RETROSPECTIVE COHORT STUDY OF DECOMPRESSION ILLNESS IN LUMUT AND THE EFFECT OF EARLY TREATMENT

by

DR. FAZRIYATI BINTI JAMHAREE

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LIST OF ABBREVIATIONS

AGE	Arterial Gas Embolism
BMI	Body Mass Index
CI	Confidence Interval
DAN	Divers Alert Network
DCI	Decompression Illness
DCS	Decompression Sickness
GCS	Glasgow Coma Scale
HBOT	Hyperbaric Oxygen Therapy
OCP	Oral Contraceptive Pills
OR	Odd Ratio
PFO	Patent Foramen Ovale
SD	Standard Deviation
TTR	Time to Recompression
URTI	Upper Respiratory Tract Infection

ABSTRACT

RETROSPECTIVE COHORT STUDY OF DECOMPRESSION ILLNESS IN LUMUT AND THE EFFECT OF EARLY TREATMENT

Introduction

Decompression illness is a rare condition among divers, aviators and astronauts in which bubbles form in blood and tissues following a reduction in environmental pressure. It has wide clinical manifestation and gives a great challenge to Emergency Physician to differentiate decompression illness from other diving related injury. Early detection of decompression illness is crucial as this will determine the type of treatment based on the severity.

Severe decompression illness is a denominator for poor prognosis and warrant a definitive treatment with hyperbaric oxygen therapy. Fast access to the treatment will be a good indicator for the recovery. This study aimed to determine recovery outcome in relation to the time to treatment from the onset of symptoms.

Methodology

This was a retrospective cohort study of all patients diagnosed as decompression illness and treated with hyperbaric oxygen therapy in Hospital Angkatan Tentera Lumut since January 2000 to December 2010. Data was collected from registration book and medical records in the recompression hyperbaric chamber. All data entered into SPSS version 21.0.1 for further descriptive statistic and analysis. Chi square test, univariate and multiple logistic regressions was used to identify significant variables ($p \leq 0.25$) in comparison of complete recovery between early TTR group (within 6 hours) and delayed TTR group (more than 6 hours).

Results

A total of 96 cases reviewed and 16 patients (16.7%) were able to get early access for the recompression therapy whereas 80 patients (83.3%) had delayed treatment of more than 6 hours from symptoms onset after surfacing. All different times of treatment was tested and significantly found that early treatment of less than 6 hours had better recovery status in getting complete resolution of symptoms (OR 8.33, P value 0.050).

Conclusion

Recompression should be administered early as it resulted in better outcome recovery by limiting disability in divers associated with DCI and prompt complete resolution of symptoms.

ABSTRAK

KAJIAN KOHORT RETROSPEKTIF MENGENAI PENYAKIT “DECOMPRESSION ILLNESS” DI LUMUT DAN KESAN RAWATAN AWAL

Pengenalan

“Decompression illness: merupakan penyakit yang jarang berlaku di kalangan penyelam, juruterbang pesawat berkuasa tinggi dan angkasawan. Ia terjadi disebabkan oleh buih-buih yang terbentuk di dalam saluran darah dan tisu-tisu berikutan pengurangan tekanan alam sekeliling. Ia mempunyai pelbagai ciri-ciri klinikal dan merupakan satu cabaran kepada Pakar Kecemasan untuk membezakan penyakit “decompression illness” dengan penyakit-penyakit lain yang berkaitan dengan menyelam. Mengenalpasti tanda “decompression illness’ dengan cepat adalah sangat penting untuk menentukan jenis rawatan berdasarkan tahap serius penyakit.

“Decompression illness” yang serius merupakan satu tanda prognosis yang kurang baik dan memerlukan rawatan muktamad dengan terapi oksigen hiperbarik. Rawatan pantas akan menjadi petunjuk yang baik bagi proses pemulihan. Kajian ini bertujuan untuk melihat hubung kait di antara masa rawatan dari bermula nya gejala penyakit dengan pemulihan sepenuhnya.

Metodologi

Ini adalah merupakan satu kajian kohort retrospektif dengan melihat kesemua rekod data pesakit yang didiagnosis sebagai "decompression illness" dan dirawat dengan terapi oksigen hiperbarik di Hospital Angkatan Tentera Lumut bermula Januari 2000 sehingga Disember 2010. Data dikumpul daripada buku pendaftara serta rekod perubatan yang terdapat di ruang hiperbarik. Kesemua data dimasukkan ke dalam SPSS version 21.0.1 untuk statistik deskriptik dan analisis lanjut. Ujian Chi square dan ujian analisis regresi logistik digunakan untuk melihat hubungan yang signifikan di antara keputusan klinikal dan masa untuk penyahmampatan.

