Decompression illness treated in Denmark 1999–2013

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Abstract

(Svendsen Juhl C, Hedetoft M, Bidstrup D, Jansen EC, Hyldegaard O. Decompression illness treated in Denmark 1999–2013. *Diving and Hyperbaric Medicine*. 2016 June;46(2):87-91.)

Introduction: The incidence, diver characteristics and symptomatology of decompression illness (DCI) in Denmark has not been assessed since 1982, and the presence of long-term residual symptoms among divers receiving hyperbaric oxygen therapy in Denmark has never been estimated to our knowledge.

Methods: We undertook a retrospective study of the incidence and characteristics of DCI cases in Denmark for the period of 1999 to 2013. Medical records and voluntary questionnaires were reviewed, extracting data on age, gender, weight, height, diver certification level, diving experience, number of previous dives, type of diving, initial type of hyperbaric treatment and DCI symptoms. Trend in annual case numbers was evaluated using run chart analysis and Spearman's correlation. Age, height, weight, and BMI were evaluated using linear regression. The presence of long-term residual symptoms was investigated by phone interviewing the subgroup of divers treated in 2009 and 2010.

Results: Two-hundred-and-five DCI cases were identified. The average annual case load was 14 with no significant trend during the study period ($P = 0.081$). Nor did we find any trend in age, weight, height or BMI. The most frequent symptoms were paraesthesia (50%), pain (42%) and vertigo (40%). Thirteen out of the subgroup of 30 divers had residual symptoms at discharge from hospital, and six out of 24 of these divers had residual symptoms at the time of follow-up.

Conclusion: We observed a more than ten-fold increase in DCI-cases since the period 1966–1980. In the subgroup of divers treated in 2009/2010, a quarter had long-term residual symptoms as assessed by telephone interview, which is in keeping with the international literature, but still a reminder that DCI can have life-long consequences.

Key words

Decompression sickness; diving incidents; hyperbaric oxygen therapy; recompression; outcome

Introduction

Decompression illness (DCI) is an acute condition that may follow a reduction in ambient pressure, typically when a submerged diver ascends back to the surface breathing hyperbaric air or oxygen-enriched breathing mixtures with either nitrogen and/or helium as inert diluent. DCI comprises two conditions: decompression sickness (DCS) and arterial gas embolism (AGE).

In DCS, gas bubbles form when the amount of dissolved gas in the diver's blood and tissue compartments decreases as ambient pressure is reduced. The gas bubbles exert a pressure on the surrounding tissue, leading to nerve injury, local necrosis and endothelial disruption.

AGE occurs when expanding gas causes pulmonary barotrauma, allowing alveolar gas to enter the circulation, or when venous gas bubbles migrate to the systemic circulation through arteriovenous shunts, e.g., a persistent foramen ovale (PFO), causing stroke-like symptoms.[1,2]

The incidence of diving-related injuries has previously been estimated to 5–152 per 100.000 person-dives.[3] In Denmark, divers suspected of having DCI are transported to the national treatment facility at the Rigshospitalet, Copenhagen, to receive hyperbaric oxygen treatment (HBOT).

To our knowledge, the incidence of DCI cases in Denmark has not been assessed since Madsen's study of the period 1966–1980,[4] and the long-term outcome of HBO-treated DCI has never been investigated. Since diving activity has changed in recent times owing to its increasing popularity as a recreational sport, we felt it was important to study the recent Danish DCI incidence and to characterise the acute and residual symptoms of the condition.

Methods

This is a retrospective, descriptive quality study of HBO-treated cases of DCI in Denmark. The study was approved by the Danish Data Protection Agency and written informed consent of data acquisition from the individual patients was obtained. The study complied with the Declaration of Helsinki. Following written consent, all divers are given a voluntary questionnaire regarding demographic data, diving experience, technical equipment and circumstances regarding the dive.

