Descriptive study of decompression illness in a hyperbaric medicine centre in Bangkok, Thailand from 2015 to 2021

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Abstract
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Introduction: This study aimed to determine the characteristics of decompression illness patients and their treatment outcomes, at the Center of Hyperbaric Medicine, Somdech Phra Pinklao Hospital, one of the largest centres in Thailand.
Methods: Past medical records of patients with decompression illness from 2015 to 2021 were retrieved and analysed.
Results: Ninety-eight records of diving-related illness from 97 divers were reviewed. Most of the divers were male ($n = 50$), Thai ($n = 86$), and were certified at least open water or equivalent ($n = 88$). On-site first aid oxygen inhalation was provided to 17 divers. Decompression sickness (DCS) cases were characterised according to organ systems involved. The most prominent organ system involved was neurological (57%), followed by mixed organs (28%), musculoskeletal (13%), and pulmonary (2%). There were three cases of arterial gas embolism (AGE). Median presentation delay was three days. Ninety patients were treated with US Navy Treatment Table 6. At the end of their hyperbaric oxygen treatment, most divers (65%) recovered completely.
Conclusions: Despite oxygen first aid being given infrequently and long delays before definitive treatment, treatment outcome was satisfactory. Basic knowledge and awareness of diving-related illnesses should be promoted among divers and related personnel in Thailand along with further studies.

Introduction

Thailand is famous as a tourist destination for its beautiful maritime landscape, coastal scenery, and other oceanic natural resources. The World Tourism Organization reported that Thailand was the country with the highest revenue from tourism in the Asia-Pacific region in 2017.[1] Out of a total of 77 provinces, 24 are coastal and attract approximately 86 million visitors per year, contributing 53.35% of Thailand's gross domestic product.[2] Some of the recommended water activities are canoeing, kayaking, yachting, and open water diving. Scuba diving is a popular recreational activity in Thailand; however, related injuries occur in both recreational and occupational settings. Decompression illness (DCI) is one such injury that has scarcely been studied in Thailand, despite it being a potential cause of morbidity and mortality amongst scuba divers.[3] DCI (a collective term embracing decompression sickness [DCS] and arterial gas embolism [AGE]) may be an indication for urgent recompression and hyperbaric oxygen treatment (HBOT). One study published in 2007, reported 453 cases treated between 2001–2005 at both public and private hospitals with hyperbaric chambers in Thailand.[4] There are currently 112 hyperbaric chambers in Thailand, with 40 facilities being able to provide treatment for DCI. These are primarily located at navy hospitals, navy facilities, and commercial diving facilities.

To further understand the characteristics and outcome of DCI patients after recompression treatment in Thailand the authors analysed medical records from the Centre of Hyperbaric Medicine at Somdech Phra Pinklao Hospital, one of the largest of its kind in Thailand. This unit operates under the Naval Medical Department of the Royal Thai Navy. It was established in 2015, with the first patient being admitted on 1 October 2015. Since then, it has provided HBOT to hundreds of patients, including those with diving and non-diving indications, with its multiplace and monoplace hyperbaric oxygen chambers. The multiplace hyperbaric chamber at Somdech Phra Pinklao Hospital can accommodate up to 30 patients in three compartments.

The aim of this study was to determine the characteristics of DCI patients and their treatment outcomes, at the Centre of Hyperbaric Medicine, Somdech Phra Pinklao Hospital.

Methods

This study was approved by the human research ethics committees of the Naval Medical Department (Case number: RP048/64).

Past medical records of patients with DCI were retrieved from 1 October 2015 to 30 June 2021. There were 97 patients with DCI. This study included only patients admitted to Somdech Phra Pinklao Hospital who declared a history of diving before a DCI incident.

The data collection form was divided into two parts: (1) personal data, including age, gender, nationality, weight, height, and history of past diving-related illness, types of divers and diving certificates, and dive site or location; and (2) data related to the incident, including date and time of symptom onset, time arrived at the Center of Hyperbaric Medicine, target organ of DCI, normobaric oxygen first aid received at scene, treatment table applied, total number of hyperbaric oxygen treatments given, and treatment outcome.

Data were analysed using descriptive statistics, via Microsoft Excel and STATA Version 14.0.

Results

Ninety-seven patients were admitted for HBOT to treat DCI over the study period. Two divers each experienced two episodes of diving-related illness. The first episode in one of these patients occurred in 2015 before the establishment of the Center of Hyperbaric Medicine, so they were treated at the Underwater and Aviation Medicine Division, Naval Medical Department and this case was therefore excluded from the analysis. The other patient suffered from diving-related illness twice in 2020 with both treatments provided at the Center of Hyperbaric Medicine. It follows that this study pertains to 97 divers and 98 DCI incidents.

