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Characteristics of Patients with Decompression Illness at the Hyperbaric Polyclinic of Prof IGNG Ngoerah General Hospital Bali before the COVID-19 Pandemic

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Abstract---*Decompression illness (DCI) is an injury suffered by divers due to the formation of nitrogen bubbles in the bloodstream and tissues during or after a pressure drop in the surrounding environment when diving. Bali is one of the most famous diving spots in Southeast Asia and also has a Hyperbaric Oxygen Therapy (HBOT) center in Prof. IGNG Ngoerah General Hospital. This study aims to determine the characteristic of DCI patients at the Hyperbaric Polyclinic in Prof. IGNG Ngoerah General Hospital, Denpasar, Bali before the COVID-19 pandemic. A descriptive retrospective study has conducted by descriptive retrospective by collecting administrative data at the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital in 2018-2019. The required examination data are demographic data, diver profiles, DCI characteristics, and the previous therapy. Data analysis using SPSS Version 24. Most DCI patients in this study were foreigner (88.1%), men (53.2%), normal BMI (37.3%), no prior history of disease (88.9%), diving depth >20 meters (n=79, 62.7%), average surface interval 101,184 minutes (30-1440 minutes), diving duration 1-3 hours (n=69.54.8%), DCI type 2 (58.7%) with major severity (57.9%). Of the overall patients, 14.3% rapid ascent, 2.4% panicked while diving, 10.3% made flights and 6.3% climbed after diving. Most of them underwent HBOT (91.3%). Diving activities require strict monitoring. Education on the factors that affect the risk of DCI events needs to be conveyed to divers as a primary and secondary preventive so that it is expected to reduce morbidity and mortality due to DCI.*

Keywords---*diving, decompression illness, decompression sickness, hyperbaric oxygen therapy.*

Introduction

The island of Bali, which is located in the central region of Indonesia, has a very beautiful and diverse sea so it has many spots for diving. Not only is it a diving destination in Indonesia, but the island of Bali is also one of the provinces that have the most famous diving locations in Southeast Asia (Gerungan & Chia, 2020). Diving is a difficult job that has many risks that can be caused, such as DCI.

The formation of intravascular or extravascular bubbles that lead to DCI will destruct local tissues or becomes an embolism that can clog blood flow and the nervous system, causing symptoms such as joint pain, muscles, headaches, and hives, paralysis, tingling or thick feeling, to death (Vann et al., 2011; Wijaya et al., 2021).

There are 2 pathomechanisms of DCI, namely arterial gas embolism and decompression sickness (DCS) (Duplessis & Fothergill, 2008; Abdelfattah et al., 2022). Both of these can happen to divers, airmen, and astronauts but arterial gas embolism can occur due to iatrogenic factors unrelated to demopression (Vann et al., 2011). DCS or also called Caisson's disease suffered by divers with self-contained underwater breathing apparatus (SCUBA), compressed water workers, astronauts, flight attendants, and jobs exposed to hyperbaric (diving) and/or hypobaric environments (Vann et al., 2011; Howle et al., 2017).

Di Indonesia, DCI is often experienced by fishermen divers. Based on data from the Sub-Director General of Epidemiological Surveillance, Immunization, and Health of the Matra until 2008, out of 1026 fishermen divers in Indonesia, it was found that 93.9% of divers had suffered from early symptoms due to diving, including 29.8% suffering from hearing loss joint pain by 39.5% and suffering from paralysis by 10.3% (Prasetyo et al., 2012). Some factors that increase the occurrence of DCI are obesity, fatigue, chills, dehydration, depth, frequency, and length of diving. Hyperbaric oxygen therapy (HBOT) is carried out as soon as possible (Wijaya et al., 2021; Uppal & Jayatunga, 2020). Prof. IGNG Ngoerah General Hospital, Denpasar, Bali, is one of the HBOT places in Indonesia. To determine the characteristic of DCI patients at the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital, Denpasar, Bali.

