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SRI LANKA NAVY

Guide to Management of Decompression Sickness (DCS) "Bends"

A collaborative publication of the
Sri Lanka Medical Association
and the
Directorate of Health Services – Sri Lanka Navy

2023





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Guide to the Management
of
Decompression Sickness (DCS)

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The Sri Lanka Navy
2nd Edition – 2023

These guidelines (1st edition released in 2013) are the result of a long-term collaboration between divers with experience in caring for DCS victims, doctors, and diving officers of the Sri Lanka Navy with experience in administering Hyperbaric Oxygen (HBO) treatment to such victims, a doctor who is a trained SCUBA diver with knowledge of the subject and a neurophysician with experience in treating victims.

This 2nd Edition of 2023 was revised by doctors of the Sri Lanka Navy, and of the Sri Lanka Medical Association.

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Guide to Management of Decompression Sickness (DCS)

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Decompression sickness (DCS), commonly called ‘bends’, is a condition seen in those who have breathed compressed air, such as SCUBA divers, for a prolonged period under high pressure and who have rapidly ascended to atmospheric pressure too quickly. This happens when they do not follow recommended diving protocols and come up to the surface atmospheric pressure too quickly after a prolonged period at a great depth in water. The result is that there is no time for inert gases dissolved in the blood and tissues to be eliminated, leading to bubbles of nitrogen being formed in the blood and tissues due to the rapid reduction of ambient pressure. DCS is uncommon at depths less than 10 metres and is usually seen following dives in excess of 30 metres (100 feet). These patients should be treated in a specialist unit by doctors trained in diving medicine and they are the best judges of the management of diving-related injury. The only unit equipped and staffed to handle such casualties is that of the Sri Lanka Navy at the Naval Hospital in Trincomalee.

It is important to understand, recognize, prevent, and treat DCS, **AS AN ACUTE MEDICAL EMERGENCY**. The presentation of dysbaric¹ diving injuries varies, as lesions may occur in any part of the body involving many systems.

¹Dysbaric injuries are those caused by changes in pressure, such as aural barotrauma, pulmonary barotrauma, decompression sickness (DCS) and cerebral arterial gas embolism (CAGE). The latter two entities are usually referred to as decompression illness (DCI).

The term DCS-I refers to a mild illness with a broad spectrum of signs and symptoms that may occur following diving, when on return to the surface, features such as pruritus, urticarial rash, cutaneous swelling (due to lymphatic obstruction), joint pains and fatigue occur. The severe form, which is known as DCS-II, presents mainly with neurological symptoms such as numbness, loss of motor power, difficulty in walking, paralysis, weakness of the body, backache, urinary retention, impaired balance, vertigo, vomiting, nystagmus, convulsions, and acute respiratory embarrassment. The onset of symptoms can be immediate, on surfacing after a dive; or be delayed up to 48 hours. If not treated immediately the signs and symptoms can evolve over a period of time. DCS is the commonest diving injury that presents as one that requires specialised treatment.

These guidelines have been prepared for doctors who may have to attend on someone with a diving injury such as DCS. It describes the steps that should be taken to prevent deterioration of the clinical state of the patient while awaiting definitive treatment at the Sri Lanka Navy Hospital at Trincomalee. The diagnosis of decompression sickness is summarised in the next pages.

The only definitive treatment of DCS is hyperbaric oxygen (HBO) treatment (also called recompression therapy). This involves placing the patient in a pressurised chamber where he/she breathes pure hyperbaric oxygen (i.e. O₂ at a pressure in excess of 1 atmosphere). The increased ambient pressure has the effect of dissolving the nitrogen (N₂) in plasma and reducing the size of the N₂ bubble which is then carried back to the pulmonary circulation for elimination. Breathing pure oxygen has the effect of replacing the N₂ in the bubble with oxygen and flushing nitrogen out of the alveoli, thereby increasing the concentration gradient of N₂ across the alveolar membrane, hastening its elimination. Another advantage is that it corrects tissue hypoxia caused by bubble-induced ischaemia, mechanical injury, or biochemical damage. The therapeutic pressures employed, the length of time at those pressures and the rate of return

to atmospheric pressure depend on the symptoms and would be in accordance with published tables.