Keputusan

Jumlah keseluruhan sampel ialah 96 kes dan 16 pesakit (16.7%) berjaya mendapatkan rawatan rekompresi dalam masa yang awal. Terdapat 80 pesakit (83.3%) lewat diberi rawatan rekompresi melebihi masa 6 jam selepas bermulanya gejala simptom. Ujian dilakukan ke atas semua perbezaan kumpulan masa kepada rawatan dan erdapat hubung kait yang signifikan di antara masa untuk penyahmampatan bagi kurang dari 6 jam dalam memperolehi kesan pemulihan sepenuhnya (OR 8.33, P value 0.050).

Kesimpulan

Rawatan rekompresi patut diberi awal memandangkan ia memberi kesan pemulihan yang lebih baik dengan mengurangkan ketidakupayaan dan mempercepatkan proses pemulihan sepenuhnya.

APPENDICES

CHAPTER 1 : INTRODUCTION

Diving is performed for various purposes including commercial, recreational, military, underwater construction, oil industry, underwater archaeology and scientific assessment of marine life. Diving related illness had became a public health concern as there are increasing in number of divers. It is important knowledge for Emergency Physician as patients usually presented to emergency department to seek treatment and one of the common diving related illnesses known worldwide is decompression illness (DCI). Currently, diving medicines is one of the established specialty with regards to the dive-related medical condition.

The incidence of DCI is low in the diving community and it’s rare to encounter in clinical practise as overall. Occurrence rate for DCI in operational open water dive varies: 0·01–0·019% for recreational divers, 0.095% for commercial divers and 0.03% for US Navy divers. In later years, approximately 0.03% of occurrence rate in DCI cases for the recreational divers done by the Divers Alert Network in 2008 (Vann *et al.*, 2011).

Decompression illness is a term been used to refer to any medical disorder, illness or injury arising as a result of decompression from a higher to lower ambient pressure (Vann *et al.*, 2011). It is a disease of divers, aviators and astronauts in which bubbles form in blood and tissues following a decompression. These bubbles may cause sufficient ischemia, mechanical damage, or inflammatory derangements which later manifest as symptoms. Symptoms are varies and the severity of clinical presentations are depending on their size, number, and location of bubbles (Mitchell *et al.*, 2004).

Occurrence of DCI in diving is not easily predictable. There are many known predisposing factors and it can be divided into divers participation (risk/diver) and diving activity (risk/dive). Diver's factor such as age, gender, obesity, smoking, alcohol intake, fitness and medical history are still important elements that contributed to DCI. Smoking and alcohol consumption are known to be a risky behaviour among the divers (Beckett and Kordick, 2007). The factors had been identified and preventive management were taken to reduce the risk of DCI. Understanding of environmental factors had developed diving procedure/ decompression tables based on level risk as well as better diving equipment such as breathing apparatus and tools to monitor depth and dive time. Furthermore, certified divers are more adherence to safe diving practise and had lower rate of dive-related injury (Beckett and Kordick, 2007).

DCI have wide ranging clinical manifestations as it can involve in any body systems. The severity of clinical manifestations such as neurological involvement are the only predictor of the poor outcome (Blatteau *et al.*, 2011). Permanent complication to central nervous system (CNS) is a major thing to be concern of and it was one of the common decompression related problem. Common long term morbidity are involving aural symptoms such as hearing loss, tinnitus or vertigo (Taylor *et al.*, 2003). It later had effect on health status especially to those who had history of DCI previously. These lead to further evaluation of health status among former divers who had experienced DCI during their career time.

The definitive treatment for DCI is a recompression and hyperbaric oxygen treatment (HBOT). Initiate early treatment after the diagnosis been made will give better chance of complete recovery from the illness (Edmonds *et al.*, 2013; Mitchell *et* *al.*, 2004). However, in area of absence of immediate availability of recompression chamber, an adjunct therapy should be provided such as giving high concentration of 100% oxygen will help in nitrogen washout and thereby reduces the free gas volume in the blood (Mitchell *et al.*, 2004).

There are several worldwide publications regarding DCI as it has became a great public concern though it is not as common as other diseases. More studies been conducted as physicians tried to untangle certain fact that is still unclear with a hope of better outcome in the future. However, there are still limited study that had been done in Malaysia even though diving is one of the vital jobs in commercial workers and military for more than 10 years and it has become more popular nowadays among recreational divers.

