A DESCRIPTIVE STUDY OF DECOMPRESSION ILLNESS AMONG SCUBA DIVERS TREATED WITH HYPERBARIC OXYGEN THERAPY AT A MILITARY HOSPITAL-BASED RECOMPRESSION FACILITY IN PENINSULAR MALAYSIA

Fazriyati Jamharee[a], Abu Yazid Md Noh[a], Tuan Hairulnizam Tuan Kamauzaman[a], Ariff Arithra Abdullah[a] , Junainah Nor[a]

[a]Department of Emergency Medicine, School of Medical Sciences, Universiti Sains Malaysia, Kubang Kerian 16150 Kelantan, Malaysia

Correspondence to:

Dr. Tuan Hairulnizam Tuan Kamauzaman
MBcHB (Leeds) MMed (Emerg) USM
Department of Emergency Medicine
School of Medical Science
Universiti Sains Malaysia
16150 Kubang Kerian
Kelantan, Malaysia
Email: hairulnizam@usm.my
Telephone number: +6 0129875007
Fax number: +6 097673219

ABSTRACT

Background: Diving related illness has become a public health concern, as there is an increasing number of divers worldwide. However, the incidence of Decompression Illness (DCI), a medical disorder as a result of sudden reduction of ambient pressure, remains generally low. This paper describes the patterns of decompression illness treated in a military hospital-based recompression chamber facility in Peninsular Malaysia from year 2000 until 2010.

Objective: The objective of this study is to determine the patterns of decompression illness patients treated with Hyperbaric Oxygen Therapy (HBOT) in a military hospital-based recompression chamber facility in Peninsular Malaysia.

Methodology: A retrospective descriptive study was carried out to utilize secondary data from Hospital Angkatan Tentera Lumut, Perak from 1st January 2000 to 31st December 2010. A total of 96 cases were included in this study.

Results: Most of the patients were male (94.8%), recreational divers (43.0%), non-smokers (56.3%), with no previous medical illness (85.4%), who had dived with compressed air (78.0%), had less than 5 years diving experience (56.3%), were non-instructors (75.0%), and had body mass index between 18.5 to 24.9 kg/m^2 (59.4%). Interestingly, 25% of the patients developing DCI dived to less than 10 meters depth, 35.4% of them went for a single dive and 71.9% performed safety stops. The majority of the patients had symptoms starting within 12 hours after surfacing (85.4%), mainly within the first 3 hours and many had neurological manifestation (61.5%). Only 16.7% of the patients treated with HBOT had therapy commenced within 6 hours from the onset of symptoms and 93.8% from this group had complete recovery. Overall, 76.0% of patients had full recovery after HBOT.

Conclusion: Diving activities must be closely monitored. Medical surveillance as well as legislations related to diving activities in Malaysia are essential to improve SCUBA discipline and to reduce mortality and morbidity of DCI in the future.

KEYWORDS: Diving, Decompression Illness, Hyperbaric Oxygen Therapy

INTRODUCTION

Underwater diving is performed for various reasons including commercial, recreational, military, and scientific exploration. Diving related illness has become a public health concern, as there is an increasing number of divers worldwide. However, the incidence of Decompression Illness (DCI) is generally low. DCI is a term used for medical disorders resulting from decompression from a higher to lower ambient pressure.[1] This causes bubbles formation in the vessels and body tissues resulting in ischemia, mechanical damage, or inflammatory derangements.[2] DCI encompasses two disease entities: Arterial Gas Embolism (AGE) and Decompression Sickness (DCS).[1, 3] AGE is caused by entry of bubbles of gas into the arterial circulation through a shunt of patent foramen ovale or resulting from alveolar capillaries rupture following a pulmonary barotrauma.[1, 4, 5] On the other hand, DCS is caused by circulating bubbles of inert gas in blood and tissues resulting from super saturation during decompression as the rate of ambient pressure reduction that exceeds the rate of inert gas to be washed out from the tissues.[1] The symptoms vary and the severity of clinical presentations depends on the size, number, and location of bubbles.[3] DCS is typically classified into Type I and Type II DCS. Type I DCS includes musculoskeletal, cutaneous manifestation and constitutional symptoms whereas Type II DCS is characterized by neurologic and systemic manifestation commonly presented with numbness, muscle weakness, psychological or motor abnormalities.[1, 2, 4] The occurrence rate for DCI in operational open water dive varies from 0·01 - 0·019% for recreational divers, to 0.095% for commercial divers and 0.03% for US Navy divers.[1] In Malaysia, cases of DCI and its sequelae have been reported among occupational divers. In 1998, there were six cases of DCI related to underwater logging in Kenyir Lake treated at a state government hospital.[6] The divers presented with severe cardiorespiratory and neurological disturbances, resulting in two deaths, while the others survived after recompression treatment. In addition, there were 21 cases of DCI treated at the military hospital in the Royal Malaysian Navy Base in Lumut from November 1996 to 1999, also related to underwater logging in Temenggor and Kenyir Lakes.[7] Underwater logging contributed to 86.2% (n=56) of DCI as compared to commercial diving.[6] Forty-seven underwater loggers (83.9%) presented with Type II DCS with severe neurological involvements and 14 (26.9%) of them suffered permanent residual disability with limbs weakness, paralysis and bladder dysfunction.[8] The aim of this study is to determine the patterns of decompression illness in patients treated with HBOT in a military hospital in Peninsular Malaysia from year 2000 until 2010.