Diagnosis of Decompression Sickness (DCS)

1. Onset of symptoms within 48 hours of surfacing after a SCUBA diving session that would have consisted of a number of dives to depths of around 10 metres (30 feet) or deeper.
2. Type I DCS: is characterized by joint pains and cutaneous rash*. The symptoms are mild, consisting only of pruritus, urticarial rash, cutaneous swellings (lymphatic obstruction), joint pains and fatigue.
3. Type II DCS: The severe form, presents with symptoms that are largely neurological and include the following: girdle pain, backache, paraesthesia, loss of motor power, urinary retention, impaired balance, vertigo, nystagmus, vomiting and acute respiratory embarrassment.

There are three common categories of Type II DCS recognised: neurological, inner ear and cardiopulmonary*.

- a. **Neurological symptoms** may include numbness; paraesthesia, or an altered sensation, such as tingling; muscle weakness; an impaired gait, or difficulty walking; problems with physical coordination or bladder control; paralysis; or a change in mental status, such as confusion or lack of alertness.
- b. **Inner-ear symptoms** may include ringing in the ears, (tinnitus); hearing loss; vertigo or dizziness; nausea; vomiting; and impaired balance.
- c. **Cardiopulmonary symptoms**, known commonly as “the chokes,” include a dry cough; retro-sternal chest pain; and breathing difficulty.

* US Navy Diving Manual, Revision 7

INITIAL ASSESSMENT AND ACTION ON ADMISSION TO HOSPITAL

1. If Type I DCS

- confined to rashes and pruritus: no treatment is necessary. However, do not ignore seemingly minor symptoms, as they can quickly become major symptoms*.
- with only mild joint pains: paracetamol in standard dose*.
- with severe joint pains, malaise, or extreme fatigue: will need HBO treatment.

2. If Type II DCS

- will need HBO treatment: follow recommendations below and facilitate admission to Navy Hospital, Trincomalee **AS SOON AS POSSIBLE**.

* US Navy Diving Manual, Revision 7, 17-5-2

RECOMMENDED HOSPITAL CARE WHILE AWAITING HBO TREATMENT

1. Keep the victim horizontal; recovery position (left lateral) if unconscious.
2. Exclude medical and psychological causes by investigations carried out by a medical professional.
3. X-ray (chest and skull) to exclude barotrauma
4. Reassure, encourage to keep calm and still, do not administer sedatives.
5. Protect against hypothermia.
6. Encourage plenty of non-alcoholic fluids orally if conscious and no nausea or vomiting; no solid foods.
7. Administer 100% oxygen through a tight-fitting (anaesthetic-type) mask starting as soon as possible with air breaks of 5 minutes every 20 minutes. (Carrying out air breaks by removing the tight-fitting mask for 5 minutes after 20 minutes continuous Oxygen supply should be done only if 100% Oxygen is being delivered to the victim)

Note: Anyone who has experienced symptoms associated with DCS is advised to seek subsequent medical evaluation. This should occur even if the diver's symptoms improved or disappeared upon the administration of oxygen, since subtle issues can be missed, or symptoms can return once oxygen delivery is stopped*.

8. Catheterise if there is urinary retention.
9. Commence intravenous infusion of normal saline, avoid dextrose; check haematocrit and maintain hydration.
10. Monitor and record neurological examination, especially the level of consciousness, sensory level, and muscle power; keep patient awake; exclude other conditions that could explain the symptoms and signs **but do not delay transfer for HBO treatment on this account.**
11. Contact Navy diving medicine specialists at the Navy Hospital (Eastern Command) on 026 776 6100 or the Diving Unit on 026 750 8153 or Director General Operational on 011 719 2230 to obtain permission before transfer for HBO treatment.
12. Ensure that the patient is transferred with adequate supplies of O₂, intravenous fluids and catheter *in-situ*, as well as a summary of the relevant history and examination record **with details of the diving profile.**
13. If circumstances so warrant, a paramedic should accompany.
14. Transport by unpressurized aircraft: The aircraft should be flown preferably at an elevation less than 1000 ft. If available, use an aircraft that could be pressurized up to 1 atm*.

* Treat nausea, vomiting, and headache symptomatically. **BUT DO NOT USE SEDATIVES**

MANAGEMENT OF A PATIENT WHO HAS NOT UNDERGONE HYPERBARIC OXYGEN (HBO) TREATMENT

Occasionally victims of DCS with symptoms and signs of a spinal lesion may present themselves at tertiary care centres or to a private clinic or hospital without having undergone HBO treatment. They may have resorted to ‘In-water Recompression’ by spending extended periods of time at various depths in the sea in an effort to relieve symptoms—without complete recovery. Unless presentation is greatly delayed (**see below**), such a patient should be referred to the Navy Hospital in Trincomalee for definitive HBO treatment.

