Diving Accidents Treated at a Military Hospital-Based Recompression Chamber Facility in Peninsular Malaysia

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SUMMARY

This paper describes the pattern of diving accidents treated in a military hospital-based recompression chamber facility in Peninsular Malaysia. A retrospective study was carried out to utilize secondary data from the respective hospital medical records from 1st January 1996 to 31st December 2004. A total of 179 cases categorized as diving accidents received treatment with an average of 20 cases per year. Out of 179 cases, 96.3% (n=173) received recompression treatment. Majority were males (93.3%), civilians (87.2%) and non-Malaysian citizens (59.2%). Commercial diving activities contributed the highest percentage of diving accidents (48.0%), followed by recreational (39.2%) and military (12.8%). Diving accidents due to commercial diving (n=86) were mainly contributed by underwater logging activities (87.2%). The most common cases sustained were decompression illness (DCI) (96.1%). Underwater logging and recreational diving activities which contribute to a significant number of diving accidents must be closely monitored. Notification, centralised data registration, medical surveillance as well as legislations related to diving activities in Malaysia are essential to ensure adequate monitoring of diving accidents in the future.

KEY WORDS:
Diving accidents, Recompression treatment, Commercial diving, Recreational diving, Military diving, Decompression illness (DCI)

INTRODUCTION

Diving has long been performed for commercial and military purposes but it has undergone a dramatic increase in popularity as a leisure sport diving activity[1]. In commercial diving activities, different techniques and breathing equipments are used to fit into working diving environment such as surface supplied diving or deep and saturation diving[2]. In military diving activities, the military divers are trained to follow the standard military diving manuals and protocols [3]. Diving technology has evolved rapidly in recent years, allowing divers to descend to greater depths and to dives in places which would previously have been impossible[1].

Any occupational (commercial and military) or recreational diving activities may carry specific risks where divers may be exposed to certain hazards such as inert gas and underwater pressure. Diving accidents such as decompression illness (DCI) or barotrauma can result from diving and consequences of these may lead to significant morbidity and mortality among the injured divers. Other potential hazards may also include oxygen toxicity, inert gas narcosis, immersion pulmonary edema and effects of hydrostatic pressure [4].

In Malaysia, diving activities mainly recreational and commercial have increased tremendously since 1990's [5, 6, 7]. The government of Malaysia has begun to promote this country as one of the world's tourist destination. One of the targeted activities of promotion was recreational SCUBA (self-contained underwater breathing apparatus) diving. With a wealth of great diving sites, Malaysia has become a destination of choice for international divers from all over the world to explore the underwater world. There is also an increase in commercial diving activities due to the growth of marine-based industries like off-shore petroleum drilling in Malaysia as well as other commercial diving such as underwater logging activities and underwater constructions [7]. In underwater logging, divers go underwater to cut trees for timber and this activity is carried out in several man-made hydroelectric dams in Peninsular Malaysia [5, 6, 7, 8]. The increases in the different types of diving activities have resulted in more diving accidents reported and treated in recent years in Malaysia.

There are very limited publications related to diving accidents reported in Malaysia. To date, there are two publications so far. Loke *et al.* [9] reported six cases of DCI treated at a state government hospital related to underwater logging in Kenyir Lake. These cases presented with severe cardio-respiratory and neurological disturbances, resulting in two deaths, while the others survived after recompression treatment. Meanwhile, Rozali *et al.* [10] reported a classical case of pulmonary overinflation syndrome (POIS) in a young underwater logger engaged in underwater logging activities in the same location. Some of these diving casualties were highlighted in the local news papers [11, 12].

So far, there is no study to describe the pattern of diving accidents treated in any recompression chamber facilities available in Malaysia. Therefore, the aim of this study was to describe the pattern of diving accidents treated in an established recompression chamber facility in a military hospital in Peninsular Malaysia.

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MATERIALS AND METHODS

A retrospective study was carried out based on medical records acquired from a military hospital in Peninsular Malaysia from 1st January 1996 to 31st December 2004. All cases categorized as diving accidents were collected. Data was classified into categories such as number of diving accident cases treated per year (from 1996 to 2004), background profile of divers (age, sex and citizenship), category of divers (civilian or military), type of diving activities (commercial, recreational or military), whether recompression treatment was received and the type of diving accidents (e.g. DCI, barotrauma, POIS, others). Descriptive analysis was used to analyse the data.

In this study, types of diving activities were defined as follows; (1) Recreational diving is where divers use SCUBA for recreational purposes or as hobbies, (2) Commercial diving is undertaken while performing heavy salvage or engineering works. Work may be done deeper than 54 metres. Air is usually supplied from the surface to the diver via a hose for a longer duration of diving and (3) Military diving is involvement of armed service personel in the salvage of military equipment, explosive ordinance disposal, general ship maintenance, clandestine diving operations and anti-terrorist activities.