METHODS

A retrospective analysis study over a period of 11 years was undertaken based on medical records extracted from a military hospital in Peninsular Malaysia from 1st January 2000 to 31st December 2010. Only cases that were categorized as decompression illness requiring HBOT were included in the study. The cases with missing data or medical records were excluded from analysis. We considered for each diver: demographic data (age, gender, BMI, smoking, alcohol consumption, past medical illness), diving profiles (years of experience, training level, type of diving activities, depth, total dive time, safety stop practice, type of tank, type of dive either single or repetitive), clinical manifestation (onset of symptoms after surfacing, types of clinical presentations) and treatment (time to treatment from onset of the symptoms). Permission to conduct the study was obtained from the Commanding Officer of the respective

military hospital, the Director General of the Malaysian Armed Forces Health Services Division and Universiti Sains Malaysia Human Ethics Committee.

Definitions

In this study, types of diving activities were defined as follows; (1) Recreational diving where divers use SCUBA for recreational purposes or as a hobby, (2) Commercial diving when heavy salvaging or engineering work was performed (the work might be done deeper than 54 metres and air was usually supplied from the surface to the diver via a hose for longer duration of diving), (3) Military diving when there was involvement of armed service personnel in salvaging military equipment, explosive ordinance disposal, general ship maintenance, clandestine diving operations and antiterrorist activities.[8] Incomplete recovery was defined as residual symptoms that remained permanently after undergoing series of complete treatment therapy. Safety stop was defined as a compulsory pause during ascend to the surface at 3-5 metres depth for 3-5 minutes for decompression requirement during a dive. [2] Severity of DCI was classified based on symptoms. Major DCI was characterized by cognitive impairment, central nervous system dysfunction, visual disturbances, loss of consciousness, amnesia and inner ear disturbance. Minor DCI was characterized by skin manifestations, paraesthesia, musculoskeletal pain, abdominal discomfort and constitutional symptoms.

Statistical analysis

Data were analysed with statistical software (SPSS, version 22, SPSS Inc., Chicago, IL USA). Descriptive analysis of the demographic and diving related data were conducted. Results were presented as frequency (percentage) for categorical variables and mean (standard deviation) for numerical variables.

RESULTS

A total number of 175 patients were treated for diving related injuries in Hospital Angkatan Tentera Lumut from January 2000 to December 2010. However, only 96 cases were reviewed in this study after considering the inclusion and exclusion criteria. Figure 1 shows that the highest number of DCI requiring HBOT was in the year 2005 where 17 cases were reported and the lowest were three cases in year 2003. There was an average of 10 cases of cases of DCI treated with HBOT per year.