Lumut in Perak is one of the places that host a recompression chamber facility in Malaysia. The facility is located in the military hospital base and run by the military physicians that provide coverage for the entire Northern part of Malaysia. It has been established and noted as the long standing recompression therapy provider since 1990's.

This study is done to determine the incidence of DCI, the risk factors that may contribute to the illness and recovery outcome after the initiation of the treatment. Previous study done by Rozali *et al.* (2008) only described the frequency of diving accidents and pattern of diving injury treated in recompression chamber of Hospital Angkatan Tentera Lumut but the effect of time to treatment was not included.

CHAPTER 2 : LITERATURE REVIEW

Decompression illness (DCI) results from the formation of bubbles in body tissues during reduction in environmental pressure. Bubbles can affect any system as it may carried to variety of organs through the bloodstream as well as may formed directly in different tissues. Thus, it may have a wide range of clinical manifestation and severity (Mitchell *et al.*, 2004).

The term of DCI are best to describe both Decompression Sickness and Arterial Gas Embolism as these two syndromes have a different pathology (Mitchell *et al.*, 2004; Vann *et al.*, 2011). Arterial Gas Embolism (AGE) is caused by entry of gas in arterial circulation through shunt in patent foramen ovale (PFO) or resulting from ruptures alveolar capillaries following pulmonary barotauma (Hall, 2014; Lynch and Bove, 2009; Vann *et al.*, 2011) ; while Decompression Sickness (DCS) is caused by circulating bubbles of inert gas in blood and tissues resulting from supersaturation during decompression as rate of ambient pressure reduction exceeds the time rate of inert gas to washout from the tissue (Vann *et al.*, 2011).

Arterial gas embolism usually precipitated by rapid ascent or present of lung diseases (Vann *et al.*, 2011). Acute onset of AGE as early as 5 minutes of ascent commonly had rapid progression of gross manifestations (Hall, 2014; Lynch and Bove, 2009). It may cause cardiopulmonary compromise but most often affect the brain (Vann *et al.*, 2011). The bubbles from the pulmonary vein travelled up via left heart and reach the cerebral vasculature resulting stroke mimics (Lynch and Bove, 2009). Thus, it require emergent recompression treatment and not uncommon fast resolution occurred once initiate early treatment (Hall, 2014; Lynch and Bove, 2009).

Decompression sickness occurred as the dissolved nitrogen resulting from supersaturation cause tissue injury through mechanical effects, vascular occlusion and activation of the clotting cascade and inflammatory mediators (Lynch and Bove, 2009). It has a wide range of symptoms depending on the site of the bubbles end up in the system (Mitchell *et al.*, 2004). It is typically classified into Type I and Type II. Type I decompression sickness include musculoskeletal symptoms, cutaneous manifestation and constitutional symptoms. Whereas Type II decompression sickness characterized by neurologic and systemic manifestation; commonly presented with numbness, muscle weakness, mental or motor abnormalities (Edmonds *et al.*, 2013; Lynch and Bove, 2009; Vann *et al.*, 2011).

As overall, DCI may develop within 24 hours after a dive. Most of cases are mild DCI which defined as symptoms occurred after 12 hours of surfacing and patient has normal blood pressure, alert, oriented, not tachypnic, able to ambulate and urinate voluntarily. Such an individual is unlikely to deteriorate and enough with supportive managements. Severe cases generally have short onset time after surfacing, severe manifestations within 12 hours and rapid progression (Mitchell *et al.*, 2004). Majority of severe cases will be evident within six hours and 50% of it is within the first hour of the dive. The time of onset of symptoms depends to the type of dive. Symptoms may even present during ascent or at the decompression stops in some extreme cases (Edmonds *et al.*, 2013).

Risk factors of the disease can be categorized to environment, diver factor and apparatus dysfunction. For past few decades, lots of studies been conducted in order to understand more about the disease; so that more precaution can be taken by divers. Currently, there are thousands of people who involved with diving activity; either as a recreational divers till up to professional group such as diver instructor, military or underwater construction.

Advancing age may increase the risk of DCI (Edmonds *et al.*, 2013). Young age group between 18 – 24 years old might be at risk for this illness due to risky behaviour and inexperienced rather than adult divers (Hagberg and Ornhagen, 2003). However, tendency for DCS was found higher with increasing of age due to maximum oxygen uptake during exercise was reduced; generally associated with an increased in adipose tissue by age (Carturan *et al.*, 2002). Though some found that there was no association between ages to the incidence of DCS as it demonstrated that the bubble formation appeared to be unrelated to the diver’s age (Dujić *et al.*, 2004); most of the physician concluded that the weight of evidence supports age as a risk factor. Not surprisingly, no clear threshold age at which risk increases has been identified. This may lead why there is no formal age limitation for diving and recommendation in elderly are based on the presence of acute or chronic illness (Lynch and Bove, 2009).

