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RECOMPRESSION TREATMENT SHOULD ONLY BE ADMINISTERED IN A HOSPITAL-BASED FACILITY

Richard E Moon

Key Words
Decompression illness, hyperbaric facilities, hyperbaric oxygen, treatment

Introduction

The five components of appropriate treatment of a diving casualty with decompression illness (DCI) are:

1 Availability of a skilled practitioner to assess the patient and make the diagnosis;
2 ability to administer initial therapy such as maintaining an airway with adequate ventilation and fluid resuscitation;
3 a treatment chamber in which 100% oxygen can be administered at increased ambient pressure;
4 appropriate procedures (i.e. treatment tables);
5 ability to assess and monitor the patient during treatment.

If all five components are available at the site of the diving accident then, since delay in treatment may involve clinical deterioration, immediate treatment is preferred. The present discussion, however, is in the context of hospital-based treatment where all components are available compared with on-site treatment, in which one or more components are not available.

Assessment requires ideally a physician but at least a person who has had specific training in assessment, treatment and monitoring of diving casualties. In addition to the trained individual, equipment is necessary. A stethoscope, sphygmomanometer, percussion hammer, otoscope, urinary catheter, equipment for administering intravenous fluids and for performing a tube thoracostomy. Ideally one would want a portable X-ray unit.

Therapeutic procedures include treatment tables that have been proven effective in the treatment of decompression illness. The US Navy tables 5 and 6, and their equivalents, have a long track record of efficacy. While shorter treatment tables designed for use in monoplace hyperbaric chambers have efficacy in treating mild or moderate bends, the available data suggest they are less effective in treating severe bends.[1]

Monitoring includes verbal assessment and objective measurement of the progress of treatment. In addition, blood pressure, heart rate and respirations must also be measured particularly in the critically ill individual:

easy in the dry but almost impossible in a one-man chamber or in the water. A patient placed in a single patient chamber would ideally also have the mask seal checked periodically to ensure that the appropriate oxygen concentration is being administered; a semi-conscious or uncooperative patient is unlikely to maintain a proper seal. Urine output is a convenient clinical assessment tool for adequacy of fluid resuscitation, but difficult to assess inside a single man chamber or in-water.

Complications that can occur during treatment include loss of airway, hyperoxic convulsions, pneumothorax, and claustrophobia. A therapeutic plan should include the means to deal with these under adverse conditions, which may be difficult to accomplish during an on-site treatment.

Ways in which the principle of *primum non nocere* can be violated

One way to address this issue is to consider specific scenarios, such as patients with the following manifestations:

Scenario A.
Joint pain and paraesthesias.

Scenario B.
Malaise, monoparesis, unilateral hearing loss and vertigo.

Scenario C.
Paraplegia

Scenario D.
Seizures, unconsciousness.

Scenario E.
Joint pain, funny voice, crackly skin.

These five scenarios represent a range of severity and some diagnostic dilemmas, as follows:

Scenario A.
Does the diver have bends or musculoskeletal injury and anxiety induced hyperventilation?

Scenario B.
Does the diver have inner ear decompression sickness (DCS) or labyrinthine window rupture?

Scenario C.
Does the diver have spinal cord bends or extrinsic cord compression?

Scenario D.
Does the diver have arterial gas embolism or hypoxic encephalopathy due to near-drowning?

Scenario E.
Does the diver, who has symptoms of pneumomediastinum, have a pneumothorax?

In this group of scenarios there is also a range of risks and practical difficulties in placing a patient inside a portable monoplace recompression chamber or administering in-water recompression.

What is the risk of delaying recompression until the patient can be assessed and placed in a hospital-based chamber? The only real down side is the delay. Data obtained from 3,899 decompression accidents reported to the Divers Alert Network from 1989-96 (Figure 1) shows that, while it is clear that delay results in a lower probability of 100% relief, significant improvement may be achieved after several hours or even a day.[2] Severe neurological symptoms include convulsions or abnormalities of vision, gait, urinary/anal sphincter function, motor strength or consciousness.