Material and Methods

This retrospective descriptive research was performed involving patients diagnosed with DCI at the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital, Denpasar, Bali by utilizing administrative data for the 2018-2019 period. Exclusion criteria is an incomplete medical record according to the required examination data, namely (1) demographic data (age, gender, body mass index (BMI), previous disease history, diving location), (2) diver profile (type, depth, and the number of dive times, use of safety stop, surface interval), (3) DCI characteristics (type, onset, severity, provoking factors such as the presence of rapid ascent, flight history or ascent after diving, panic during diving), and (4) the therapy obtained, namely the use of immediate oxygen supplementation and HBOT. Descriptive analysis of demographic and diving data processed by using SPSS Version 24 and presented in frequency (percentage) for categorical variables and average (standard deviation) for numeric variables.

In this study, several terms will be classified, namely, (1) type of diving which is divided into single or repetitive diving, (2) safety stop, diving stop compulsorily during rising to the surface every 3-5 meters for 3-5 minutes for decompression needs during diving, (3) type of DCI, which is type 1 which includes musculoskeletal manifestations, cutaneous and constitutional symptoms, and type 2 in the form of neurological and systemic manifestations, such as numbness, tingling, muscle weakness, psychological disorders, (4) the severity of DCI, i.e. major DCI if there is cognitive impairment, central nervous system dysfunction, visual impairment, loss of consciousness, amnesia, or ear trauma, while minor DCI if skin manifestation, paraesthesia, musculoskeletal pain, abdominal complaints, and constitutional symptoms, (5) rapid ascent, i.e. divers rise to the surface quickly known from the patient's anamnesis in the medical record (Foster et al., 2016; Jamharee et al., 2016).

Results

We identified 132 patients enrolled with DCI in Hyperbaric Polyclinic in the 2018-2019 period and 118 patients excluded from this study. Figure 1 shows the overall number of DCI cases per year that is starting to decline. Almost most (90.7%) of DCI patients at the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital, Denpasar, Bali, are foreigners.

Of the 118 DCI divers, the average age is 33.11 years (10-68 years). Of 67 DCI patients who had BMI data, most of them had a normal BMI (35.6%). Most of the DCI divers had no history of the previous disease (88.1%), but 11.9% had a history of the previous disease before the last dive, namely diarrhea (n=4), previous decompression

disease n=4, patent foramen ovale (PFO) (n=1), dehydrated (n=1), diabetic (n=1), gout arthritis (n=1), and tinnitus (n=1). The dive locations recorded are mostly from the island of Bali, namely 74.6% (the most on Tulamben Beach, then Gili Trawangan, Amed, Nusa Penida, Nusa lembongan, Alor Karangasem, Menjangan, Pemuteran), 7.9% outside the island of Bali (Kalimantan, Komodo Island, Labuan Bajo, Raja Ampat, Sulawesi, Sumatra), and 4% from outside Indonesia (Philippines, Australia, Thailand, Caribbean, Rarotonga). This can be seen in Table 1.

Table 2 shows the diving profiles of DCI patients in this study. Most divers perform repetitive dives (n=92.78%) with a depth of >20 meters (n=73.61.9%) and an average surface interval of 101,184 minutes (30-1440 minutes). The total duration of diving time was mostly 1-3 hours (n=65.55.1%). Only 4.2% of DCI patients used the safety stop procedure at the end of the dive, 14.4% admitted to rapid ascent and 2.5% admitted to panicking while diving. After diving, 10.2% of patients admitted to flying for a specific reason (accidental or related to DCI symptoms that began to arise), and 6.8% hiked.

Table 3 shows the distribution of clinical manifestations of DCI in this study. Most of the divers experienced type 2 DCI (56.8%) which corresponded to major severity, which was 59.3%. The results of this study also showed, that the manifestations of DCI mostly appeared < 6 hours from the last dive (86.4%). Of all patients, 75.4% of patients had received oxygen supplementation before reaching HBOT and 91.5% underwent HBOT at the Hyperbaric Polyclinic of Sanglah Hospital Denpasar Bali.