For many years it has been proposed that women might be at higher risk of DCI than men. There were only small differences between male and female in the incidences of decompression sickness which considered as insignificant (Hagberg and Ornhagen, 2003). It has been suggested that higher mean body fat percentage in women make this gender more susceptible for the illness (Edmonds *et al.*, 2013). Hormonal changes during menstruation might increase the risk but it was hard to establish the relationship between menstrual cycle and DCI as most of the female divers changed their diving habit during their menstruations. This is related to the perceived of their dive safety may be impaired (Dowse *et al.*, 2002). No statistical difference between group of women who were taking oral contraceptive pills (OCP) who suffered the illness and those who were not. When analyzed by the level of experience, estimation rate for DCS in men was 2.60 greater than women as women had less aggressive dive profiles than men (Dowse *et al.*, 2002).

Smoking had been linked with many diseases but very little information with DCI. Rates of DCI occurrence between smokers and non smokers group was not significant (Dowse *et al.*, 2002). However, the amount of smoking correlated with the severity of DCI. Heavy smokers group had a higher percentage to present with a more severe symptoms rather than light smokers group. It closely related with the fact that cigarette smoking associated with a lung diseases that predisposed a diver to pulmonary barotraumas and severe form of DCI. But there was no significant difference between light smokers and non smokers group (Buch *et al.*, 2003).

One of the risky behaviour for safe dive is alcohol. Divers who over-indulge in alcohol may susceptible to DCI. This is also applied to those who were taking other drugs or medications. Taking an alcohol within 12 hours prior to dive (taken the night before); may affect as it associated with dehydration or the vascular dilatation ("hangover") which may lead to increase the nitrogen uptakes (Edmonds *et al.*, 2013). Statistically not remarkable with only 3.3% of frequent divers admitted to the consumption of alcohol or an illicit substance within 12 hours of a dive; but this suggest more risky behaviour (Beckett and Kordick, 2007).

Obesity appears to be a predisposing factor for DCI; probably due to higher solubility of nitrogen in fat tissue causing increases the total nitrogen content in the body which subsequently increase the risk of DCI. This may be relevant for those with a body mass index (BMI) of more than 25 kg/m² (Edmonds *et al.*, 2013). Association between bubble formation and adipose tissue were proved with the combination of poor physical fitness (Carturan *et al.*, 2002). Comparing to both genders, no significant differences in rates of DCS in relation to those who had a higher BMI (Dowse *et al.*, 2002).

Not all divers are physically fit and healthy. Both these had close relationship with the obesity. The less physically fit the diver, the more likelihood of DCI. Quite a number of researchers studied over relationship between exercise and gas bubbles formation. It is probably due to more energy used and more blood flow is required for the same outcome leading to more nitrogen transported in the blood flow (Edmonds *et al.*, 2013). In term of times, exercise within 24 hours before performing a dive significantly reduced the number of bubble in the right heart of divers (Dujić *et al.*, 2004). Younger, slimmer or aerobically fitter divers produced fewer bubble than older, fatter and poorly fit divers. Being elderly, overweight and unfit still could reduced their bubble production by improving their physical fitness and encourages elimination of bubbles by slow ascending during decompression (Carturan *et al.*, 2002). Gentle exercises during decompression may also promoting circulation by enhancing inert gas eliminations (Edmonds *et al.*, 2013; Nishi *et al.*, 2000). Thus, it concluded that exercise enhance the diver's safety and have some preventive effect on occurrences of DCI. For a professional group of divers such as military personnel's or commercial divers, exercise is an essential to them and both are required to maintain a high level of fitness (Nishi *et al.*, 2000). This might be why this group had lower incidence of DCI than others.

An underlying medical condition in some divers is one of the concerned. Apparently, quite a number of divers continued to dive despite of their medical condition and only one third of population sought for an expert regarding their illness (Beckett and Kordick, 2007). One third of diver's population had some condition called patent foramen ovale (PFO). This group are more susceptible to develop DCI as the bubbles passed through the foramen by passing the lungs which associate with more serious symptoms (Edmonds *et al.*, 2013). Risk was about 5 times higher than among divers without PFO. The risk of suffering major DCI is closely related with the size of PFO; which it will increase for every degree of PFO. While a small size of PFO had similar risk like those who had no PFO. Every degree (Torti *et al.*, 2004). A screening to detect PFO is a way of reducing the risk of DCI. Nevertheless, a routine screening not warranted as the risk from a PFO is not great enough to be appropriate to test in all divers and it is not a cost effective (Edmonds *et al.*, 2013; Vann *et al.*, 2011). It was only less than 0.02% of incidence related with absolute neurological DCI (Vann *et al.*, 2011).