We undertook a retrospective audit of all cases treated at the Rigshospitalet, Copenhagen in the period from 01 January 1999 to 31 December 2013. The inclusion criterion was receiving HBOT because of suspected DCI. Medical records and questionnaires were reviewed, and the following data were extracted: age, gender, weight,

Table 1

Demographics, diving experience, certification level and initial type of hyperbaric oxygen treatment of 205 divers with decompression illness (DCI), treated with hyperbaric oxygen therapy in Denmark in 1999–2013. [a] PADI open water, CMAS*; [b] PADI advanced OW/Rescue diver/dive master/assistant instructor, CMAS**, CMAS***, CMAS nitrox basic; [c] PADI instructor/master diver, CMAS instructor*/instructor**/instructor***; USN T6 – US Navy Treatment Table 6; USN T6 ext – US Navy Treatment Table 6, extended; [d] US Navy Table 5 or RH14

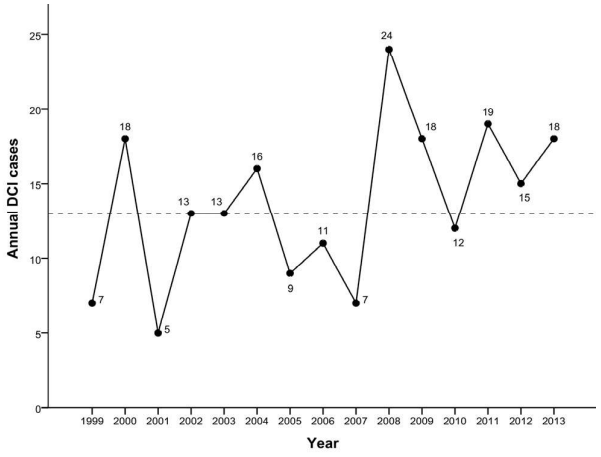
Demographics	**Number**	**%**
Sex (n = 205)		
Male/Female	161/44	79/21
	Mean (SD)	
Age (years)	35.5 (10.1)	
Weight (kg)	79.6 (15.7)	
Height (cm)	178.1 (9.0)	
BMI (male)	25.8 (3.4)	
BMI, female	21.8 (2.6)	
Type of diving (n = 164)		
Commercial	13	8
Recreational	151	92
Experience level (n = 90)		
Number of previous dives	1–5	8
	6–10	4
	11–50	28
	51–100	17
	> 100	39
Self-estimated level of experience (n = 112)		
Inexperienced	14	13
Some experience	40	36
Experienced	34	30
Very experienced	24	21
Certification level (n = 157)		
Basic open water[a]	31	20
Advanced[b]	95	60
Instructor[c]	29	19
Other	2	1
Initial HBO treatment (n = 205)		
USN T6	103	50
USN T6 ext	38	19
Other[d]	64	31

height, diver certification level, diving experience, number of previous dives, type of diving, type of HBOT and DCI symptoms. Both subjective and objective symptoms present at the time of hospital admittance were included.

Identification of any trend in annual number of DCI cases was our primary end-point. Secondary end-points were identification of trends over time in age, height, weight or BMI. We also wished to determine the prevalence of long-term residual symptoms after HBOT. To do this, we reviewed the medical records of the subgroup of divers treated during the period of 01 January 2009 to 31 December 2010 to identify symptoms at hospital discharge, and conducted

Figure 1

Annual decompression illness (DCI) cases in Denmark 1999–2013; the interrupted line marks the median



telephone interviews during July/August 2012 to determine the presence of long-term residual symptoms. Long-term sequelae were defined as the persistence of subjectively experienced symptoms after a period of 1.5 to 3.5 years from the onset of DCI.

STATISTICAL ANALYSIS

The data were analysed using IBM SPSS version 20. Annual number of DCI cases were depicted in a run chart and subsequently checked for shifts, trends, or abnormal amounts of runs as signals for non-random variation.[5] A possible trend in annual caseload was analysed using Spearman's rho correlation coefficient. Trends in age, weight, height and BMI were analysed using linear regression. A P-value of 0.05 or less was considered statistically significant.

Results

A total of 205 HBO-treated DCI cases were identified in the period 1999 to 2013. Out of these 205 cases, the voluntary questionnaires regarding type of diving, number of previous dives, self-estimated level of experience, and certification level, were answered by 164 (80%), 90 (44%), 112 (55%), and 157 (77%) divers respectively. Demographics, diving characteristics, and initial type of HBOT are summarized in Table 1.

The mean annual incidence of treated DCI for the entire 15-year period was 14 (rounded, range 5–24; Figure 1). No shifts, trends or abnormal runs were detected, only random variation. There was a slight increase in annual DCI cases but this was not significant ($\rho = 0.465$; $P = 0.081$). Mean age was 35.5 (SD 10.1). No trend in diver age ($P = 0.44$) was found nor was there any trend in weight ($P = 0.52$), height ($P = 0.22$) or BMI ($P = 0.82$) over the 12-year period.

