In-Water Oxygen Recompression: A Potential Field Treatment Option For Technical Divers

by Dr. Carl Edmonds

The failure of decompression illness to respond to recompression chamber therapy is often related directly to the delay in treatment (see *"Get Me To The Chamber On Time,"* staff*. aquaCorps Journal* N1, 1990). Sometimes chambers are simply not readily available. For these reasons, immediate in-water air recompression has been used in Hawaii, with good results, and also among the professional shell divers of Australia, at least until the underwater oxygen became available. Interesting enough, most diving medical text books do not even mention in-water therapy as an option.

When using in-water air recompression therapy, pressure is exerted by water instead of in a recompression chamber, while air is usually supplied from compressors sited on the diving boat. Although this treatment is frequently ridiculed by those in the cloistered academic environments, especially those committed to elaborate recompression facilities, it has frequently been the only therapy available to severely injured divers, has had many successes, and is recognised by many experienced and practical divers to often be of life saving value. This has certainly been the case in remote localities such as the pearl fishing areas of Northern Australia, where divers spend long times underwater using standard diving equipment**.** In-water air treatment continued to be used, in the absence of available recompression chambers.

Despite the value of in-water air recompression therapy, there are many problems associated with it that are well recognised by both divers and medical advisers. First, the majority of amateurs or semi-professional divers do not carry the compressed air supplies or compressor facilities necessary for the extra decompression. Most have only scuba cylinders, or simple portable compressors that will not reliably supply divers (the patient and his attendant) for the depths and durations required.

What's more is that environmental conditions are often not conducive to in-water air treatment. The depths required for these treatments (often as deep as 50 msw/165 fsw) can usually only be achieved by returning to the open ocean, where the advent of night, inclement weather, rising seas, tiredness and exhaustion, and boat safety requirements, make the choice of in-water treatment a very serious decision. In addition, because of the considerable depths and time involved, hypothermia as a result of wet suit compression becomes likely. Seasickness in the injured diver and the diving attendants and the boat tenders, is also a significant problem. Nitrogen narcosis produces added difficulties in the diver and the treatment. Because of these difficult circumstances, treatment must often be aborted, resulting in DCI in the attendants, and aggravating it in the diver.

In-water air treatment of DCI is not to be undertaken lightly, however, in the absence of a recompression chamber or other options, it may be the only treatment available to prevent death or severe disability. Fortunately, a newer methods has been developed that address many of the problems associated with air treatments.

Oxygen Therapy

The value of substituting oxygen for air, in recompression chamber treatment has been well established. The pioneering work of Yarborough and Behnke (1939) eventuated in the oxygen tables described by Goodman and Workman (1965). They received widespread acceptance, with revisions and modifications they are now incorporated in oxygen treatment tables of most Navies.

The advantages of oxygen over air tables include; increasing nitrogen elimination gradients, avoiding extra nitrogen loads, increasing oxygenation to tissues, decreasing the depths required the exposure time and improving the overall therapeutic efficiency. The same arguments are applicable when one compares in-water air and oxygen treatment.

Australian in-water oxygen therapy

In response to an urgent need for managing cases in remote locations, both time and distance from hyperbaric facilities, oxygen therapy was first applied to the in-water treatment decompressions illness in Australia, in 1970. Because of the success of this treatment and its ready availability, it became known and practised, even when experts were not available to supervise it.

The physiological principles on which this treatment is based are well known and not contentious, although the indications for treatment have caused some confusion. Like conventional oxygen therapy tables, it was first applied mainly for the minor cases of DCS, but was subsequently found of considerable value in serious cases.

The techniques and equipment for Australian in-water oxygen therapy were designed to increase safety, ease and ready availability, even in medically unsophisticated countries (see box). It is now in widespread use in the Pacific Islands and the northern parts of Australia. It spread to the colder southern waters of Australia, where it is now used by abalone divers who sometimes dive in areas difficult to service by conventional transport. It has also been included in certain diving manuals (Table 81 & 82 in the Royal Australian Navy Diving Manual and has been modified by allowing the use of oxygen rebreathing equipment, in the current US Navy Diving Manual. The French have had a very similar table (Comex12) which was immediately applicable to underwater use, and some Italian groups claimed to have employed the full US Navy oxygen therapy tables underwater - although how they managed this is not clear.