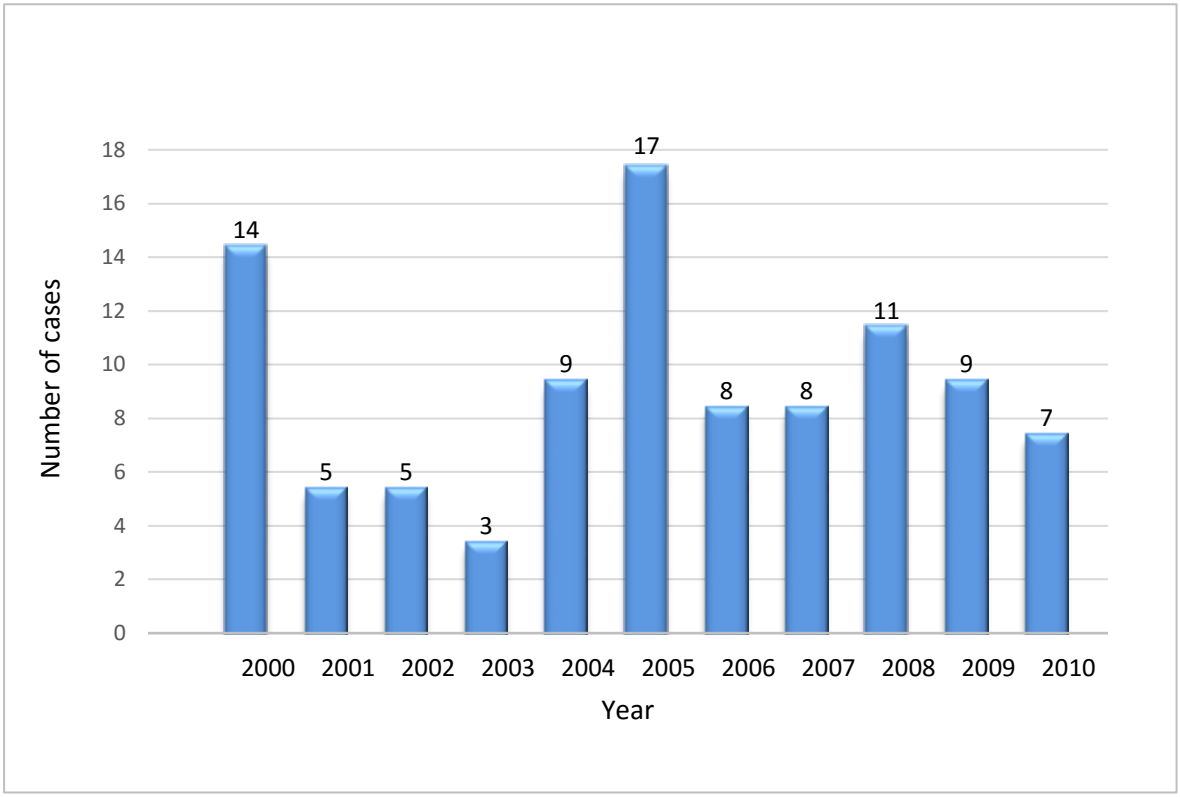

Figure 1 : Total cases of decompression illness (DCI) from year 2000 until 2010

Socio-demography

Most the divers were recreational divers (n=41, 43%) followed by commercial divers (n=33, 34%) and military divers (n=22, 23%). The majority of the treated divers were male (n=91, 94.8%) (Table 1). The mean (SD) age of the divers was 32 (8.67) years and ranging from 19 to 61 years old. Most divers (59.4%) had BMI less than 25 kg/m². 56.3% (n=54) of the divers were non-smokers. 9.4% of patients consumed alcohol but more than 12 hours prior to the dive whereas the rest of the divers did not consume alcohol at all. The majority of the divers in our study did not have any previous medical history (PMH) (85.4%). In the group of the divers with PMH, 2 patients had mild asthma with a very good control, 4 patients with previous history of DCS with complete recovery after HBOT, 3 patients with hypertension, 2 patients with heart problem and another 2 patients had upper respiratory tract infection prior to the event. Concerning years of experience in diving, 43.8% of them had more than 5 years of experience. Most of the divers in the study were non-instructors (75.0%).

Table 1 : Socio-demographic of divers with DCI treated with HBOT

Variable	n (%)	Mean (SD)
Age		32 (8.67)
Gender		
Male	91 (94.8)	
Female	5 (5.2)	
BMI (kg/m^2)		24.15 (3.05)
18.5 - 24.9	57 (59.4)	
≥ 25	39 (40.6)	
Smoking		
Yes	42 (43.8)	
No	54 (56.3)	
Alcohol consumption		
Yes	9 (9.4)	
No	87 (90.6)	
Past medical illness		
Yes	14 (14.6)	
No	82 (85.4)	
Years of diving experience		
Less than 5 years	54 (56.3)	5.48 (5.01)
More than 5 years	42 (43.8)	
Training level		
Instructor	24 (25.0)	
Non Instructor	72 (75.0)	

Divers' dive profile

Table 2 summarizes the divers' dive profile in the current study. Most of the divers (n=40, 41.7%) dived to the depth between 10 to 20 meters. Most dives had a total dive time between 1 to 3 hours of total time. Majority of the divers (n=62, 64.5%) had DCS after multiple dives as compared to a single dive. In this study, only 18 divers (18.8%) used oxygen tank while the rest (n=78, 81.3%) dived with compressed air cylinders. None of the divers in our study dived with mixed air cylinders. Overall, 69 divers (71.9%) performed the obligatory safety stop procedure at the end of their dives.