Diving with asthma is another controversial issue. Asthmatic may increased the risk of acute bronchospasm possibly due to airway resistance, increase work of breathing at depth and cold exposure during a dive. Pulmonary obstruction, air trapping and hyperinflation during acute asthmatic attack increased the risk of severe DCI. It is difficult to determine the relative risk of injury for asthmatic divers but there was no evidence of increased risk of diving related injury among mild asthmatic group (Lynch and Bove, 2009). Besides that, a previous history of DCI made the divers predisposed to subsequent episodes especially if it was unexpected from the dive profile and involved with neurological manifestation (Edmonds *et al.*, 2013).

Generally, the deeper the dive the greater the risk as there will be more gas been absorbed. Risk was higher with a dive deeper than 10 metres (Edmonds *et al.*, 2013). A lifetime incidence of DCI in deep diving group of more than 40 metres depth was 2.5 fold than group of less than 40 metres (Klingmann *et al.*, 2008). The same principle goes to the duration of dives. More gas absorbed if the diver had a longer dive at any one depth. This increased the risk of DCS (Edmonds *et al.*, 2013).

Apart from that, people tend to dive repetitively. There was some degree of nitrogen load from the previous dive in each repetitive dive. A repetitive dive will often start with the diver carrying nitrogen bubbles from the previous dive. Nitrogen elimination is less rapid from bubbles than it is from the same amount of gas in solution. These remnant bubbles will be supplemented by nitrogen taken up during subsequent dives causing DCI is more likely (Edmonds *et al.*, 2013).

Multiple ascents during a dive imply multiple decompressions and it often involves rapid ascents. There is a significant relationship between ascent rate and the bubble production. Higher grades of bubbles associated with faster ascent and it was higher from 50 minutes after surfacing (Carturan *et al.*, 2002). The bubbles may not be adequately filtered by the lungs and passing along into the tissues which increased risk of DCI (Edmonds *et al.*, 2013).

Some speculated the type of gas used during a dive may give a risk. In military system, commonly use a 100% oxygen tank in a closed circuit for operational dives. It gives a risk of oxygen toxicity practically at depth limit greater than 9 metres (Edmonds *et al.*, 2013; Hall, 2014).

Education and training reduced the incidence of DCI. An instructor group had a lower incidence of DCI symptoms than dive masters. It also lowered among those who had frequent dives (Hagberg and Ornhagen, 2003). There was highly significant correlation between experiences and reporting decompression sickness (Dowse *et al.*, 2002). Less experienced divers with less 200 logged dives had a higher risk of DCI (Klingmann *et al.*, 2008). Higher level of training with more experiences taught them to be more alert and do safe diving.

Those findings also supported by Rozali *et al.* (2008) based on collected data in treated DCI cases in Hospital Angkatan Tentera Lumut. Occurrence of DCI recorded higher among civilian with 87.2% compared to military divers at 12.8%. These incidences were not common among the military group as they are obligated to declare their health status, and undergone necessary training/safety practices meanwhile civilians do not have any legal obligation for medical assessment.

Other indicator that differentiate these groups are exercise which is essential to professional group of divers such as military personnel's or commercial divers; and both are required to maintain a high level of fitness (Nishi *et al.*, 2000). It contributed to the reason why this group had lower incidence of DCI than others. Furthermore, more training following a standard diving navy manual, more safety practised and better equipments were an important key. In this study, requirements for routine diving medical surveillance, equipment maintenance requirements and additional training may result in lower incident rates mainly in military.

Once the diagnosis had been made, physician will assess the condition, severity and determine the type of treatment accordingly. Although identification to both pathology of DCI are useful for epidemiology and helpful for further recommendation for on future diving, the end treatment still the same as both pathology required hyperbaric oxygen treatment. However, in mild group of DCI, they may only need supportive treatment.

Principles of first aid treatment in DCI are basic life support, 100% oxygen, fluid replacement and positing at rest. Hyperbaric oxygen treatment (HBOT) is the standard and definitive treatment for DCI (Vann *et al.*, 2011). It's involves in the delivery of 100% oxygen inside a treatment chamber at a pressure of more than one atmosphere (1 ATA). Recompression tables were decided by the physician. In case of partial recovery, additional hyperbaric oxygen treatment (HBOT) sessions were given until the patient fully recovered or until no further improvement observed (Stipp, 2007).