Figure 2
Symptom characteristics in 30 DCI cases from 2009–2010 on admission (white); 13 cases with symptoms at discharge from hospital (grey) and among the six divers with long-term residual symptoms at the time of the follow-up interview (black)

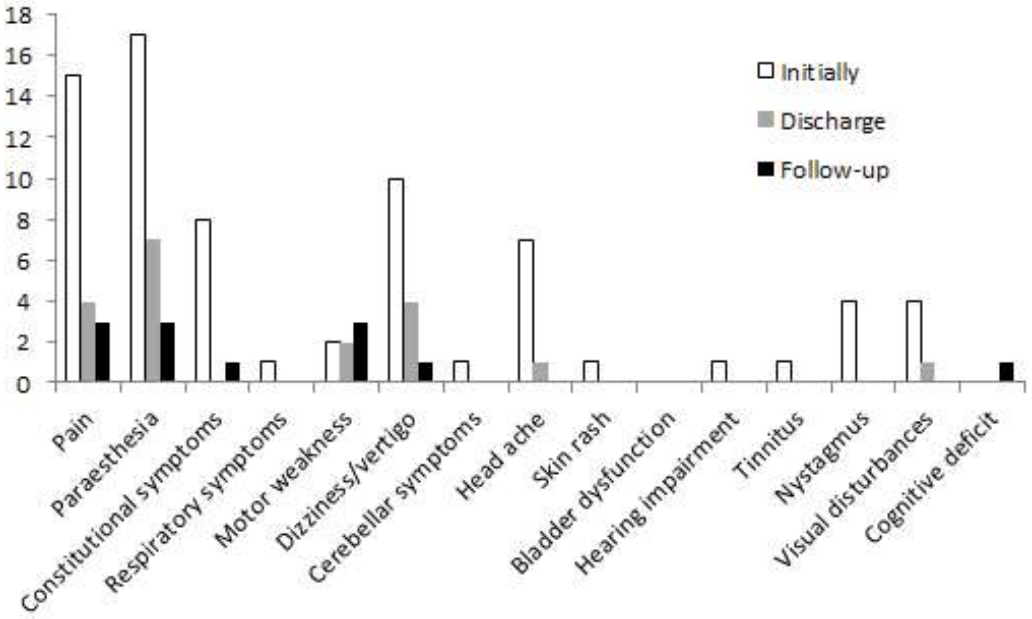


Table 2
Number of decompression illness (DCI) cases with a given symptom; constitutional symptoms comprise general symptoms such as nausea and malaise

Symptom	(*n* = 205)	%
Paraesthesia	103	50
Pain	87	42
Dizziness/vertigo	81	40
Headache	57	28
Constitutional symptoms	51	25
Motor weakness	48	23
Respiratory symptoms	28	14
Visual disturbances	25	12
Cerebellar symptoms	19	9
Bladder dysfunction	10	5
Skin rash	10	5
Nystagmus	8	4
Hearing impairment	7	3
Tinnitus	6	3

The most frequent DCI symptoms are listed in Table 2. Paraesthesia (50%), pain (42%) and vertigo (40%) were the three commonest symptoms. Few divers exhibited cerebellar symptoms, bladder dysfunction, skin rash, nystagmus, hearing impairment or tinnitus (Table 2).

Among the 30 subjects who were treated in 2009/2010, 13 had reduced but lingering symptoms at discharge from hospital. At the time of the follow-up interview, one subject had died from a subsequent diving accident. It was possible to successfully contact 24 of the remaining 29 subjects in 2012, of whom six had residual symptoms. As five divers were lost in the follow-up interview, the true prevalence of residual symptoms is between 20% and 37% depending on the prevalence of residual symptoms in the lost group.

Out of the six divers with subjective, residual symptoms, three had no symptoms at discharge from hospital. One of the six divers had suffered a concussion during the period between treatment for DCI and the follow-up interview. It was not possible to determine whether his reported symptoms derived from DCI or the later concussion. However, this diver had symptoms from the time of hospital discharge in 2010 until the concussion in December 2011. Figure 2 illustrates symptoms present at the time of hospital admittance in all DCI cases ($n = 30$) in 2009/2010, compared to the symptoms present among 13 divers at discharge and among the six divers with residual symptoms at the time of the follow-up interview.

The average duration of hospital stay was 2.5 (range 0–8) days among the six divers with residual symptoms compared to 2.0 (range 0–12) days for the entire subgroup. All six divers with residual symptoms were employed at the time of the interview in 2012, one having reduced to part-time work because of their residual symptoms. Three of the six divers were still active divers, one as an occupational diver.