In this study, diving accidents were categorized as follows: (1) DCI, (2) barotrauma, (3) POIS, and (4) others. DCI results from formation of bubbles in the tissues or circulation as a result of inadequate elimination of inert gas (nitrogen) after a dive. DCI used to encompass Type I decompression sickness (DCS) (pain only, skin or lymphatic), Type II DCS (cardiopulmonary or neurological involvement) and arterial gas embolism (AGE) [13]. Barotraumas refers to trauma or damage caused to body tissues by the mechanical effects of a pressure differential (between a body cavity and the hydrostatic pressure surrounding the body). Cases of barotrauma included trauma to the sinus, ear (external, middle and inner), thoracic, face mask, gastrointestinal and teeth[3]. POIS is a specific group of barotrauma-related diseases caused by the expansion of gas trapped in the lung, or overpressurization of the lung with subsequent overexpansion and rupture of the alveolar air sacs. This group of disorders includes AGE, tension pneumothorax, mediastinal emphysema, subcutaneous emphysema and rarely pneumopericardium [3].

Permission to conduct the study was obtained from the Commanding Officer of respective military hospital and the Director General of the Malaysian Armed Forces Health Services Division.

RESULTS

Out of 182 cases registered in the hospital information system, only 179 cases were selected and categorized as diving accidents in this study. Three cases were excluded due to incomplete data information. Figure 1 shows that the highest number of diving accident cases was in year 2000 where 45 cases were reported and the lowest were eight cases in year 1998. The average numbers of diving accidents were 20 cases per year.

Table I shows that 93.3% (n=167) of the treated divers were males. The mean (SD) age of the divers was 31.7(7.9) years old and ranged between 19 and 59 years old. Majority of divers were non-Malaysian citizens (59.2%; n=106). One-hundred-and-fifty-six (87.2%) were categorized as civilian divers as compared to military divers (12.8%; n=23). Out of 179 cases, only 173 (96.6%) received hyperbaric recompression treatment and the rest was treated through either out-patient or in-patient observation, and or using other conventional treatments.

Almost half of the cases were related to commercial diving activities (48.2%), followed by recreational (39.0%) and military (12.8%). In commercial diving activities (n=86), majority of cases were contributed by underwater logging (87.2%) as compared to other commercial diving activities (12.8%). In cases secondary to recreational diving activities (n=70), 44.3% were non-Malaysians citizens. With combination of all diving activities (commercial, recreational and military), more than half of the cases consisted of non-Malaysian citizens (59.2%) (Table I, Figure 2). Among the military divers (n=23), majority of cases (65.3%) consisted of navy divers, followed by army (21.7%) and air force divers (13.0%) (Table I, Figure 3).

Table II shows that among the non-Malaysian cases (n=106), majority consisted of Thai citizens (73.8%; n=78) who were underwater loggers (96.2%; n=75). The rest consisted of recreational divers from various parts of European countries, South Pacific region, United States of America as well as from Asia and South East Asia (0.9 to 3.9%).

Figure 4 shows that DCI (96.1%) was the main outcome of diving accidents in this study followed by barotrauma (2.8%). There was also one case of POIS.

DISCUSSION

This study found that there was an average of 20 diving accident cases per year and the incidence is ranged between 8 and 45 cases per year. Majority of cases were males, civilians and non-Malaysian citizens. Commercial diving activities, mainly underwater logging among Thai citizens have contributed to a higher percentage of diving accidents as compared to recreational and military diving. Among the military divers, navy divers constituted the highest percentage. The most common outcome of diving accidents was DCI and this was mainly caused by commercial diving activities. This finding is similar to a study by Dankner *et al.*[14] who reported that there were about 20 diving accidents per year for the past 23 years among recreational divers treated in a recompression chamber facility in Israel. However, their study showed lower percentage of male divers (76.3%), a lower mean age (mean (SD) = 28.5 (9.1) years old) and majority of cases were local citizen (Israeli).

This study found that three specific groups of diving activities contributed to diving accidents. These groups were; (1) commercial diving secondary to underwater logging activities, (2) recreational SCUBA diving and (3) military diving.

Table I: Profile of divers (n=179) treated in a military hospital-based recompression chamber facility in Peninsular Malaysia from 1996 to 2004.