Generally, severe cases of DCI had a shorter time interval to hyperbaric chamber as neurological manifestation warranted immediate transportation. A number of additional HBOT sessions were significantly higher in the neurological group

(DCS2AGE). However, the final outcome was good in both group of neurological and non-neurological manifestation with no significant difference (Kot *et al.*, 2008).

There was an evidence of greater effectiveness and outcome in those neurological DCI group that receiving early HBOT. It could limit the disability in divers and it was suggested to receive HBOT within 6 hours after surfacing (Stipp, 2007).

Kizer (1982) reviewed cases of delayed recompression therapy of more than 12 hours delayed after the onset of symptoms. Of serious affected DCS group had 84% of complete recovery in 12-24 hours group compared to those of more than 24 hours group.

Treatment of more than 12 hours after the onset of injury showed no substantial improvement for most of the severely injured divers. Given additional treatments were only had a little contribution to overall improvement. Residual complication was strongly related with the severity of the symptoms rather than time to treatment (Ball, 1993).

Study by Xu *et al.* (2012) also concluded that a complete recovery rate was significantly lower with a longer delayed of treatment. It was significantly higher of full recovery in group treated within 12 hours from symptoms onset with achievement of 91.3% regardless of the severity of at the presentation.

Though there was statistical relationship between the shorter time to recompression with higher probability of complete resolution, but it was not a clinical relevance. Shorter time to recompression was not a guarantor of better recovery but the poor outcome was strongly associated with the severity of neurological symptoms at presentation (Blatteau *et al.*, 2011). Delayed to recompression of less than 3 hours were not improved the outcome of DCS divers despite of using a deeper treatment table (Gempp and Blatteau, 2010)

However, recent study by Hadanny *et al.* (2015) showed that delayed HBOT still had a significant value despite of recorded cases were greater than 48 hours after surfacing. It still had complete recovery rates that not much differ from early treatment group. It also found no association between the time to recompression and the short term clinical outcome.

The severity of the presentation was the only factor of the poor outcome. Poorer outcome not only need earlier treatment but also associated with the need of more HBOT sessions for a better result.

Nowadays, dive computers are being used by divers to track their dive and decompression time accurately without having to calculate diving time based on depth and the dive tables. Despite advances with dive computers, divers still develop DCI either from disobeying their decompression guidelines or other factors. Even if a diver is adherent to appropriate dive time and depth, DCI may still occur as the dive tables are only based on decompression theory.

CHAPTER 3 : OBJECTIVES

3.1 GENERAL OBJECTIVES

To conduct survey on decompression illness cases among divers treated in Lumut, Perak.

3.2 SPECIFIC OBJECTIVES

3.2.1 To analyze the general incidence and demographic of decompression illness treated with hyperbaric oxygen therapy in Lumut, Perak.

3.2.2 To determine the association between incomplete recovery and time to treatment within 6 hours and more than 6 hours in cases of decompression illness.

3.3 NULL HYPOTHESES

There will be no significant association between delayed of treatment and recovery of decompression illness.

CHAPTER 4 : RESEARCH METHODOLOGY

4.1 STUDY DESIGN :

This was a retrospective cohort study.

4.2 POPULATION AND SAMPLE :

4.2.1 Reference population:

Divers with decompression illness in Malaysia.

4.2.2 Source population:

Confine only reported divers with decompression illness treated in Lumut, Perak.

4.2.3 Inclusion criteria:

- All recorded decompression illness cases between 2000 to 2010 and required hyperbaric oxygen therapy (recompression therapy) in Hospital Angkatan Tentera Lumut, Perak.

4.2.4 Exclusion criteria:

- Any recorded decompression illness cases that not occurred within year of 2000 to 2010.
- Decompression illness cases not required for hyperbaric oxygen therapy
- Missing data or patient’s medical record.

4.3 SAMPLE SIZE:

All cases of decompression illness that had been treated with recompression therapy during study period were obtained.

By using Power and Size Software, the sample size calculations as below:

Variables	**p0**	**p1**	**m**	**α**	**Power**	**n**	**10% drop rate**	**Total Sample Size = (n x 2)+ 10%**
Recovery	0.053	0.135	1	0.05	0.8	198	19.8	415

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Therefore, the sample size of 415 patients was a figure to be achieved.

4.4 RESEARCH TOOL:

See sample data collection sheet with reference to Appendix A.