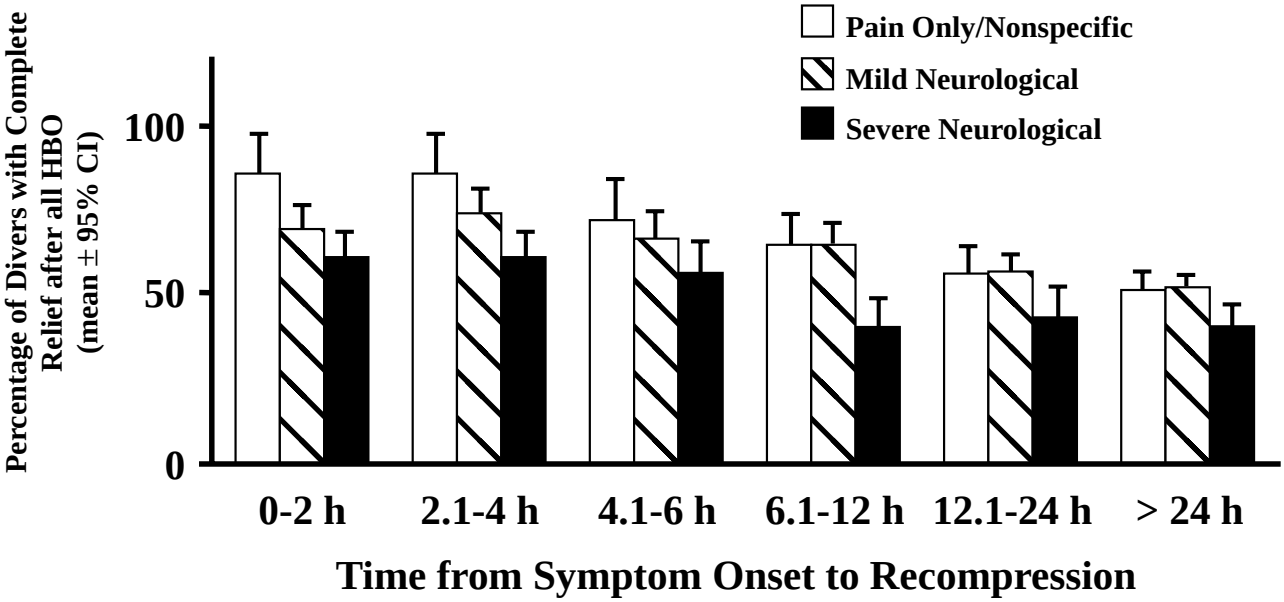

Figure 1. The effect of delay to HBO_2 on results of hyperbaric treatment. Severe neurological symptoms include convulsions or abnormalities of vision, gait, urinary/anal sphincter function, motor strength or consciousness. From Moon et al.[2] with permission.

Considering each scenario individually:

Scenario A.

This patient probably has decompression illness (DCI) and, even if the diagnosis is wrong, the risk of recompression treatment on site would be low. On the other hand, the risk of serious deterioration during transport to a hospital-based chamber is also very low.

Scenario B.

Decompression illness is highly likely here, although without direct inspection middle ear barotrauma cannot be excluded. Furthermore, recompression of a diver with inner barotrauma could be detrimental, as labyrinthine window tear could be worsened if there is difficulty with middle ear pressure equalisation. Even under ideal circumstances, differentiating between inner ear DCI and inner ear barotrauma can be difficult. While the risk/benefit of immediate recompression in this setting is at least debatable, the potential for exacerbating what could produce a permanent disability (hearing loss) must be considered. Anyone other than a trained diving doctor is unlikely to be qualified to make a reasoned decision.

Scenario C .

An acutely paraplegic patient is almost certain to be fluid-depleted and, in addition, to be hypotensive due to the loss of sympathetic tone in the lower extremities. Of the five scenarios this patient is probably the one who deserves the most rapid compression. However, it is arguable that aggressive fluid resuscitation to maintain blood pressure and administration of surface oxygen with delayed recompression might be as effective as immediate recompression without the ability to fluid resuscitate, assess and monitor vital signs.

Scenario D.

A patient with seizures and unconsciousness is likely to require sophisticated airway management, and is unlikely to do well in a portable recompression chamber or during in-water recompression. For this patient delayed treatment in a hospital is inevitable.

Scenario E

It is unlikely that many diving doctors would recommend that a patient experiencing mild bends symptoms, but with obvious clinical evidence of pulmonary barotrauma, should be treated in the water or in a single man chamber, particularly when the means to assess and treat pneumothorax are not available.