1. If there is retention of urine, then that needs a catheter and appropriate bladder care.
2. If for any reason that is not possible or acceptable, high doses of methyl prednisolone, preferably intravenously, should be administered—as given for traumatic spinal injury from other causes¹.
3. Physiotherapy should be started early, be intensive and continued for as long as there is muscular weakness with paresis and/or paralysis. This should be done even for residual symptoms after HBO treatment. Improvement of function can be expected in the long term.

* How long is “greatly delayed” is difficult to state. Fonseka, Ekanayake and de Silva reported two cases of Type II bends with neurological deficits recovering after recompression therapy four and five days after the injury (CMJ, 1995, **40**, 37-38). One published report (Myers & Bray, *Annals of Emergency Medicine*, 1985, 14(3): 254-257.) suggested that after even 10 to 14 days delay, HBO treatment should be undertaken for neurological symptoms.

¹There is scientific evidence to support benefits of IV high dose methylprednisolone in inflammatory and traumatic myelopathies. Based on these research findings, intravenous methylprednisolone may be beneficial for subsequent inflammation following decompression sickness.

End of guidelines

Justification and evidence on which the guidelines are based

By Dr. Malik Fernando

This guide on the management of decompression sickness has been designed to fulfil two objectives:

1. To provide the population at risk i.e. self-trained commercial divers principally engaged in ornamental fish, sea cucumber and chank collecting — with authoritative advice on the action to be taken in the event a diving injury (decompression sickness) is suspected; and
2. To provide authoritative information to doctors (excluding those who provide hyperbaric oxygen treatment) who might be called upon to attend to a victim of a diving injury.

DCS in Sri Lanka is seen usually in divers who have descended to depths of 30 m (100 ft) or more repetitively; using even up to 5 air cylinders in one session, with short surface intervals between dives. DCS is uncommon at depths of less than 10 mⁱ.

The guide has been drawn up based on personal experience and on published literature; epidemiological observational studies, reviews, and guidelines. The level of evidence is not of the highest: one review found only one prospective randomised trial of treatment published in the last twenty yearsⁱⁱ. The guidelines proposed here relate exclusively to the management of a victim from the time a diving injury is suspected following the manifestations of symptoms up to the commencement of hyperbaric oxygen (HBO) treatment, also called recompression therapy.

The basic format of the guide follows that put out by Scottish Diving Medicineⁱⁱⁱ. Their Diver Help Card under the authority of the 'British Diving Safety Group' summarizes the important points in the following statements:

- Lay the casualty down
- Give 100% oxygen by tight-fitting mask
- Give non-alcoholic fluids (aim for 1 litre)
- Keep the casualty at a comfortable temperature
- Keep under observation until evacuated
- Reassure patient and buddy/buddies ['buddy' = divers' jargon for 'diver partner']

The guide has been divided into two sections: the first section titled 'First Aid' (not a part of this booklet) is aimed at the divers' companions such as other divers on the boat, as well as himself and his associates on land. It may be his employer, the exporter or middle-man whom he supplies, or other diver-members and helpers of his group.

The second section, physically separated from the first (this publication), is directed at doctors, especially those in primary care or in a peripheral hospital with limited facilities and even those in tertiary centres with more facilities. By and large doctors are not exposed to the subject of dysbaric² injuries during their training and would be totally at a loss when confronted by a patient who says, in Sinhala, that "he has the bends". This has been the experience of countless people presenting at hospitals with symptoms following diving.

The numbered sections in the guide [see coloured boxes) are explained and justified in the paragraphs below.

² Dysbaric injuries are those caused by changes in pressure and include aural and pulmonary barotrauma and cerebral arterial gas embolism (CAGE) as well as decompression sickness (DCS). The latter two entities (CAGE & DCS) are referred to as Decompression Illness (DCI).

Initial Assessment and Action...

In Sri Lanka HBO treatment is given according to tables published in the U. S. Navy Diving Manual, volume 5, by the United States of America's Navy^{iv}. An outline of the diagnosis of Type I and Type II has been given in the Guide to which this section is a part.

Mild rashes and pruritus are transient and do not require recompression. A severe rash with marbling of the skin that leads to thickening (*cutis marmorata*) is a more serious sign as it may progress to obvious type II DCS: this needs recompression. The Manual describes the treatment tables to be followed for the various symptoms at presentation.