Fifty divers were male and 47 were female. The mean age was 35.7 years with a range of 19–63 years. The body mass index (BMI) of the divers was calculated and categorised according to the Thai Department of Disease Control, Ministry of Public Health.[5] The mean BMI for this group of divers was 23.9 $kg \cdot m^{-2}$ (range 17.0–44.8 $kg \cdot m^{-2}$). Most of the divers (45%) were within normal BMI limits (18.5–22.9 $kg \cdot m^{-2}$), 15% were overweight (BMI 23–24.9 $kg \cdot m^{-2}$), 37% were obese (BMI ≥ 25 $kg \cdot m^{-2}$) and 3% (BMI < 18.5 $kg \cdot m^{-2}$) were underweight.

Not surprisingly, the majority of divers (86) were Thai, while 11 were foreigners, including one each of American, Belgian, English, Guatemalan, Israeli, Japanese, Dutch, Spanish, Swedish, and two of Austrian nationality.

The majority of divers (80 cases, 82%) were reported to have dived in Thailand while 18 had dived overseas, including Indonesia (8, 8%), Maldives (3, 3%), Philippines (3, 3%), Japan (1, 1%), Malaysia (1, 1%), Palau (1, 1%), and one overseas dive site not stated.

Of 79 recreational dives, 62 were local dives in Thailand. Twenty-one (34%) occurred in provinces with Andaman Sea coastlines including Krabi, Phangnga, Phuket, and Satun. The other 36 dives (58%) took place in provinces with the coastal zoning of the Gulf of Thailand. Dive site data for the remaining five divers were either not properly recorded or missing. The province with the highest incidence of DCI was Surat Thani, especially in the Koh Tao area, a popular site among Thai and foreign divers, followed closely by Chonburi province in the Sattahip district, both of which are parts of the Gulf of Thailand coastlines. For Andaman coastlines, the most prominent provinces were Phangnga and Phuket.

Indonesia, being a popular dive destination among Thais, comprised the most common (8) site for diving-related illnesses of the 18 overseas dive sites. The others were three incidents each from the Maldives and the Philippines, one each from Japan, Malaysia, Palau, and one overseas dive site was not stated.

On-site first aid with normobaric oxygen was provided to only 17 divers (17%). In Thailand there were 13 incidents out of 80 (16%) in which divers received first aid oxygen, compared with four out of 18 overseas dives (22%). One Thai diver who had been diving in Indonesia received treatment with HBOT before arriving at the Center of Hyperbaric Medicine.

There were 16 divers with diving insurance, nine of which were Thai, while the other seven were foreigners. The rest of the divers did not have diving insurance or did not provide such information.

Regarding diving certification, 19 divers were certified to 'open water' level or its equivalent, while 69 divers were qualified to more advanced levels. There were nine divers without any diving certification, or their level of certification was not clearly specified.

Defining the duration between the first day that symptoms appeared and the day that the divers arrived at the Center of Hyperbaric Medicine as presentation latency, after excluding 14 outliers, the range of presentation latency was 0 to seven days, and the median was three days.

The most prominent organ system diagnosis was neurological DCS with 56 cases (57%). Twenty-three cases (23%) presented with mixed signs and symptoms (more than one involved organ system). Musculoskeletal DCS comprised 13 cases, while two cases most prominently showed pulmonary symptoms. There were three cases of AGE as shown in Figure 1.

Figure 1
Number of reported arterial gas embolism and decompression sickness cases by organ systems and year; AGE – arterial gas embolism

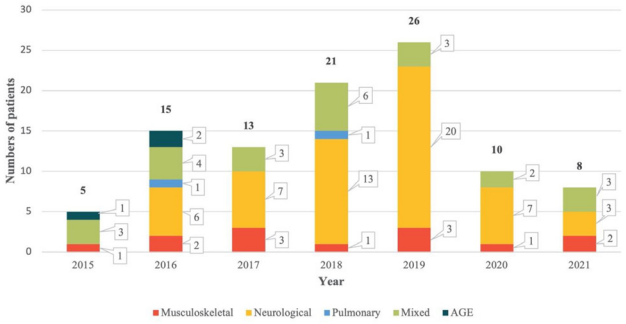


Table 1
Initial hyperbaric oxygen treatment administered in relation to clinical diagnosis; AGE – arterial gas embolism; TT5 – United States Navy Treatment Table 5; TT6 – United States Navy Treatment Table 6

Diagnosis	TT5	TT6	Kindwall	Total
Musculoskeletal	3	10	0	13
Neurological	2	51	3	56
Pulmonary	0	2	0	2
Mixed	0	24	0	24
AGE	0	3	0	3

The recompression treatment table utilised for cases grouped by organ system involvement is shown in Table 1. Ninety out of 98 cases (92%) were initially treated with US Navy Treatment Table 6 (USNTT6).[6] US Navy Treatment Table 5 (USNTT5) was used in five cases, and the remaining three cases were treated with Kindwall's monoplace treatment table, which can be utilised to treat both mild and severe DCI with no air breaks.[7]

Nearly half of the divers (48) underwent two to five hyperbaric oxygen treatments, another 48 divers had only one treatment, while the remaining two underwent more than five treatments. By completion of all recompression treatment, 64 cases (65%) had completely recovered, while 34 cases had residual symptoms.

