly affected elements are:

- clouding of thought revealed by slowing or failure at complex mental tasks. (Many diving specialists use a standard mini mental-state questionnaire.)
- impaired balance and/or co-ordination.
- lower limb weakness (may be unilateral or bilateral)
- patchy, non-dermatomal, reduced sensation
- upgoing plantar response.

Ears: Bleeding and rupture of the tympanic membrane indicates significant barotrauma.

Skin: A patchy erythematous rash is common and is usually short lived and mobile. The area affected may change while being observed.

Response to oxygen: 50% of cases respond rapidly to high flow oxygen therapy, but a good response does not indicate that recompression can be avoided.

COMMON PITFALLS

- Don't be falsely reassured by a "sensible" dive history: About 50% of divers treated for decompression illness in Australia have not violated their dive tables or computer limits for depth and duration of the dive.
- Ensure patients lie down throughout physical examination, chest X-ray or during transfer: sitting or standing can result in movement of intravascular bubbles and neurological deterioration during acute illness.

Treating suspected decompression illness

THE GEMS

- In any acute diving injury, give high-flow oxygen, administer intravenous crystalloid fluids and keep the patient lying down.
- Seek advice from a recompression facility for any medical problem arising within 24 hours of diving (for which there is no probable alternative cause).
- Tissue bubble injuries (decompression sickness) are most unlikely if symptoms begin before the end of a dive.
- Timely first aid and recompression results in a high rate of complete recovery.
- A return to diving after decompression illness is best managed by a specialist diving physician.

If decompression illness is suspected, there are a few standard simple first aid measures that should be instituted while seeking advice and referral to a recompression facility.

Acute illness

If a diver presents within 12 hours of a dive and is significantly unwell, the recommended approach is:

- Institute standard emergency management protocols to support airway, breathing and circulation.
- Administer 100% oxygen (or as close to it as possible) with available equipment.
- Keep the diver lying flat – sitting or standing has resulted in movement of intravascular bubbles and neurological deterioration. In particular, don't sit or stand for physical examination, chest X-ray or during transfer.
- Administer crystalloid fluid replacement. Adults should receive 1L of fluid (usually normal saline or Hartmann's solution) over 30 minutes, followed by appropriate maintenance. All divers should be treated as significantly dehydrated until passing urine copiously (but being careful to avoid fluid overload).
- Urgently seek advice and referral to a recompression facility.

Subacute illness

When the presentation is less acute, first aid measures are likely to be unnecessary and unhelpful.

However, oxygen administration and oral fluid can be administered for presentations occurring up to 24 hours after the dive, while awaiting transfer to a recompression facility.

Low-level transfer – such as pressurised fixed-wing aircraft, special helicopter or even road transport – avoids the risk of symptom deterioration from hypoxia and further depressurisation. The specific type of low-level transfer is best decided by the recompression chamber staff and retrieval team.

A recompression chamber: the only definitive treatment for decompression.

Specialist advice

Once first aid measures have been instituted, discuss all cases with the local recompression facility. There is at least one such facility in each state and territory (except the ACT).

In addition, Royal Adelaide Hospital's hyperbaric medicine unit runs a 24-hour emergency advice line, Divers Emergency Service. Call 1800 088 200 (Australia) or +61 8 8212 9242 (from overseas).

Recompression

Recompression is the only definitive treatment for decompression illness. It involves placing the patient in an airtight vessel, increasing the pressure and administering 100% oxygen.

This greatly enhances the movement of nitrogen out of any remaining bubbles down a steep diffusion gradient, as well as delivering a greatly increased partial pressure of oxygen to the tissues.

At the same time, the volume of bubbles is directly reduced through the operation of Boyle's Law (volume of a given mass of gas is inversely proportional to the ambient pressure).

Treatments typically involve pressurisation to 2-6 atmospheres absolute (ATA) for between two hours and several days as a single treatment.

NSAIDs may offer symptomatic relief and may shorten the amount of recompression needed.

Life after decompression illness

In most cases, the outcome of even serious decompression illness is for a return to full health. In up to 10% of cases, any of the presenting symptoms and signs may persist for months or years, particularly if there has been a delay in first aid or recompression. It is most unusual for new problems to develop after definitive treatment.

The most serious sequelae are those following severe neurological decompression illness where leg weakness, loss of balance and/or fine co-ordination may be permanent and disabling.

CASE OUTCOME

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Alex is probably suffering from decompression illness. Although he would technically be described as having "static neurological decompression illness with no features of cerebral AGE or barotrauma and a moderately high gas burden", the illness is affecting his life and work.

The natural history suggests he would recover slowly, over weeks or months, but referral to a hyperbaric centre via low-level transfer for recompression is preferable and appropriate.

After three sessions of hyperbaric oxygen recompression and a regular NSAID, Alex feels well and is normal on examination. He agrees to dive less intensively in the future – a maximum of two dives a day is safest.