IN-WATER OXYGEN RECOMPRESSION THERAPY FOR DECOMPRESSION SICKNESS

John Knight

The correct treatment for decompression sickness is recompression in a multi-man chamber. This chamber should have at least two compartments. A multi-man chamber is necessary so that an attendant may be in with the sufferer, and the two compartment chamber is necessary so that the doctor may come into the chamber, examine the patient, and exit.

Unfortunately, chambers like this are not too common in Australia. At the last count, the available multi-man chambers were:

one at Townsville, at the Australian Institute of Marine Science;
one at HMAS Penguin in Sydney;
one at Prince Henry Hospital, in Sydney;
one at Mallacoota, in north eastern Victoria, owned by the Fishermen's Co-operative;
one at Morwell, run by the National Safety Council of Australia, Victorian Division;
one at Braeside in Melbourne, run by the Melbourne Metropolitan Board of Works, but activated only when they are tunnelling in compressed air;
one at Hobart, run by the Royal Hobart Hospital;
one at Fremantle, at HMAS Leeuwin.

I believe there is a multi-man chamber available in Adelaide, but I am not sure of its location. Of course there are the multi-man chambers used by the diving industry both in Bass Strait and on the North West Shelf, but these are not normally available for the treatment of civilians. They are there for the support of the diving operations that are being conducted. If they are used for treating other people, those diving operations must stop. As this involves a considerable financial penalty, we will leave them out of the discussion.

Experience has shown that the success rate for the treatment of decompression sickness is much better if less than six hours has elapsed since the onset of symptoms. This is partly due to the blood-bubble interactions that occur and result in the bubbles in the blood acquiring a coating of protein material which converts them from being effectively "easily squashed ping pong balls" into "difficult to squash tennis balls". The ideal is to treat the diver as soon as possible after he develops symptoms.

If there is no chamber handy, one has to arrange transport to a chamber. As reduction in pressure will allow the bubbles in the patient's body to increase in size and make him worse, the patient should be transported as close to sea level as possible, preferably in an aircraft pressurised to ground level. That will take a while unless you are lucky and find one in the airport nearest you. It usually means the aircraft has to be flown from Australia to wherever the diver is and back again.

There are many places in Pacific where lots of people go diving which are more than six hours door-to-door to one of these chambers.

Some years ago, Carl Edmonds was worried about the number of people who were coming to HMAS PENGUIN having developed decompression sickness on a Pacific island and taking days to reach HMAS PENGUIN for treatment. He sat down and compared what was available to him and what was available on the island.

At HMAS PENGUIN there is a chamber into which the patient and his attendant can be put. The patient is given oxygen breathe and the normal practice is to take the patient to a depth equivalent to 60 feet of seawater (fsw). The patient then breathes oxygen for 20 minutes and air for five minutes, and so on until his symptoms are improved. About 85 to 90% of people improve and lose their symptoms on this minimum pressure oxygen treatment. Sixty feet of sea water is used as it is pretty close to the highest safe partial pressure of oxygen. The danger is oxygen-induced convulsions, acute oxygen poisoning. These convulsions, are provoked by exposure to oxygen partial pressures of two atmospheres and more. There is a pressure and time relationship. At 60 fsw, 100% oxygen has a partial pressure of 2.8 atmospheres and is safe to breathe, for most people, for periods of up to two hours. After a while the chamber pressure is reduced to the equivalent of 30 fsw and the process of oxygen and air breathing continued.

On a Pacific island there might be oxygen. There might be an airstrip that would take a Hercules or a Lear jet. There would certainly be water close by.

The problems of decompression sickness are bubbles which are usually treated by having their size reduced by recompression and oxygen breathing. There is always tissue anoxia which benefits from hyperbaric oxygen. All divers become dehydrated during their dive from the effects of immersion displacing blood from the legs and abdomen into the chest, so triggering stretch responses from the great vein volume receptors, although the blood volume is still normal. Decompression sickness causes leaky capillaries, among other problems, so the diver becomes further haemoconcentrated and dehydrated. He needs fluids. Two aspirin will discourage platelet aggression on the bubbles. The most important part of the treatment is recompression.

Recompression breathing air adds nitrogen to a body already overloaded with nitrogen. Therapeutic recompression in water breathing air is condemned by all diving medical authorities as it takes many hours to perform properly and exposes the diver to the risks of hypothermia. Most attempts by divers end disastrously.