Divers Profile	Mean ± SD	Frequency	Percentage (%)
Age	31.7 ± 7.9		
Sex			
Male		167	93.3
Female		12	6.7
Citizenship			
Malaysians		73	40.8
Non-Malaysians		106	59.2
Category of divers			
Civilian		156	87.2
Military		23	12.8
Recompression treatment			
Yes		173	96.6
No		6	3.4
Types of diving activity			
Commercial		86	48.2
Underwater loggers		75	
Other commercial		11	
Recreational		70	39.0
Malaysians		39	
Foreigners		31	
Military		23	12.8
Army		5	
Navy		15	
Air Force		3	

SD = Standard Deviation

Table II: Citizenship of divers among non-Malaysians citizen (n=106) treated in a military hospital-based recompression chamber facility in Peninsular Malaysia from 1996 to 2004.

Citizenship	No of cases	Percentage (%)
Australia	1	0.9
Belgium	1	0.9
Brazil	2	1.9
British	4	3.9
Canada	2	1.9
Finland	1	0.9
France	1	0.9
Holland	2	1.9
Hong Kong	1	0.9
Indonesia	1	0.9
Ireland	1	0.9
Italy	1	0.9
Jerman	1	0.9
New Zealand	1	0.9
Pakistan	1	0.9
Scotland	1	0.9
Sweden	2	1.9
Thailand	78	73.8
United States of America	4	3.9
Total	**106**	**100.0**

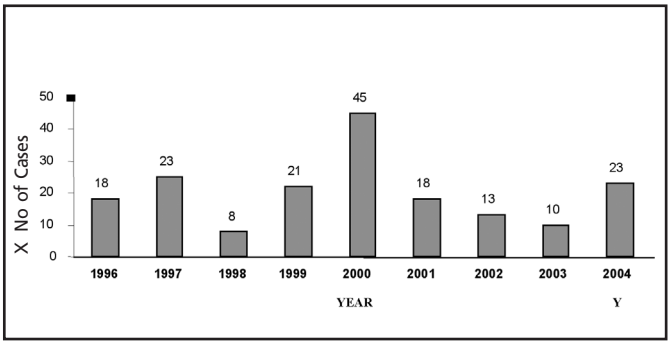

Fig. 1: Distribution of diving accidents (n=179) treated at a military hospital-based recompression chamber facility in Peninsular Malaysia from year 1996 to 2004.

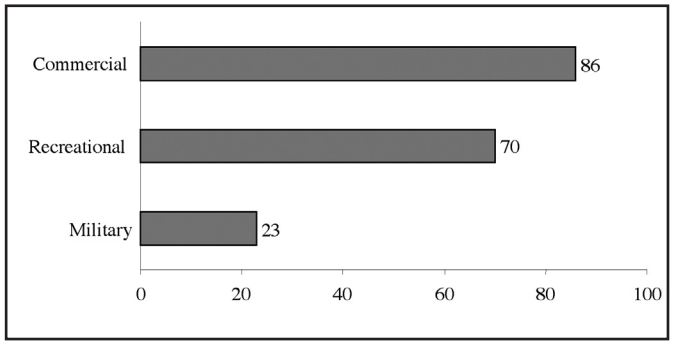

Fig. 2: Type of diving activities (n=179) with diving accidents treated at a military hospital-based recompression chamber facility in Peninsular Malaysia from 1996 to 2004.

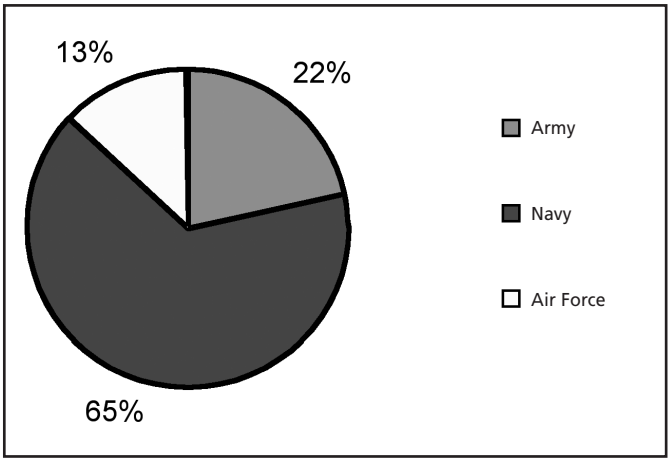

Fig. 3: Military divers (n=23) with diving accidents treated at a military hospital-based recompression chamber facility in Peninsular Malaysia from 1996-2004.