In this range of clinical scenarios it can be seen that on-site treatment of individuals with severe decompression illness (those most likely to benefit from early recompression) is accompanied by practical difficulties and real risks. On the other hand, whenever the risk of on-site treatment is low, so is the benefit.

Summary

In an ideal world all divers with decompression illness would receive immediate expert assessment and recompression treatment with or without the necessary adjunctive therapy to maintain blood pressure and ensure appropriate pulmonary gas exchange. However, in recreational diving the ability to administer such prompt and sophisticated therapy rarely exists. While in-water recompression procedures have been available for several years,[3] special equipment is required and there are definite risks associated with its use. Safer alternatives, such as portable recompression chambers, are available. However, the other components that are usually necessary to achieve the desired therapeutic outcome are missing. Specifically, trained individuals, suitable procedures, the ability to monitor the patient appropriately and to administer adjunctive therapy such as airway control and intravenous fluids cannot be applied in these monoplace chambers. Given that excellent results can often be obtained even after many hours' delay, the evidence thus far supports the contention that recompression should only be administered in a hospital-based facility.

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AUDIENCE PARTICIPATION

John Knight

In-water recompression has its place. The person with the crackly voice and the limb pain, will probably get completely better with surface oxygen, 100% oxygen, over the next 3-4 hours. The person with the paraplegia is the one I would put in the water, because he is the one who has the most to gain. If one can get him 3 hours of in-water oxygen and he has his power back, one will save him being a late case with a poor prognosis when he gets to the hospital. Even if he develops an oxygen convulsion he will not come to harm with a full face mask, and the treatment laid down for oxygen convulsions is to pull them up. There is no harm. The main advantage of the in-water oxygen table is it removes a lot of nitrogen as well as providing some pressure to compress bubbles.

The point about in-water oxygen treatment is that it is for places hours from evacuation. In some places it takes 12 hours to fly in and then a 12 hour flight out, plus the time bureaucrats spend messing about organising the flight. Put a paraplegic in the water on oxygen and if he gets movement back in his legs, even if he hasn't got his full power, he is a lot better off than a paraplegic who has not had any movement in his legs for 24 hours before he is flown away to a chamber. In-water oxygen was originally designed for remote areas, with the assumption that ordinary divers would be able to diagnose DCI which needed prompt treatment.

I fully appreciate people's worries about the oxygen toxicity, but a lot of people spent a lot of time trying to find cases where Carl Edmonds' oxygen treatment had caused problems. There has been only one reported case, from Townsville. The person who reported it said he was quite sure it was oxygen toxicity while Carl is quite sure it was salt water aspiration. For about 5 years, the hyperbaric world was looking for cases that had gone wrong and they never found any. Eventually the US Navy was convinced that it was a reasonable thing to do.

I think it would be stupid to do in-water recompression if one can get a patient to a chamber in an hour or four, but if I have to wait 8 hours before I can get a plane to take me to a chamber to get my paraplegia treated, I would be out there with the oxygen, even sitting in the bight of a rope which gets very painful, hoping that the bubbles would be shrunk enough, and enough nitrogen taken out of me, that I will be better when I come to the surface.

Richard Moon

I think that is an arguable point but let me suggest that fluid resuscitation, monitoring and maintenance of blood pressure are as important in treating severe spinal cord injury as immediate recompression. There are few cases of severe neurological bends in which there is no clinical response to recompression, even after a delay.

John Knight

Intelligent divers can make reasonable conclusions from injured divers. With training they can deal with a patient who has a swollen bladder who needs catheterising as the Broome pearl divers did 100 years ago. Part of a diver's kit was his catheter for when he would be paralysed. A lot of diving is done without doctors within cooee, or even much further away. I think that hospital treatment advocates want a perfect world, where medical attention is easy to get and divers report their illnesses early.

But on an outer island off the coast of Australia, there may be 7 or 8 hours to get to port, and a diver is getting worse before ones eyes. What should a diver, not a doctor, do. Divers know that the common cause of paralysis after a dive is decompression sickness. They have got oxygen on board, they have got the full face mask. Would it be a better chance for his future to cure him quickly? We know that if a commercial diver comes up with anything wrong, he is put in a chamber immediately and made better.

Richard Moon

I am not arguing that there should be no treatment before the hospital; I am only arguing the point that it should not necessarily be recompression treatment.

Unidentified speaker

Firstly for John Knight. You have just told us that in water recompression is very safe, that there has only ever been one adverse case reported, and that SPUMS has brought a full face mask and kit. Why is it not here?