Mild joint pains may be treated with analgesics but are best avoided as increase of pain suggestive of progression to type II DCS may be masked. Paracetamol is the drug of choice. Aspirin is used in some centres but there is no evidence from the literature to support the efficacy of aspirin in DCS^v. There is also the danger of aspirin interfering with blood clotting and causing haemorrhage: haemorrhage is already a major pathology in spinal cord and inner ear DCS^{xi}.

Recommended Hospital Care...

1. Keep horizontal

The consensus on the ideal position for an injured diver has changed over the years. There may be benefit in a transient head-down posture for divers with arterial bubbles, but balance of opinion and data favours a horizontal position^{vi}. This agrees with a conclusion reached by a Swiss worker who pointed out that newer experimental research shows that, contrary to the old theory, positioning the head below feet level increases intracranial pressure, injuring the blood-brain barrier. He concludes that the current recommendation asks for laying the injured diver horizontally on his or her back, or sideways, if he or she is unconscious^{vii}.

1.2. **Recovery position (left lateral) if unconscious**

This follows current practice in the management of an unconscious patient.

1.3 In 'First Aid for bends victims', as no. 6. **Carry victim on shore and keep horizontal**

This is an amplification of recommendations (1) and (1.2).

2. **Reassure, encourage (the diver) to remain calm and still**

This follows the advice given by Scottish Diving Medicine on their website on the page dealing with Treatment for Decompression Illness First Aidⁱⁱⁱ. It is recommended that sedatives are not given so as not to mask a deteriorating level of consciousness.

3. **Protect against hypothermia**

This follows the advice given by Scottish Diving Medicine on their website on the page dealing with Treatment for Decompression Illness First Aidⁱⁱⁱ. Even in the hot climate of Sri Lanka it is possible for a diver to lose a lot of body heat in the course of repeated dives. Being exposed to wind in wet clothes can further lower the temperature. If the diver has attempted in-water recompression (explained in a later paragraph) and has therefore spent a long period of time underwater without a break, he would be very cold on surfacing; particularly if this happens at nighttime. Not all divers wear wet suits that provide thermal protection; even with these suits prolonged immersion leaves a diver cold. Removing wet clothing and drying the body is essential.

4. **Encourage plenty of non-alcoholic fluids by mouth**

This follows the advice given by Scottish Diving Medicine on their website on the page dealing with Treatment for Decompression Illness — First Aidⁱⁱⁱ. We have not included the

suggestion that the target should be 1 litre if given by mouth in the interests of brevity. This is something that could be put over during oral awareness programmes. (See also comments under (7) Intravenous infusions below.) Solid food should be withheld so as to avoid loading the bowel. HBO treatment can take many hours and precipitating bowel evacuation during treatment is best avoided.

5. Administer 100% oxygen in spells of 20 minutes starting as soon as possible

This is by far the most important recommendation but difficult to achieve at the First Aid stage for a number of reasons. Firstly, oxygen is not carried on dive boats, though usually available on shore to supply the fish bags of fish collectors, but not medical grade O₂. However, oxygen may not be available at the shore bases of chank and sea cucumber divers. Secondly, delivering 100% oxygen to the patient needs special equipment, as discussed below. Although these two shortcomings are real, they are not insurmountable and including them in the First Aid recommendations leads the way to encouraging provision of these facilities within easy reach of the population at risk.

A study of 2,231 diving injury reports collected by the USA based Divers Alert Network (DAN) showed that first aid oxygen increased recompression efficacy and decreased the number of recompression treatments required if given within four hours after surfacing^{viii}. A study carried out at the North Sea Medical Centre (Norfolk, UK) for the Health and Safety Executive of the UK showed that normobaric oxygen administered to the diver before HBO tends to protect the diver against a delay in treatment with HBO. (HBO or hyperbaric oxygen treatment involves the delivery of 100% oxygen in a treatment chamber at a pressure of more than one atmosphere. Normobaric oxygen means administration of 100% oxygen at atmospheric pressure)^{ix}. There is general agreement that normobaric oxygen at the highest possible concentration should be administered,

with air breaks, starting as early as possible until commencement of HBO^{ix,xi}.

Ensuring that 100% oxygen reaches the diver can only be achieved by using an “anaesthetic type mask or an O₂ diving regulator as used in technical and commercial diving”^{xi} that will produce an air tight seal. A simple hospital plastic oxygen mask will not be adequate.

6. Catheterise if urinary retention

Retention of urine is a principal reason for bends victims to seek hospitalisation as otherwise there is a tendency to resort to in-water recompression -- this is the observation of those who have been involved with the care of DCS victims in Sri Lanka. Once catheterised in a hospital the patient should be released for transfer to the Navy Hospital with the catheter *in-situ*.