There are advantages in breathing oxygen. The patient is no longer taking up nitrogen and he has the highest possible gradient for excreting the nitrogen load. This gradient increases considerably if the patient is in the water breathing oxygen.

PRINCIPLES

So Carl Edmonds decided that the divers who took days to reach his chamber would be better served if they were recompressed in the water while breathing oxygen soon after the onset of symptoms. He chose a depth of 9m (30 feet) because oxygen convulsions are unknown at this depth in people at rest. There have been convulsions in divers working hard in oxygen rebreathing sets at this depth, but investigations have always shown a raised PCO_2 in the set. The convulsion threshold of oxygen is lowered by a raised PCO_2. The diver having in-water oxygen recompression is still and has a normal PCO_2.

The advantages of in-water oxygen recompression at 9m can be summarized:

1. No nitrogen is added to the tissues during treatment.
2. There is a large gradient for nitrogen excretion.
3. The bubble volume is almost halved.
4. The diameter of circular bubbles is reduced by about 20%.
5. There is increased tissue oxygenation.
6. There is no risk of oxygen toxicity.
7. There is no risk of decompression sickness for the attendant.
8. The wetsuit is still effective insulation.
9. It can be instituted relatively quickly anywhere there is 9m of water.

There are disadvantages. I must emphasise that it is not ideal treatment. It is a treatment that is better than waiting around for six hours for an aircraft to fly you to a treatment centre that is properly equipped.

The water must be warm. It is not a treatment to be indulged in in cold water. Some three or four years ago this treatment was tried at Heron Island. After half an hour the patient complained bitterly of the cold, and insisted on terminating his exposure to pressure. By then he was improved but had not completed the treatment. It is not a good idea to add hypothermia to the problems of decompression sickness.

There are problems of breathing high partial pressures of oxygen. Vasoconstriction is induced. The immersion of a human in thermoneutral water increases his peripheral circulation, but thermoneutral water is not all that common in the ocean. It is more likely that the vasoconstriction induced by cold from the first dive and the heat loss from the treatment in water will induce vasoconstriction, so slowing the elimination of nitrogen from the tissues.

However, when compared with the problems of late treatment in-water oxygen recompression has its place where the water is warm and when transport to the nearest recompression centre will take more than six hours.

In-water oxygen recompression has been used on quite a number of occasions, with success, including at least one person who was unconscious when lowered into the water with his buddy alongside. He woke up under pressure and made a complete recovery from his central nervous system decompression sickness. So far I have not heard of any failures, and that news would go round the diving medical world very fast indeed, as many people consider that in-water oxygen recompression therapy is misguided, to put it mildly.

Certainly, if I was to develop decompression sickness and it would take more than six hours to get me to a recompression chamber, I would opt, if I was in the tropics, for the in-water recompression therapy immediately, on the basis that rapid treatment is much more effective than delayed treatment.

The requirements for in-water oxygen recompression are simple.

1. A large (F or G) size oxygen cylinder.
2. An oxygen reducing valve (regulator) set to deliver at least 80 psi. The regulator from an oxy-acetylene outfit will do very well as it delivers a higher pressure than the usual medical oxygen regulator, which is set to 60 psi.
3. 12 m of high pressure hose to connect the regulator to.
4. A full face mask.
5. The patient wears a full wet suit, including a hood.
6. A rope marked in metres or feet so that the patient's depth is known.
7. An attendant in the water with the patient.
8. A support for the patient.
9. A communication system both between the patient and his attendant, and between the attendant and the surface. The patient can speak quite comfortably if he is wearing a full face mask because there is an airspace for him to speak into and it is possible, if the buddy holds his breath for a moment, to hear quite clearly what the diver is saying. The other way around is more difficult, and an underwater slate is a good idea. The simplest method of communication between the attendant and the surface is to have another standby attendant who can go down when signalled for and relieve the existing buddy so that he can go up and give a verbal report.

A full face mask, in my opinion, is essential, although I know this treatment has been carried out without such things, because the full face mask allows the person to speak, it is less tiring than holding a regulator in the mouth for three hours and should the patient go unconscious and go on breathing, he will not drown. When using a normal face mask and a separate regulator, if somebody goes unconscious, their jaw muscles slacken and the regulator falls out of their mouth. They may or may not go on breathing. If they go on breathing, they are likely to drown.

PRACTICE

The procedure is to ready a seat for the diver to sit on. This is more comfortable than sitting in the bight of a rope.