Secondly for Richard Moon. Your scenarios have suggested two question marks. Can I put it to you there are two groups of patients, one who would benefit from in-water treatment, and another you, and I agree, definitely would not put back in the water.

John Knight

SPUMS purchased the in-water oxygen equipment in 1977. We took that kit with us to every meeting until Chris Acott became President in 1985. Because Chris Acott is a firm believer that a doctor must run all treatment and only in a chamber we gave up the in-water oxygen equipment.

I do not think SPUMS should be carrying in-water equipment now. At the time, 1977-1984, it seemed a good idea to be able to treat people if anyone developed DCI. We were happy they never did. It was an easy insurance policy with a middle sized bag of equipment and a big cylinder of oxygen.

Richard Moon

I have no experience whatsoever with in-water recompression, but the published data are all self-reported by local fisherman, with no recorded corroborative observations by medically trained individuals. It could be argued that anecdotal reporters are more likely to recount successful cases than unsuccessful ones. A few years ago I asked Carl Edmonds whether there were any cases of in-water recompression in pearl divers (in whom the largest series of in-water recompressions has been collected) that had been documented by a physician. He said he was not aware of any. It may well be that in-water recompression is a good idea, but there are few data on its effectiveness or safety.

Alf Brubakk

I would like to make several points. Even if it is self reported, the majority of cases of in-water recompression have actually been treated with air. It is not just that oxygen is probably more efficient, but it also seems that air is also quite efficient if used with early treatment. I fully agree that, if a hospital is close by, it makes absolutely no sense to

do in-water or on site recompression. You may not be aware that we have evacuated one of our participants from this island, half an hour ago, because of decompression sickness. We treated with fluids and oxygen, the patient has been taken away, and is probably already now in a chamber. Even if we had the in-water recompression kit here, I do not think that anybody would suggest that we should put the patient back in the water. It is clear that in situ treatment is something that one does in a remote location.

There are very good examples from other areas, like in climbing, where some teams now are going very high. Some take some method of over-pressure to deal with mountain sickness. There is no doubt that the ideal treatment is to take the patient down and to fly them out to proper treatment at lower levels in a hospital facility. But the problem is what to do if one is far away? Is it reasonable to believe that results will be as good from treating someone with fluids and oxygen and waiting for 8 or 9 hours, as recompressing the sufferer immediately? We know that even recompression with air, if there is no oxygen at all, is better.

There is no real argument that a hospital is the best place to be with a serious diving accident. On the other hand, if there is no hospital, and no doctors, does that mean one should only use oxygen and fluids on the surface, if you has a compression system available.

Mike Bennett

I think Richard Moon has successfully deflected the focus of the meeting onto in-water recompression, which is indefensible. That is making the case look very good. I would like to ask your comments to the proposition of a functional chamber, outside a hospital. This is an option in New South Wales. There are chambers that we know of where people who are bent could be treated quickly. But chambers are not run by people with medical skills.

Richard Moon

I would support the use of on-site chambers for recompression of selected cases of decompression illness. In the absence of haemodynamic instability and claustrophobia and, this is most important, if there is somebody on site who knows what they are doing, at least a subset of bends could be treated. The first scenario in my presentation I think would fit into that category. But, if the complexity of treatment is even slightly greater, with the necessity of monitoring blood pressure, administering fluids and measuring urine output, I think it is extremely difficult, and perhaps impractical, to treat outside a hospital. I could modify my statement to accept that a subset of bends could be treated with immediate recompression provided a two man chamber is available and a physician who is qualified in diagnosis is on site as well.

Robyn Walker

The Royal Australian Navy sends a portable two-man chamber with all diving teams. I have certainly supervised treatments remotely. The divers have treated in a small chamber. The difficulty is it does not have monitoring capabilities, nor ventilator capabilities. Basically our guidelines are that if there is anyone who is haemodynamically unstable, or an unprotected airway, or altered consciousness, they are not to be put into the chamber until it has been discussed with a diving doctor. For all other accidents, such as a spinal hit with no altered conscious, the diver is treated immediately. They have done very well indeed.