7. Commence intravenous infusion of normal saline, avoid dextrose; check haematocrit and maintain hydration

Severe DCS can be accompanied by haemoconcentration due to endothelial leakⁱ. It is important that blood haemoglobin and packed-cell volume are checked regularly, and appropriate amounts of intravenous fluids given. Glucose-containing fluids are best avoided because of the potential for adverse effects of hyperglycaemia in neurological injury^{i,xii}. Oral fluids can also be given if there is no nausea and/or vomiting.

8. Monitor and record neurological examination ...

“Neurological examination is essential for all divers with suspected decompression illness...”ⁱ. Vann et al (2011) go on to explain that generally, the findings in neurological assessment differ from those noted during most common stroke syndromes. Non-dermatomal hypoaesthesia and truncal ataxia are common in neurological decompression sickness. Coordination can be affected disproportionately and can be assessed by finger-nose

test and the ability to stand and walk with eyes open, and then with eyes closed. Level of consciousness, mental status, cranial nerve function and motor strength are pertinent examinations.

Keeping the patient awake enables assessment of level of consciousness. Communicating the neurological examination to the doctors who are to provide HBO treatment is necessary as it will indicate whether the condition is still evolving as this will influence the treatment schedule adopted.

"The diagnosis of decompression sickness is based entirely on clinical manifestations". Vann et al (2011) point out that imaging studies are not useful for assessment of whether a patient needs recompression treatment and should not delay recompression unless there is a strong suspicion of a non-diving related cause (e.g., cerebral haemorrhage).

9. Inform doctor/hospital staff that symptoms are likely to result from diving injury

DO NOT ADMINISTER OXYGEN UNDERWATER

Ideally a diver with DCS should seek admission to the Naval Hospital at the Navy Base in Trincomalee as soon as possible where he will be given HBO treatment if that is required. However, a widespread practice amongst ornamental fish, chank and sea cucumber divers is to resort to in-water recompression in the first instance. This practice is popular as it reportedly gives relief of symptoms frequently; but there is no data, only anecdotal evidence. One fish exporter — Darrel Fryer — who is a former diver himself has had a lot of experience of this practice around Colombo and is the principal source of our information.

In-water recompression as practiced in Sri Lanka involves going down (or being taken down if the diver is incapacitated) with a fresh air cylinder to various depths and various time intervals as the diver feels appropriate; usually to a depth where there is relief of symptoms. Ignorant divers descend to excessive depths and aggravate the problem. To address this

issue Darrel Fryer had come up with a protocol containing recompression depths and times that were considered appropriate. This was incorporated into a leaflet in 1998 describing decompression sickness — the do's and don'ts — by a team that included the author and a naval officer involved in recompression chamber operation at the time. It was translated into Sinhala and Tamil and distributed amongst the divers. In essence, in-water recompression entails descending to a depth where symptoms are relieved and then ascending in step-wise fashion spending longer and longer periods at progressively shallower depths.

In-water recompression (IWR) is not recommended as a routine practice. However, it should be appreciated that many divers have recourse to this for two reasons: firstly, it is beneficial in many instances as shown by the experience of their peers; secondly, difficulties in gaining admittance to the Navy Hospital on account of distance and cost makes this an available alternative, though not ideal. It is also used in other countries, by fishermen-divers who practice their occupation far away from hyperbaric facilities. A study by a team from the International Labour Office in Geneva, Switzerland^{xiv} who interviewed a small group of divers in Thailand concluded that "in-water recompression has, within the diving population, proved to be an appropriate first-aid measure for decompression illness". Subsequent studies addressed diving practices^{xv} and diving-related mortality and morbidity^{xvi}. These divers had been using a surface demand air source.

A number of methods of IWR have been published, but these require the use of oxygen at pre-determined depths not exceeding 9 metres. The US Navy Diving Manual describes IWR using air, based on depth stops specified in the Air Decompression Tables — this would not be practical in Sri Lanka.

We do not recommend the use of oxygen for IWR in Sri Lanka: unless used with care so as not to exceed the prescribed maximum depth of 9 m there is a danger of oxygen toxicity that results in tonic-clonic spasms leading to death. Prevention of misuse of oxygen by untrained divers is best served by not recommending O₂ use underwater.