Discussion

The mean age of divers in this study, at 35.7 years, was lower than the 45 years reported in the DAN Diving Incidence Reporting System (DIRS). Gender results also differed, with 48% male divers in this study and 68% in the DIRS study.[8]

A total of 79 divers were reported to have dived in Thailand, while 18 dived overseas. The median presentation latency did not differ between divers whose incidents occurred in Thailand and divers who dived overseas, even though transportation time from local dive sites would suggest it should be shorter. While the median presentation latency between the two groups of divers were similar, the treatment outcome differed markedly. Full recovery status was noted in 70% of divers in Thailand compared with 47% in those who had been diving abroad. The reason for this difference in recovery rates is unknown, and but it may simply arise from 'statistical noise' associated with small samples. Also, it is interesting to note that similar to a study from Geneva, a delay to definitive treatment was not associated with a worse outcome, even though the median presentation latency in the Geneva was six hours, compared to our finding of three days.[9] This is also consistent with an Israeli study that showed that treatment delayed more than 48 hours is still effective in reducing DCI symptoms.[10]

First aid oxygen at scene was infrequently given to divers both in Thailand and overseas. This is comparable to a study from the Canary Islands, which also reported a low rate of provision of on-site first aid.[11] A contributing factor might be lack of awareness regarding symptoms and proper management for DCI among divers and even some physicians.[12] Of the 17 divers who received first aid oxygen on-site, 12 (71%) completely recovered from their symptoms after HBOT, compared with 53 of 82 divers (64%) without first aid oxygen (Figure 2). Accepted best practice is to administer high-concentration oxygen along with hydration as first aid for divers suspected of having DCI.[13] Apparently, either this notion is still not widely recognised, or there was not enough proper first aid kit provided at dive sites, both local and abroad, considering the low proportion of divers given oxygen first aid.

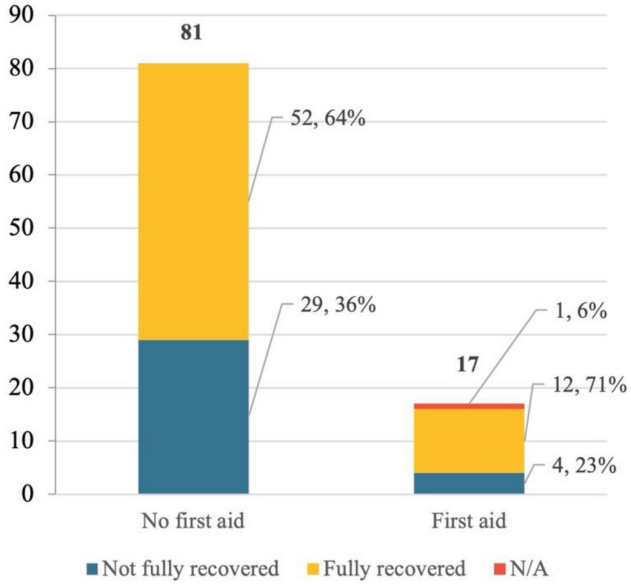
In this study, almost half of the patients received only one session of HBOT while the other half required two to five sessions. As reported elsewhere, most cases of DCS respond satisfactorily to a single session of HBOT, however, subsequent sessions are also encouraged if stepwise improvement is evident.[14]

Most dives were recreational (79 dives out of 98). There were also 14 professional dives and five dives by informal workers. The recovery rate was independent of the purpose of the diving, with 65% of both recreational and professional divers showing full recovery.

Most of the divers in this study were qualified with at least open-water certificates or equivalent. A study conducted in New Zealand, reported a declining incidence in DCI in recent years partly due to increased diving safety together with a decreased number of entry-level diving certifications.[15] A study with a larger number of cases is indicated in order to further investigate any trends in case numbers in Thailand.

The study had some limitations. The medical records were retrieved from only one treatment centre, despite many other governmental and private organisations providing

Figure 2
Number of reported decompression illness cases by first aid oxygen treatment received and recovery status; N/A – not available



HBOT in Thailand. Hence, the sample size was small, and no inferential statistical analyses could be performed.

Conclusions

Decompression illness is regularly encountered in Thailand. It appears to occur in males and females almost equally. First aid treatment with normobaric oxygen is given quite infrequently. Two-thirds of the divers who received HBOT reported full recovery after treatment. The median presentation latency of three days before receiving recompression was longer than ideal, and was similar in those who dived locally and abroad. This suggested that more knowledge and awareness of diving-related illnesses should be promoted in divers, diving schools, and those involved in the tourism industry. Additionally, so as to better understand the associated factors affecting the disease and treatment outcome, more comprehensive and thorough research is needed.

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