Oxygen fits are unpleasant but safe with the proper equipment. The RAN has divers who dive on oxygen, and a number of them fit from oxygen convulsions in the water every year. The divers call it the “chicken dance”. The divers have a buddy beside them, they have a line, and people survive oxygen convulsions in the water. There is no reason, if one is going to use in-water oxygen recompression, why divers should not survive a fit. One certainly needs to know what to do. Using in-water oxygen treatment at 5 m instead of 9 m, would certainly reduce the risk of oxygen convulsion.

Richard Moon

That is true, but it is likely that the efficacy of treatment would also be reduced at 5 m. Before recommending it, data should be collected on the efficacy of such treatment.

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ON-SITE RECOMPRESSION TREATMENT IS ACCEPTABLE FOR DCI

Alf Brubakk

Key Words

Accidents, decompression illness, treatment.

Introduction

"I think it has been clearly established, that treatment in a recompression chamber by people who are trained and competent probably constitutes the best scenario. On the other hand, if that treatment can't be carried out for six or seven hours because of the location of the dive or for any other reasons mentioned today, then transport may not be the best decision for that diver." Overlock 1999.[1]

There is general agreement that treatment of DCI using the USN 6 with oxygen at 18 m is the standard treatment.[2] However, in most parts of the world, the diver is far away from any proper treatment facility for DCI. Pressure chambers are only available on site in commercial operations in parts of the industrial world. Furthermore, many of these chambers are operated by individuals with only limited experience and certainly little medical know-how. Thus, proper treatment and diagnosis is only available to divers after lengthy and often difficult transport. Due to the fact that it is accepted that the time to treatment is important, transport is often performed under dangerous conditions. All the above would indicate that it is well worth exploring if there are other possibilities.

For many years there was a discussion about the advisability of training the average citizen in cardio-pulmonary resuscitation (CPR). The discussion was mostly centred around the problems and the risks to the patient, ignoring the fact that there were few alternative to prevent death of the patient. It is recognised today that even if the treatment performed by a layman is not optimal, it can be of benefit to the patient. This analogy is not perfect in so far as we are in many cases not dealing with a life threatening condition, but still one which may lead to serious morbidity.

Why on-site recompression treatment?

It is accepted that pressure and oxygen are the main ingredients of DCI treatment. Oxygen at the surface is now widely used as a primary treatment for DCI symptoms and data indicate that the use of oxygen will reduce symptoms before definite treatment can be instituted.[3] However, for definite treatment, pressure is also needed, in particular in severe cases. The main point about on-site recompression is to reduce the time between injury and treatment.

What is the result of traditional treatment ?

In a report from the treatment chamber in Barcelona, the majority of the patients arrived after 1-6 hours, but many with a considerable longer delay.[4] Most of the diving was done within one hour's flight of the chamber and many sites were much closer. Even so, the usual time to treatment was quite long. Their results showed that about 30% had mild sequelae and 4-5% had serious sequelae or handicap after the treatment. The results are similar to those seen in many centres, approximately 70% of those who get treated after a 6 hour delay get better or are healed.[5,6] The results can be seen in Figure 1.

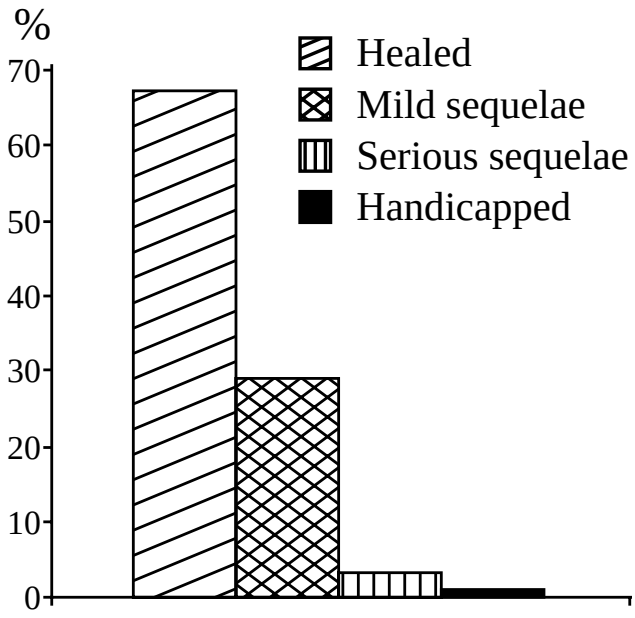

Figure 1. The outcome of treatment in a major treatment centre (Barcelona).[4]