4.5 STUDY APPROVAL:

This study was approved by Human Research Ethics Committee (HREC) Universiti Sains Malaysia on 5th June 2014 (Appendix B). Consent for record tracking was obtained from Commanding Officer of Hospital Angkatan Tentera Lumut Perak on 17 July 2014 (Appendix C). No written consent was needed according to the local ethics regulations.

4.6 DATA COLLECTIONS:

Hyperbaric chamber in Hospital Angkatan Tentera Lumut, Perak were only kept a record of all cases treated with hyperbaric oxygen therapy. Data for this study was collected retrospectively from registration book and medical records in the recompression hyperbaric chamber. Only decompression illness cases that been treated with hyperbaric oxygen therapy from January 2000 to December 2010 taken for this study.

The following details were gathered from the patient's files including demographic data (age, sex, BMI, smoking, alcohol consumption, past medical history), years of experience and training level, dive profiles (depth, total dive time, dive safety stop, type of tank), type of dive (single/repetitive), onset of symptoms after surfacing, clinical presentations, time to treatment from onset of the symptoms, number of HBOT sessions and recovery outcome. Evaluation for clinical outcome or any permanent sequelae was done after a series of treatment session. However, important data on surface interval between dives were dropped as most of patient's data had no records on this.

Further information on dive profiles was able to determine the types of diving activities. It categorized into 1) military diving which involved with armed personnel and related to the military equipment/activities, 2) commercial diving with involved with performing of the heavy or engineering work and 3) recreational divers who dive for hobby and recreational purpose.

The divers were divided into two groups: early recompression group and delayed recompression group. Early recompression group was defined as less than 6 hours of time to recompression (TTR) from the onset of symptoms whereas delayed recompression group is more than 6 hours of TTR from the onset of symptoms. The cut of value for early TTR used based on medical evidence supported the optimal effect of HBOT within 6 hours after surfacing. The delayed group was further divided into 6-12 hours, 12-24 hours and more than 24 hours (Stipp, 2007; Xu *et al.*, 2012).

It is difficult to distinguish decompression sickness from arterial gas embolism on the basis of the information provided by the divers; as neurological DCS and AGE share similar symptoms. Thus, term decompression illness has been used instead.

4.7 DATA ENTRY AND STATISTICAL ANALYSIS:

4.7.1 Data entry

Data entered and analysed by using SPSS version 21.0.1 by using SPSS software in Medical Informatics Laboratory, School of Medical Sciences, University Sciences Malaysia.

4.7.2 Descriptive statistic

The categorical variables involving the demographic data and diving related informations were described in frequency and percentage.

4.7.3 Statistical analysis

Objective 2 : Results were expressed in number and percentage.

Recovery outcome was used as an ordinal dependent variable (complete recovery and incomplete recovery). Univariate analysis was performed using Chi square test to identify significant variables ($p \leq 0.25$) in comparison of complete recovery between early TTR group (within 6 hours) and delayed TTR group (more than 6 hours). The delayed group was further divided into 6-12 hours, 12-24 hours and more than 24 hours. Factors with a univariate p-value ≤ 0.25 were incorporated into a univariate and multiple logistic regression analysis.

4.8 TERM DEFINITION

1. Decompression Illness :

   An illness caused by formation of bubbles in blood vessels or tissues during or after a reduction in environmental pressure (decompression). It consists of decompression sickness and arterial gas embolism (Vann *et al.*, 2011).

2. Decompression sickness :

   A condition due to circulating bubbles that formed and increases in size of inert gas in blood vessels or tissues; as a result if the rate of ambient pressure reduction exceeds the rate of inert gas washed out from tissues (supersaturation during decompression) (Vann *et al.*, 2011).

3. Arterial Gas Embolism :

   Arterial Gas Embolism (AGE) is caused alveolar gas introducing into the arterial circulation through shunt in patent foramen ovale (PFO) or resulting from ruptures alveolar capillaries following pulmonary barotauma (Vann *et al.*, 2011)