Discussion

The present study is, to our knowledge, the first to describe the incidence of DCI cases in Denmark since Madsen's study of DCI cases in Denmark in the period 1966 to 1980.[4] The incidence found in this study represents a more than ten-fold increase in DCI cases compared to then, when only three out of 21 DCI cases were the result of recreational diving. In the present study, 92% of the DCI cases were the result of recreational diving. We speculate that this shift is because of the increase in recreational scuba diving since the 1960/70s. A major strength in our study compared to other international studies is that treatment for DCI is centralized to one centre in Denmark. Hence, all patients were examined by doctors from the same department and received HBOT in the same recompression chamber.

Others have studied the connection between annual number of DCI cases and the number of diving certificates issued. In New Zealand (NZ), a decline in annual DCI cases was found over the period 1995 to 2012, and this was linked to a similar decline in the number of newly issued diving certificates in NZ over the same period.[6] Likewise, a decline in the incidence of DCI in Australia in the period 1995 to 2007 was found.[7] There are no official statistics on numbers of new diving certificates issued in Denmark. As many Danish recreational divers take their certificates abroad, and consequently many diving incidents that lead to DCI happen abroad, it would be misleading to compare the DCI caseload with certificates issued in Denmark. We attempted to obtain data regarding the annual number of new diving certificates issued in Denmark by three major diver training agencies but were unsuccessful.

The lack of any significant trend in annual DCI caseload in the present study could be owing to the low number of cases, with an average of only 14 DCI cases per year in 1999–2013, compared to 31 cases per year in New Zealand in 1996–2012 and 274 per year in Australia in 1995–2007.[6,7]

We found paraesthesia to be the most common DCI symptom followed by pain. In the NZ series, musculoskeletal pain was the most frequent symptom (65% of cases) followed by cutaneous tingling (45%) among 520 DCI cases.[6] Similarly pain (68.0)% and numbness/paraesthesia (63%) were the commonest symptoms in another study of 2,346 divers.[8]

We did not investigate the use of mixed gases such as trimix or heliox, nor did we estimate the use of rebreathing systems. These advanced types of diving were previously reserved to commercial and military diving activities. We speculate that in the future they will become more widespread among recreational divers and potentially affect the incidence of DCI, as they permit deeper and longer dives.

DCI is associated with long-term neurological and psychiatric symptoms, along with reduced health-related quality of life.[9,10] To our knowledge, the long-term outcome of HBO-treated DCI has not been investigated previously in Denmark. Other studies have found residual symptoms among 22 to 55% of divers at hospital discharge, and 26 to 33% of divers after one month.[11–14] The outcome in the small cadre of divers followed up for 1.5 to 3.5 years in the present study is in agreement with these studies. There were no significant differences between the number of HBOT given to each of the patients in this subgroup, but the group is too small to determine whether length of hospital stay could be used as a measure of DCI severity and the risk of developing long-term symptoms.

There is evidence from several studies, such as that from Scotland of 536 cases, that divers presenting with more severe symptoms are likely to have a poorer outcome.[15] The prevalence of long-term residual symptoms is merely a snapshot at the time of the follow-up interview. Ideally each patient should be interviewed at a fixed time after the initial treatment e.g., after one year, and even if this was done, exclusion bias would still be present.

As this was a retrospective study, the assumption that all patients were equally and thoroughly examined, and all findings, both subjective and objective, fully documented in the medical records is a potential weakness. Furthermore, some selection and recall bias can be expected regarding the voluntary questionnaires.

Conclusions

Annual DCI cases in Denmark during the period 1999 to 2013 have increased ten-fold since the period 1966–1980. We found an annual DCI caseload of 14, predominantly from recreational diving, with no significant trend in annual caseload or secondary endpoints during the period. In a subgroup of 30 divers treated in 2009/2010, nearly half had residual symptoms at discharge from hospital and a quarter developed subjective long-term symptoms, a rate similar to the published literature. This is a reminder that DCI is a serious condition with possible devastating consequences for the individual.

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The database of randomised controlled trials in hyperbaric medicine maintained by Michael Bennett and his colleagues at the Prince of Wales Hospital Diving and Hyperbaric Medicine Unit, Sydney is at:
<http://hboevidence.unsw.wikispaces.net/>

Assistance from interested physicians in preparing critical appraisals is welcomed, indeed needed, as there is a considerable backlog. Guidance on completing a CAT is provided.
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