Delayed treatment

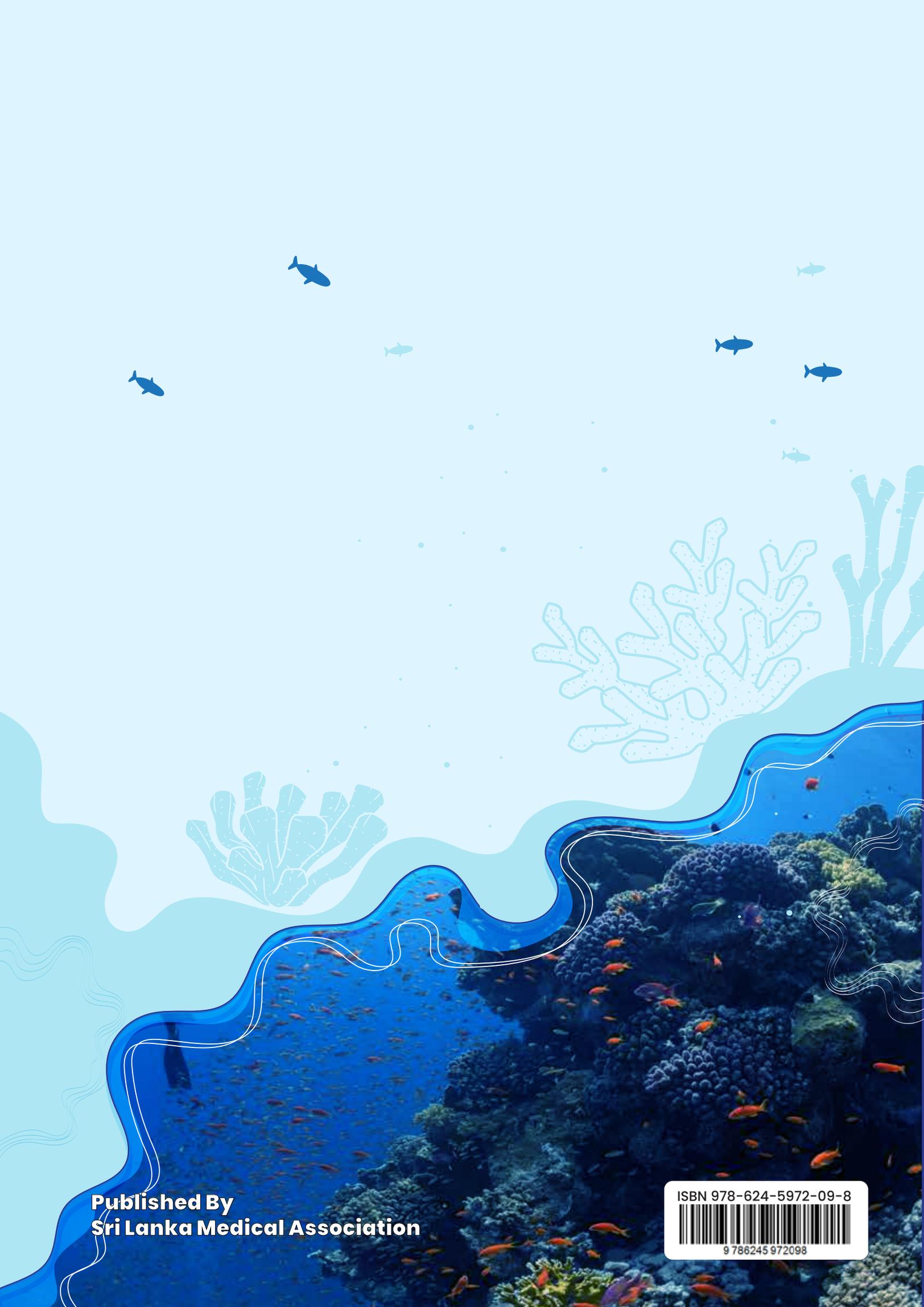
Prompt HBO treatment when necessary, gives the best chance of complete recovery. However, even delayed treatment can also be effective, and all stricken divers should be given the opportunity of being recompressed in a chamber. In the North Sea Medical Centre study referred to earlier analysis of the study data suggested that in order to achieve the greatest response to HBO the interval between surfacing from the incident dive and receiving treatment should be less than 350 minutes (or approximately six hours)^{ix}. Fonseka et al (1995) from Sri Lanka reported two cases of Type II bends with neurological deficits recovering after recompression therapy four and five days after the injury^{xvii}. Myers and Bray (1985) recommend that DCS symptoms be treated whenever they are seen, even 10 to 14 days post injury based on their experience of treating three patients who presented three to seven days following the original exposure^{xviii}.

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