Table 2: Dive profiles of divers with DCI treated with HBOT

Variable	n (%)	Mean (SD)
Depth of diving (meter)		21.76 (11.75)
Less than 10m	24 (25.0)	
11 - 20m	40 (41.7)	
More than 20m	32 (33.3)	
Type of dive		
Single dive	34 (35.4)	
Repetitive dive	62 (64.6)	
Total time of dive (hours)		1.90 (1.19)
Below 1 hour	3 (3.1)	
1 - 3 hour	86 (89.6)	
More than 3 hour	7 (7.3)	
Type of cylinder gas		
Compressed Air	78 (81.3)	
Oxygen Tank	18 (18.8)	
Safety stop		
Yes	69 (71.9)	
No	27 (28.1)	

Clinical manifestations

Majority of the divers (n=82, 85.4%) developed symptoms within 12 hours after surfacing with half of them presented within 1 to 3 hours post diving. More than half of patient (n=59, 61.5%) had developed neurological manifestations, which varied from mild symptoms like numbness to severe forms such as loss of consciousness, seizure or paralysis. This was followed by cardiovascular system presentations (n=17, 17.7%) which were mainly chest pain and shortness of breath. Other clinical presentations recorded in this study were of vestibular system (n=11, 11.5%) and joints and musculoskeletal pain (n = 9, 9.4%).

Treatment and outcome

Patients were divided into 4 groups based on their time to recompression (TTR) from the onset of symptoms. Only 16 patients (16.7%) had access for early treatment within 6 hours of symptoms. Majority of divers of the delayed TTR group (n=36, 37.5%) received treatment within 7-12 hours. Another 13 patients (13.5%) were treated within 13-24 hours and 31 patients (32.3%) received treatment after more than 24 hours (Figures 2).

There were 93.7% patients (n=15) who received treatment within 6 hours after onset of symptoms who achieved complete recovery making only 6.3% patient (n=1) from this group with incomplete recovery. For those with more than 6 hours TTR, 72.5% patients (n=58) had complete recovery while the remaining 27.5% (n=22) had incomplete recovery. Overall, 76.0% of patients (n=73) had achieved full recovery after completion of treatment with 20.5% of them (n=15) were treated within 6 hours. Only 24.0% patients (n=23) had an incomplete recovery with 95.7% of them (n=22) received treatment with TTR of more than 6 hours.