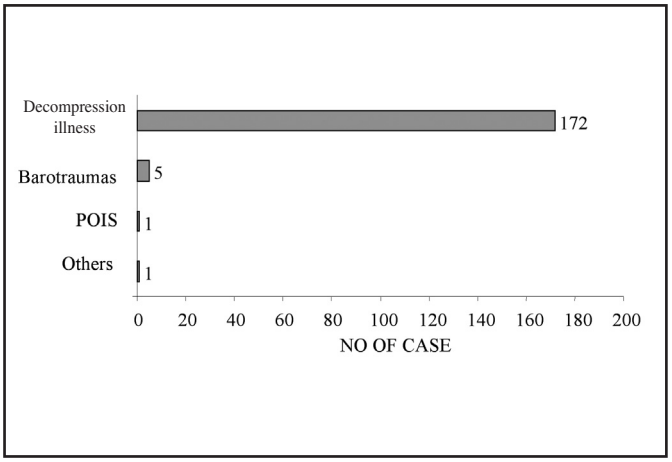

Fig. 4: Types of diving accidents among the 179 divers treated at a military hospital-based recompression chamber facility in Peninsular Malaysia from 1996 to 2004.

In Peninsular Malaysia, the construction of hydroelectric dams in Pergau Lake (Kelantan), Pedu Lake (Kedah), Temenggor Lake (Perak) and Kenyir Lake (Terengganu) in late 1970's and early 1980's have resulted in large areas of man-made submerged forests. The underwater logging activities involve divers (also known as underwater loggers) who go underwater to harvest submerged timbers [7]. These activities have been also reported primarily in North and South America, Russia, Brazil, Chile and Laos [15]. These submerged forests preserve high-quality of tropical hardwood timbers and this commercial logging industry has generated millions of dollars to the state countries [16]. Divers are brought in from Thailand by the local logging concessionaires since the early 1990's [5]. These divers have developed their own underwater logging diving equipments and techniques to harvest the timber underwater, and some of them have experience working in the Nam Ngum Reservoir in Laos [17].

In the beginning, most underwater logging activities were not well supervised. However, during the peak seasons in 1990s, foreign 'experts' from a neighbouring country were brought in to Malaysia to train underwater loggers, but this may have been carried out on an ad-hoc basis. Loke *et al.* [9] found that none of the injured divers were able to produce any evidence of diving professional certification. Abd Halim Mohamed [6] reported in his observations that diving accidents among underwater loggers had increased due to lack of underwater diving training, incorrect use of diving techniques and use of faulty breathing equipments. Repetitive multi-day diving, strenuous working and cold water temperatures were also contributing factors to diving accidents among underwater loggers. There were no recompression chamber facilities available on operation sites and the nearest was about 200km in Royal Malaysian Naval (RMN) Base in Kuantan or 500km in RMN Base in Lumut[7]. This is another important contributing factor to the increase in mortality and morbidity among the injured divers.

The second commonest cause of diving accidents was recreational SCUBA diving. Recreational SCUBA diving has become an increasingly popular sport in Malaysia, due in part of rapid growth of tourism and international travel [18]. Wreck diving has also become another attractive diving activity since there are a number of wrecks in Malaysian waters [7]. Although all recreational SCUBA divers must complete a basic open water diving course, not all of them are experienced divers. This might be a reason for the cases of diving accidents witnessed among them. In addition, recreational SCUBA divers do not have legal obligations for medical assessment prior to diving in Malaysia [8, 18]. However, profesional training bodies do require divers to declare their health status by filling a standard questionnaire and medical opinion is only required if there are uncertainties about their fitness to dive [19].

Military diving activities contributed the least to diving accidents compared to commercial and recreational diving. Among the military personnel, the navy contributed the highest percentage of diving accidents. This is due to the more frequent diving activities during training, exercise and operational tasks undertaken by the navy as compared to other services.

Most of the cases in this study were referred by government healthcare facilities, private hospitals and general practitioners as well as walk-in individuals. Although majority of the diving accidents from 1996 to 2004 were treated in this military hospital, the actual incidence or prevalence of diving accidents in Malaysia maybe still unknown. There may be significant under-reporting of diving accidents, as mild cases may be misdiagnosed, left untreated, or treated at the diver's country of origin. There are also several recompression chamber facilities available in other parts of Malaysia such as in other army or naval bases, universities and private health sectors where treatment might have been given [7]. However the number of cases treated at these other recompression chamber facilities are most likely to be small. The private facilities were only recently developed in 2001, and the facilities in other army and naval bases are relatively small.

It is recommended that preventive measures need to be emphasized in order to reduce the number of diving accidents

specifically related to occupational diving activities. Legislations, notification, centralised data registration, occupational diving training facilities as well as medical surveillance which also include examination prior to diving are essential to ensure adequate monitoring of all diving accidents in Malaysia. Future studies should be carried out to look for the severity of each category of diving accidents as well as outcome of this problem at the national level.

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