The original Australian in-water oxygen procedures and tables seem simpler and less likely to cause problems for the general diver population than these various alternatives, however, other procedures have evolved. Hawaiian commercial divers have included a **deep "air" spike** prior to the underwater oxygen treatment, in an attempt to either force bubbles back into solution or to allow bubbles trapped in arteries to transfer to the venous system. The relative value of this additional deep air dip is subject to some controversy and discussion, and its value remains to be clarified (*Note that the deep "air " spike to 50 msw/165 fsw used in the USN 6a recompression table appears to be increasingly falling "out of favor" in U.S. treatment circles due to problems of additional nitrogen loading and other* *complications. Many leading edge facilities are now using enriched air nitrox, and or heliox, in place of air for these treatments & endash; ed.)*

In-water Oxygen Treatment Procedures

Oxygen should be supplied at maximum depth of 9 msw (30 fsw), from a surface supply system. The ascent is commenced after 30 minutes in mild cases, or 60 minutes in severe cases, if significant improvement has occurred. These times may be extended for another 30 minutes, if there has been no improvement. The ascent is at the rate of 12 minutes per metre (4 minutes/foot). ***A diver attendant should always be present, and the ascent controlled by the surface tenders.*** The duration of the tables range from 2 hours 36 minutes or 3 hours 6 minutes depending on the treatment options used.

After surfacing the patient should be given periods of oxygen breathing, interspersed with air breathing, usually on a one hour on, one hour off, basis, with respiratory volume measurements and chest X-ray examination if possible. The treatment can be repeated twice daily, if needed.

The equipment required for this treatment is similar to that used in an surface supplied oxygen decompression system with some important differences. In the case of an in-water treatment, a G size cylinder (220 cubic feet or 7000 litres) of medical oxygen is probably adequate though specific requirements can easily be calculated. This is usually available form local gas supply companies or hospitals, although in some cases industrial oxygen has been used. ***For a diver at rest, breathing this volume of oxygen at a depth varying between 9 meters (30 feet) and the surface is usually insufficient to produce either neurological (CNS) or respiratory oxygen toxicity*** *(see "In Case Of Convulsion" below).* Note that all equipment used with pure oxygen must be rated for oxygen service. Also, whenever oxygen is given, the cylinder should be turned on slowly and the flow commenced, before it is given to patients or divers.

A 2-stage regulator, set at 550 kPa (80 psi) is fitted with a safety valve, and connects with 12 metres (40 feet) of supply hose. This allows for 9 metres depth, 2 metres from the surface of the water to the cylinder, and 1 metre around the diver. A non-return valve is attached between the supply line and the full face mask. ***The full face mask is critical as it enables the system to be used with a semi-conscious or unwell patient. It reduces the risk of aspiration of sea water, allows the patient to speak to his attendants, and also permits vomiting to occur without obstructing the respiratory gas supply.***

The supply line is marked in distances of 1 metre from the surface to the diver, and is tucked under the weight belt, between the diver's legs, or is attached to a harness. The diver must be weighted to prevent drifting upwards in an arc by the current.

A Field Treatment Option For Technical Divers

It was originally hoped that the underwater oxygen treatment would be sufficient for the management of minor cases of DCI, and to prevent deterioration of the more severe cases while suitable transport was being arranged. When the regime is applied early, even in the severe cases the transport is often not required. It is a common observation that improvement continues throughout the ascent, at 12 minutes per metre. Presumably the resolution of the bubble is more rapid at this ascent rate than its expansion, due to Boyle's Law.

Certain other advantages are obvious. During the hours of continuous hyperbaric oxygenation, tissues become effectively de-nitrogenated. Bubbles are initially reduced in volume, due to the hyperbaric exposure and Boyle's Law, and the resolution is speeded up by increasing the nitrogen gradient form the bubble. Attendant divers are not subjected to the risk of DCI or nitrogen narcosis, and ***the affected diver is not going to be made worse by premature termination of the treatment if this is required*** *(for example, in order to transport the diver & endash; ed.).* In addition, hypothermia is much less likely to develop, because of the greater efficiency of the wet suits at these minor depths (*Note that the majority of technical divers utilise dry suits even in relatively warm water, so hypothermia is unlikely to be a major issue in most cases. See discussion below & endash; ed.).*

The site chosen can often be in a shallow protected area, reducing the influence of weather on the patient, the diving attendants and the boat tenders. Communications between the diver and the attendants are not difficult, and the situation is not as stressful as the deeper, longer, in-water air treatments, or even as worrying as in some recompression chambers.

When hyperbaric chambers are used in remote localities, often with inadequate equipment and insufficiently trained personnel, there is an appreciable danger form both fire and explosion. There is the added difficulty in dealing with inexperienced medical personnel not ensuring an adequate face seal for the mask. These problems are not encountered in-water treatment.

In spite of these advantages, in-water oxygen recompression is not applicable to all cases, especially when the patient is unable or unwilling to return to the underwater environment. It is also of very little value in the cases where gross decompression staging has been omitted, or where the disseminated intravascular coagulation syndrome has developed. The author would be reluctant to administer this regime where the patient has either epileptic convulsions or clouding of consciousness. Reference to the case reports reveals that others are less conservative.