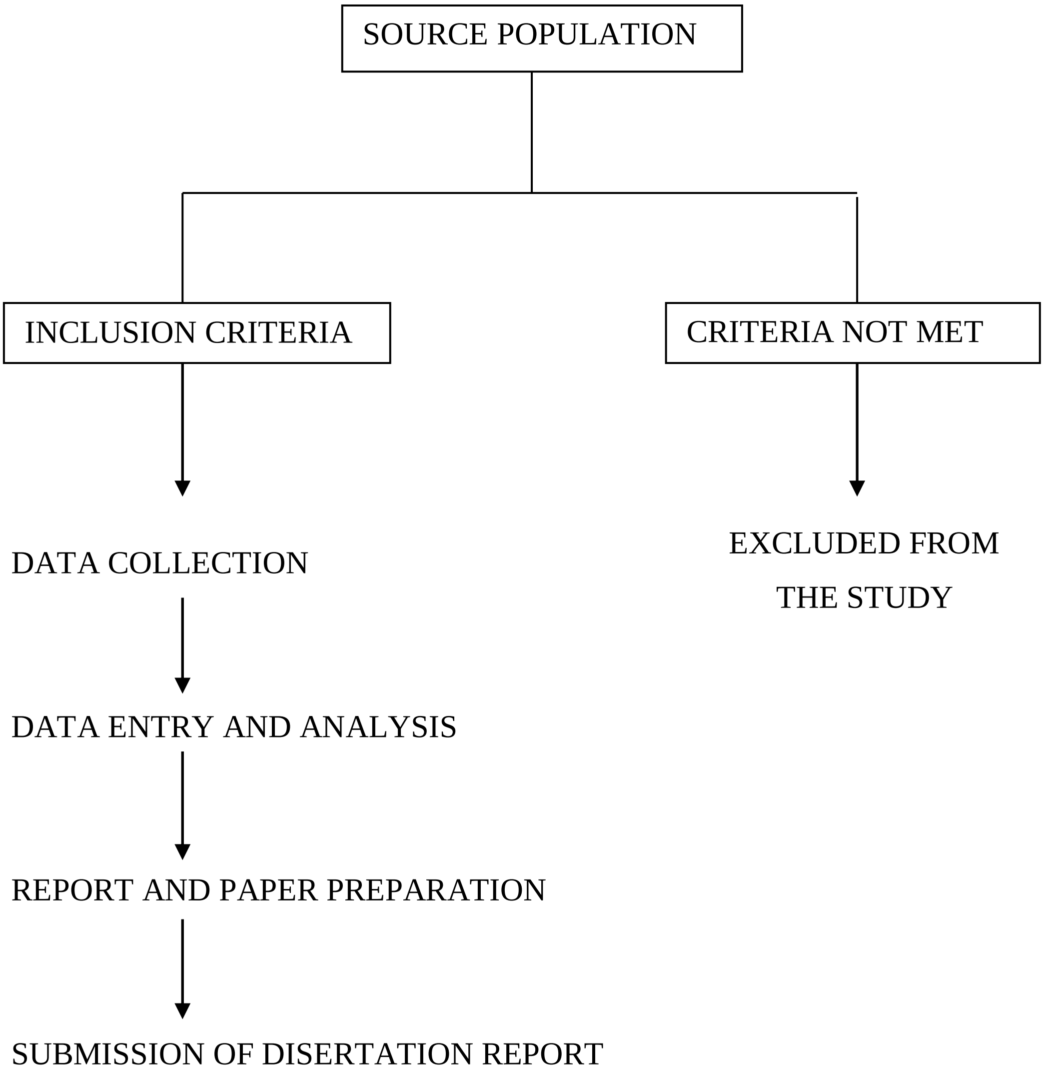
4. Incomplete recovery (Sequelae)

   Residual symptoms that remain permanently after underwent series of complete treatment therapy.

5. Safety stop

   Safety stop is often indicated at shallow depth of 3-5 metres for 3-5 minutes for decompression requirement for a dive and routinely done if exceeding 12 metres depth. It allow the diver to tune his buoyancy before ascending to surface and also give an extra time for absorbed nitrogen to be released from the body (Edmonds *et al.*, 2013)

4.9 FLOW CHART



CHAPTER 5 : RESULTS

5.1 INTRODUCTION

A total number of 175 patients had been treated for diving related injury recorded in Hyperbaric Department of Hospital Angkatan Tentera Lumut from January 2000 to December 2010. All registered cases had various types of diving related illness and were treated with HBOT. However, only 96 cases were accepted for this study after excluding all the exclusion criteria (Figure 5.1) and the numbers of cases treated by years are varied (Figure 5.2). Most of the cases in this study were referred by government healthcare facilities, private hospitals and general practitioners including walk-in individuals. Hospital Angkatan Tentera Lumut received cases from various types of diving activities and group due to limited recompression chamber facilities availability in Malaysia as well as being one of the nearest facilities the Northern region.

On average, 10 cases of DCI recorded per year and the incidence ranged between 5 to 17 cases per year. All 96 cases were diagnosed as DCI by attending physician throughout those 10 years and required hyperbaric oxygen therapy (HBOT) for definitive management. All the patients were admitted to the ward and were only discharged once fully recovered or in some cases declared with no further improvement after series of complete treatment session.