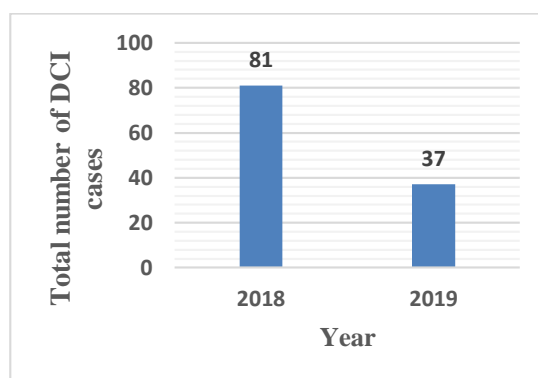


Figure 1 Total number of DCI cases in the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital in the period 2018-2019

Table 1

Socio-demographic data of DCI patients in the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital in the period 2018-2019

Variable	n (%)	Mean (SD)
Age		32.93(10.139)
Gender (male/ female)	59 (50)/59 (50)	
BMI (Kg/m ²)		
• Underweight	4 (3.2)	
• Normal	42 (35.6)	
• Overweight	13 (11)	
• Obesity class I	1 (0.8)	
• Obesity class II	- (0)	
• Obesity class III	1 (0.8)	
Previous disease		
• Yes	14 (11.9)	
• No	104 (88.1)	
Diving location		
• Bali island	88 (74.6)	
• Domestic, outside Bali	9 (7.6)	
• Abroad	4 (3.4)	

Table 2
Diving profile of DCI patients in the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital in the period of 2018-2019

Variable	n (%)	Mean (SD)
Diving type		
Single	26 (22)	
Repetitive	92 (78)	
Depth of diving (meter)		
<10 m	5 (4.2)	
11-20 m	39 (33.1)	
>20 m	73 (61.9)	
Diving total duration (hours)		
<1 hour	37 (31.4)	
1-3 hours	65 (55.1)	
>3 hours	8 (6.8)	
Safety stop		
Yes	5 (4.2)	
No	113 (95.8)	
Rapid ascent		
Yes	17 (14.4)	
No	101 (85.6)	
Have flight after diving		
Yes	12 (10.2)	
No	106 (89.8)	
Hiking after diving		
Yes	8 (6.8)	
No	110 (93.2)	
Have panic during diving		
Yes	3 (2.5)	
No	115 (97.5)	
Surface interval in repetitive diving (minutes)		102.603 (165.2989)

Table 3
Clinical manifestations of DCI in the Hyperbaric Polyclinic of Prof. IGNG Ngoerah General Hospital in the period of 2018-2019

Variable	n (%)
Type of DCI	
Type 1	51 (43.2)
Type 2	67 (56.8)
Severity of DCI	
Major DCS	70 (59.3)
Minor DCS	48 (40.7)
Clinical Onset	
< 6 hours	102 (86.4)
6-12 hours	8 (6.8)
>12 hours	8 (6.8)
Oxygen supplementation	
Yes	89 (75.4)
No	29 (24.6)
HBOT	
Yes	108 (91.5)
No	10 (8.5)

Discussion

This study showed 118 divers who were diagnosed with DCI at the Hyperbaric Polyclinic of Prof IGNG Ngoerah General Hospital, Denpasar Bali from January 2018 to December 2019 with the highest percentage of divers being foreigner. Most of the divers in this study underwent HBOT at the Hyperbaric Polyclinic of Sanglah Hospital, Denpasar Bali. However, this study was unable to estimate the incidence of DCI due to the unknown number of divers or diving activities on the island of Bali as well as the number of cases recorded in hyperbaric therapy centers on the island of Bali that were not included in this study (Chong et al., 2005; Wang et al., 2011). Tulong et al. (2016), showed that 46.7% of patients conducted by HBOT at RSUP Prof. Dr. R. D. Kandou Manado for the period 2013-2016 were DCS patients.