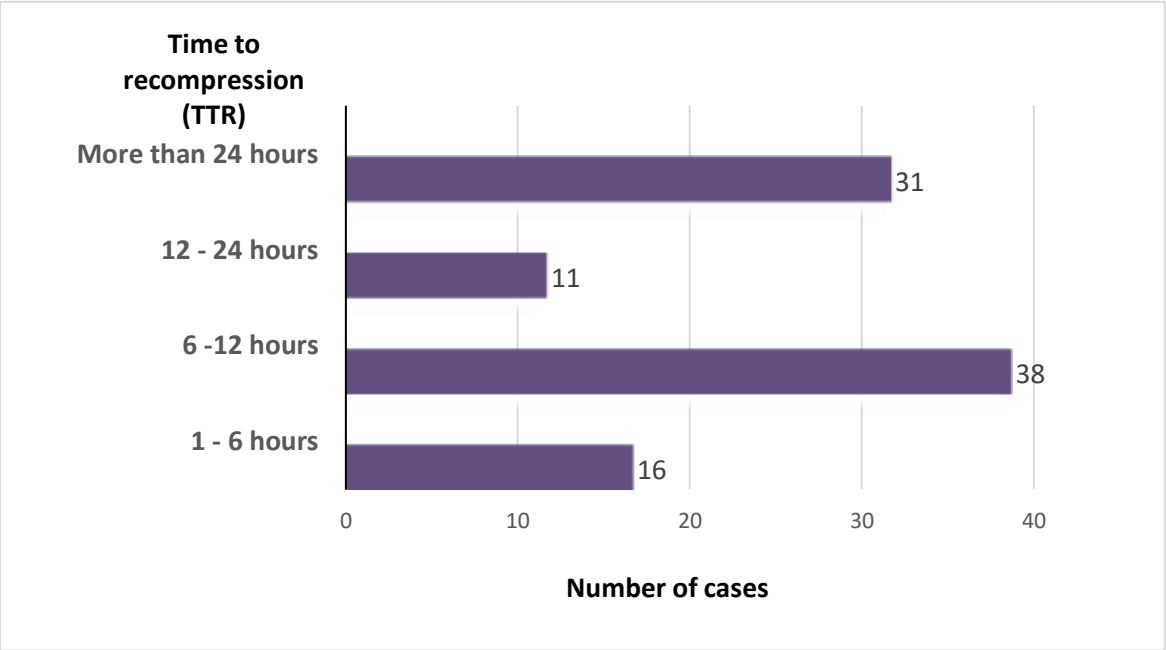

Figure 2 Distribution of time to recompression (TTR) from the onset of symptoms

Table 3: Time to recompression (TTR) and recovery status upon completion of HBOT sessions

Time to recompression	Recovery Status			Percentage of complete recovery (%)
	Complete (%)	Incomplete (%)	Total (%)	
Within 6 hours	15 (20.5)	1 (4.3)	16 (16.7)	93.8
More than 6 hours	58 (79.5)	22 (95.7)	80 (83.3)	72.5
Total	**73**	**23**	**96**	
(% over total population)	(76.0)	(24.0)	(100.0)	

DISCUSSION

This study involved a total of 96 cases diagnosed as DCI and treated with HBOT in Hospital Lumut from January 2000 until December 2010. However, we were unable to compute the incidence rate of DCI since the denominator such as actual number of divers or activity in Malaysia was unknown. Additionally, the number of DCI cases treated at other recompression centres in Malaysia were not gathered in this study rendering the numerator of incidence calculation inadequate. However, the incidence of DCI remains low worldwide. Divers Alert Network Project Dive Exploration estimated of the incidence of DCI in the recreational community to be 2.0–4.0/10,000 person-dives and the rate has been decreasing for the last decade.[1] DCS rate among instructors has been estimated at 12.7–15.2/10,000 person-dives.[9] The rate of DCI among military sport divers has been estimated at 1.34/10,000 person-dives.[10] The US National Oceanic and Atmospheric Administration (NOAA), which conducts both working dives as well as scientific dives, reported a DCS incidence of 1.8/10,000 person-dives.[11] The incidence of DCS in commercial diving, however, has been reported to be comparatively high at 35.3/10,000 person-dives.[12]

There are different groups of divers in the community. This study analysed three groups of divers that contributed to this diving accident. Out of 96 cases, only 22.9% cases were military divers and the rest were civilians. The civilians group were further divided into recreational SCUBA divers (42.7%) and commercial divers (34.4%) who were mainly involved in underwater logging activities. This finding was consistent with two other local studies that showed higher occurrence of DCI among civilians (87.2%) as compared to military divers (12.8%).[7,8] Similar pattern was also reported in Northern America which showed higher incidence rate of DCI among commercial groups (0.35%) as compared to military divers (0.013%).[13] The incidence was low among the military group as they have frequent diving training, with structured operational tasks and also a much higher safety profile. The professional group of divers such as military personnel or commercial divers, are required to maintain a high level of fitness. High physical activity is correlated with the reduction of bubble formation in tissues thus decreasing the risk of decompression illness.[14] The high

occurrence of DCI among commercial divers in the current study could be explained by the construction of major hydroelectric dams from 1980's until late 1990's, resulting in timbers being submerged in the forest area in Temenggor Lake (Perak), Kenyir Lake (Terengganu) and Pergau Lake (Kelantan). These workers developed their own makeshift equipment and technique for underwater logging. Lack of training, improper dive techniques, low quality equipment, strenuous work and extreme environment caused high morbidity among this group.[8] In later years of the study, cases were more prevalent among recreational group as diving was becoming popular. Most of the recreational divers were required to only declare their medical condition without having to undergo medical examination prior to SCUBA training and certification. Recreational divers do not have any legal obligation for medical assessment.[8] We discovered that 14 (14.6%) divers had previous medical illness in this study. Interestingly, we noted that 3 out of 14 patients had experienced DCS previously with non-residual complications after few cycles of HBOT. A previous episode of DCS also made a diver more susceptible to a subsequent DCS episode.[2] A centre in Chicago, US found that quite a number of divers continued diving despite their illnesses and only one third sought medical consultation regarding fitness to dive.[15] These medical conditions such as heart disease and asthma might have disqualified them from SCUBA diving. These could contribute to the high occurrence rate in this group as compared to military divers who were required to undergo rigid medical clearance prior to diving.[8]