One of the common myths in Australia, is that in-water treatment is applicable to the semi-tropical and tropical areas, where it was first used, but not to the southern parts of the continent, where water temperatures may be as low as 5° C (41° F). There are certain inconsistencies with this statement. First, if the diver developed DCI while diving in these waters, then she is most likely to already have an effective thermal protection suit available. Also, the duration underwater for the oxygen treatment is not excessive, and is conducted at a depth at which even wet suits provide effective insulation. If the diver is wearing a dry suit, the argument is even less applicable. The most effective argument is that in-water oxygen recompression is used, often very successfully, in these very areas.

Some claim that the in-water oxygen treatment is useful only when there are no transport facilities available. Initially this was also our own teaching, but with the logic that comes with hindsight, ***a three hour gap is all that is needed between the instituting of in-water oxygen therapy and the arrival of transport, to be able to effectively employ this procedure.*** It is probably just as important to treat the serious cases early, even though full recovery is unlikely, than to do nothing and watch the symptoms progress during those hours. Note that transport should be sought while the in-water treatment is being utilised, especially in serious cases.

There has also been a concern that if this technique is available for treatment of DCI, other divers may misuse it to decompress on oxygen underwater and perhaps run into subsequent problems This is more an argument in favour of educating divers, than depriving them of potentially valuable treatment facilities. *(Note that in-water oxygen decompression has become a "community standard" among technical divers in the U.S. and other parts of the world, though it is not an accepted procedure for recreational divers who are not trained in decompression diving & endash; ed.).* With the same rationale, one could use this argument to totally prohibit all safety equipment, including recompression chamber, and thereby hope to circumvent all diving related problems.

It has also been argued that this treatment is unlikely to be of any value for those patients suffering from air embolism. Such may well be the case. The treatment was never proposed for this, and nor was it ever suggested that the in-water oxygen treatment should be used in preference to recompression facilities where they exist and are easily accessible to the diver. It is, however, possible that the treatment may be of value for cases of mediastinal emphysema, and perhaps even a small pneumothorax.

In conclusion, in-water oxygen recompression is an application and modification of current treatment regimes. It is not meant to replace the formal treatment techniques of recompression therapy in chambers. It is an emergency procedure, able to be applied with equipment usually found in remote localities and is designed to reduce the many hazards associated with the conventional in-water air treatments. The customary supportive and pharmacological adjuncts to the treatment of recompression sickness are in no way avoided, and the superiority of experienced personnel and comprehensive hyperbaric facilities is not being challenged. In-water oxygen treatment is considered as a first aid regime, not superior to portable recompression chambers, but sometimes surprisingly effective and rarely, if ever, detrimental.

Dr. Carl Edmonds is regarded as the leading authority on in-water treatment of decompression illness, and has made major contributions to diving medicine in a variety of capacities including;

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Australian In-water Oxygen Table

This technique may be useful in treating cases of decompression illness in localities remote from recompression facilities. It may also be of use while suitable transport to such a centre is being arranged.

In planning, it should be realised that the therapy may take up to 3 hours. The risks of cold, immersion and other environmental factors should be balanced against the beneficial effects. The diver must be accompanied by an attendant.

Equipment

The following equipment is essential before attempting this form of treatment:

1. Full face mask with demand valve and surface supply system or helmet with free flow.
2. Adequate supply of 100% oxygen for patient, and air for attendant, typically about **200** cf per treatment.
3. Shot with at least 10 metres of rope (a seat or harness may be rigged to the shot).
4. Some form of communication system between patient, attendant and surface, preferably voice communications.

Method

1. The patient is lowered on the shot rope to 9 metres (30 fsw), breathing 100% oxygen.
2. Ascent is commenced after 30 minutes in mild cases, or 60 minutes in sever cases, if improvement has occurred. These times may be extended to 60 minutes and 90 minutes respectively if there is no improvement.
3. Ascent is at the rate of 1 metre every 12 minutes. Staging may be applied where applicable.
4. If symptoms recur remain at depth a further 30 minutes before continuing ascent.
5. If oxygen supply is exhausted, return to the surface, rather than breathe air.
6. After surfacing the patient should be given one hour on oxygen, one hour off, for a further 12 hours.

Table Aust 9 (RAN82), short oxygen table

<u>Depth Elapsed time Rate of ascent</u>
(metres) Mild Serious

9 0030-0100 0100-0130
8 0042-0112 0112-0142
7 0054-0124 0124-0154
6 0106-0136 0136-0206 12 minutes
5 0118-0148 0148-0218 per metre
4 0130-0200 0200-0230 (4 min/foot)
3 0142-0212 0212-0242
2 0154-0224 0224-0254
1 0206-0236 0236-0306

Total table time: 2 hours 6 min - 2 hours 36 minutes for mild cases
2 hours 36 min - 3 hours 6 minutes for serious
cases