Some studies show an association between overweight and obesity in the number and weight of DCI 11, but other studies have also shown no significant difference between age, age, sex, and BMI on DCI severity (Webb et al., 2003; Honěk et al., 2019). Patent foramen ovale (PFO) is one of the diseases known to be a potential risk factor for DCI. Some studies state that PFO can trigger unprovoked DCI due to nitrogen bubbles detected in the venous blood that arise in single diving, so it is called a paradoxical embolism (van Treeck & Schuhmacher, 1999; Barker & Roberts, 2004). The incidence of PFO was found in 40% of divers with 7% of divers experiencing unprovoked DCI (54 episodes) with an incidence rate of 0.03%. A significant 86.1% of PFO divers with an unprovoked DCI history had PFO grade 3 (Honěk et al., 2019). Another history of comorbid diseases that has been shown to affect the quality of life of divers is dehydration. The results showed that dehydration can change inert gases by reducing blood flow to poorly perfusion tissues, or it can lower surface tension thereby facilitating bubble formation and increasing the risk of decompression disease occurrence (Widyastuti et al., 2019; Diniari et al., 2023).

In this study, most divers performed repetitive dives ($n=92.78\%$) with diving depth > 20 meters ($n=73.61.9\%$) and an average surface interval of 101,184 minutes. The frequency of diving >2 times increases the risk of DCS 4 times compared to diving ≤ 2 times a day (Wijaya et al., 2021). DCS almost does not occur on a single dive to a depth of <6 meters, however arterial gas embolism can arise after rising from the deepest depth then DCS will start at least at 6 meters depth of diving (Vann et al., 2011; Buzzacott, 2012). Research by Widyastuti et al. (2019), shows that diving ≥ 30 meters are 38.41 times the risk for the occurrence of worse quality of life in divers with DCS. The longer the dive time, the more nitrogen the body absorbs, causing DCI symptoms (Kusnanto et al., 2020). In addition, safety stop and rapid ascent procedures can determine the severity of DCS (Suzuki et al., 2018). Other provoking factors in DCS are flight (incidence rate specifically $<0.1\%$ per exposure) and panic (Vann et al., 2011; Wijaya et al., 2021). The onset of the appearance of DCS manifestations depends on the depth of dive that generally arises within 6 hours of rising to the surface. Jamhareea et al. (2016), showed that 85% of divers experienced DCS symptoms in the first 12 hours and half of those divers experienced symptoms 1-3 hours after diving with 61.5% experiencing neurological manifestations such as tingling, loss of consciousness, seizures or paralysis. Surface intervals or rest periods between dive periods are needed to neutralize the nitrogen content in his blood. The longer the rest period, the more nitrogen gas is released, so the risk of decompression is reduced (Madden & Laden, 2009; Liou et al., 2015). Research shows surface intervals of less than 56 minutes are at 8,167 times the risk of suffering from decompression compared to divers who rest longer than 56 minutes, however, other studies have shown there is no risk of surface intervals with decompression events (Wijaya et al., 2021).

The first aid of DCI is 100% oxygen supplementation for several hours even if the manifestations have already improved. Pure oxygen can remove inert gases from the lungs and confirm a higher difference in inert gases in tissues than alveolus gases (Vann et al., 2011). DCI definitive therapy is a recompression therapy, namely HBOT, which should be obtained as quickly as possible after onset which is influenced by availability, transportation, distance to the HBOT center, DCI onset, and patient beliefs about the spontaneous improvement of symptoms. Jamharee et al. (2016), showed that most divers (37.5%) with DCI received delayed HBOT (7-12 hours).

Conclusion

DCI is a disease that causes various clinical manifestations. The severity of DCI consists of the minor (symptoms of paraesthesia, skin disorders, musculoskeletal pain, and constitutional) and major (heart and respiratory disorders, neurological symptoms such as paralysis, visual or ears disorders, autonomic disorders, and consciousness or cognitive impairment). The emergence of DCI events and their severity can be influenced by the diver's profile (age, history of disease, type of diver), diving process (depth, duration of diving, type of diving, safety stop procedure), and HBOT (frequency, time of getting recompression). In this study, not all data could be collected due to a lack of information.

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