The onset of symptoms depends on the type of diving as well as the depth. Symptoms commonly appear within 6 hours after the ascend.[2] Results in this study showed that about 85% of patients developed symptoms within 12 hours after surfacing with 73 out of 82 subjects from this group had clinical manifestation within 6 hours after the ascend. This could be classified as moderate to severe DCI based on the signs and symptoms including the progression of the illness. Studies have shown that divers with severe presentation had shorter time interval from surfacing to the onset of symptoms.[12] Patients with type I DCS are likely to ignore their own symptoms thus delaying treatment since they have mild ailments such as minor pain or skin lesions. Although type I DCS presents with minor symptoms, it may also lead to serious complications such as osteonecrosis and progression to type II DCS.[16] It might be aggravated by certain activities like vigorous exercise or higher altitude exposure.[2, 17] The other 15% of patients in this study presented with late symptoms after more than 12 hours after surfacing which might be defined as mild DCI based on the time of onset. Their initial symptoms included joint pain and mild giddiness. Symptoms that may indicate escalation of severity in this group of divers include confusion, truncal or girdle pain and lower limb paraesthesia and weakness.[3]

Most of the patients with severe presentations were seen in the earlier years between year 2000 to 2004 where the commercial groups of divers presented with neurological deficit such as loss of consciousness, seizures, paralysis and bladder dysfunction. The severity of DCI depends on the dive profile of the divers such as depth, rate of ascend and safety stop. However, DCI does occur in a relatively conservative dive especially in the presence of patent foramen ovale (PFO), which occurs in 27% of the general adult population.[18] Major DCI was observed significantly more commonly in divers with PFO than those without (18/1,000 vs. 3/1,000, $p = 0.02$).[18] This may suggest that future assessment of DCI should include PFO screening. The severity of the clinical presentation may predict the prognosis of morbidity and

mortality of the patient. Those who had serious manifestation especially life threatening DCI needed urgent evacuation and treatment. Remote areas where the recompression facility is not immediately available might delay the time to treatment and thus may increase the probability of a poor outcome [8].

Definitive treatment for DCI is recompression therapy. Performed quickly after onset, HBOT commonly results in complete resolution in most cases and in few cases mild residual symptoms may remain.[1] Results of the current study showed that only 16.7% patients had early access to HBOT within 6 hours after the onset of symptoms. Few factors were identified to contribute to the delay of HBOT. One major reason was that majority of the patients were referred cases from remote sites. Thus, transportation to the nearest hospital for emergency treatment and stabilization was the only option. Most of the cases were referred from Grik and Kuala Terengganu hospitals where diving injury commonly occurred among commercial divers. Both were the nearest available hospitals from Temenggor and Kenyir dams construction site which took approximately 30 minutes to one hour journey by road. Kuala Terengganu Hospital also received patients from Perhentian and Redang Islands, which were popular spots for recreational divers. Another reason for delayed HBOT was late presentation of DCI. This could be observed mainly in more experienced groups of divers in hoping that the symptoms would resolve spontaneously.[19] We found that majority of the patients with full recovery (72.5%) had HBOT initiated after 6 hours from onset of symptoms. This is consistent with result from a study in Sagol center for Hyperbaric Medicine and Research, Israel showed that 76% of the patients with DCS achieved complete recovery with delayed (>48 hours) HBOT.[19] Additionally, earlier review of 140 cases of DCS with average delayed recompression therapy of 93.5 hours showed 87% of complete recovery.[20] This suggests that HBOT has significant clinical value even if the treatment is delayed.

CONCLUSION

There is a need to establish a national database for divers and diving activities to determine the incidence of DCI in Malaysia. Further studies are needed to study the risk factors of DCI specifically in Malaysia. Hyperbaric treatment is useful and can achieve complete recovery even if the treatment is delayed.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interests in this study.

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