The diver must wear a wetsuit, including hood, because he is probably already cold from his dive, and is certainly going to get cold sitting still even in tropical water, because he will not be generating any noticeable amount of heat. Shivering is undesirable as it increases his oxygen usage, makes his muscles move and will precipitate the formation of extra bubbles in his body. The diver has to be overweighted so that he will stay at the depth chosen. If he is sitting it is a good idea to have weights on his ankles so that they do not tend to float up. This means that the diver must be attached to a safety line which is attached to the boat or jetty so that he cannot sink further than the length of the line. So we now have two lines. One to hold his seat, and one to catch him if he slips off.

Then there is the full face mask and the oxygen cylinder on the boat or jetty.

There has to be a team to carry out the procedure. At least one person to watch the time, the depth and the oxygen supply. Two attendants for the patient. More people are an asset.

The patient and his attendant disappear over the side and the patient is lowered to a depth of 9 m.

He then stays there for 30 minutes, regardless of how soon his symptoms are cured. In most cases these symptoms have been cured within the first 30 minutes. If the symptoms are not completely cured after 30 minutes the patient spends another 30 minutes at 9 m. If he had a neurological bend he spends at least 60 minutes before the ascent is commenced. If there are still symptoms remaining at the end of the hour, the time is extended by another 30 minutes.

So after 30, 60 or 90 minutes the return to the surface starts. Ascent is at the rate of 1 m every 12 minutes, or alternatively, for those who date from the pre-metric days, one foot every four minutes. You will have noticed that one foot every four minutes is slightly slower than 1 m every 12 minutes, and I think that the slower rate of ascent is to be recommended. Also the ascent of a foot at a time is nearer a lineal decompression than an ascent of a metre. For a given time span lineal decompression is a better method than a staircase decompression. At this rate the ascent takes about two hours.

If symptoms recur during ascent the ascent is halted for 30 minutes. I have never heard of this being necessary.

If the oxygen runs out the patient is brought straight to the surface. NEVER give the patient compressed air.

When the diver is out of the water, he is then given oxygen to breathe. Alternating oxygen on for an hour, oxygen off for an hour for twelve hours.

I have used the Edmonds table in a single man chamber. It seemed better at the time to compress the patient on oxygen in a small single man chamber than to lower him into the sea as dusk approached as we would have had to go some way out from the island of Moen to get the 9 m of water we needed. It was a wrong decision for the bus ride over a very pot-holed road converted him from being a person with mild neurological decompression sickness, stocking anaesthesia of both feet, into a paraplegic with the left arm also paralysed, who was having difficulty with his breathing. However, within half an hour at thirty feet with oxygen, he was able to move all three paralysed limbs. He was then taken to 60 feet but had little further improvement. Nitrogen loads in the body take a long time to decay. This man had last dived more than 48 hours before he appeared, mildly drunk, at the hotel that we were staying in. Travelling for 15 minutes over a very pot-holed road converted him from a mild case to a very severe case of decompression sickness so that there must have been a lot of gas available to form enlarged bubbles, even forty eight hours after diving.

Any procedure that gets this extra gas out of the body is to be recommended, and if somebody develops decompression sickness they should be given first aid consisting of oxygen to breathe and fluid to drink, because all divers are slightly dehydrated by the end of a dive, and two aspirin to inhibit platelet aggregation. As soon as this has been done, the buddy races to the telephone and gets advice as to what should be done next. Which in most cases on the Australian mainland, is to transport them immediately, at low level, to the nearest chamber.

However, if you are on the island of Truk in the middle of Micronesia, there is no quick arrival at the nearest chamber in Guam. It would be a very expensive trip indeed to charter a Lear jet, if there is one at Guam, to fly over to Truk and then pick up the patient and fly him back to the US Navy Hospital at Guam. Far better to arrange for an in-water recompression, in warm water with good visibility and watch the symptoms disappear.

TRANSPORTATION OF PATIENTS SUFFERING FROM DECOMPRESSION SICKNESS

Chris Acott

I am keenly interested in the transportation and retrieval of patients. I will discuss general aspects of patient transport with special reference to the transportation of patients with decompression sickness (DCS).

One would always like to know the overall general medical condition of the patient, however this is often hard to obtain. Is the patient deteriorating? Will he need specialized help before transport? Will transport at this stage adversely effect the patient?

DCS patients are usually stable, and need to be transported to the nearest recompression chamber as soon as possible. However the patient may be unconscious, fitting, or in respiratory difficulties, or have a spinal cord lesion that is progressing rapidly.