Int Marit Health
2013; 64, 3: 142–147
www.intmarhealth.pl

ISSN 1641–9251

ORIGINAL PAPER

Prevalence and causes of loss of consciousness in former North Sea occupational divers

Endre Sundal[1], Ågot Irgens[1], Kari Troland[1], Einar Thorsen[1, 2], Marit Grønning[1, 3, 4]

[1]Norwegian Centre for Diving Medicine, Department of Occupational Medicine, Haukeland University Hospital, Bergen, Norway
[2]Department of Clinical Science, University of Bergen, Bergen, Norway
[3]Department of Clinical Medicine, University of Bergen, Norway
[4]Neuro Clinic, Haukeland University Hospital, Bergen, Norway

ABSTRACT

Background: *Loss of consciousness (LOC) is a serious event during diving. The purpose of this study was to estimate the prevalence and causes of LOC during diving in former North Sea divers, and the impact on health-related quality of life.*

Materials and methods: *Up to 1990 a total of 373 Norwegian offshore divers worked in the North Sea. From 2000 to 2011, 221 of these were referred to the Department of Occupational Medicine at Haukeland University Hospital for examination due to health complaints. They filled in a questionnaire for registration of diving experience and health complaints, including the SF-36 version 1 for the assessment of quality of life. The questionnaire and the hospital records were systematically reviewed by 2 independent observers. Episodes of LOC during diving and the causes were registered. All participants underwent a clinical neurological examination. Electroencephalogram (EEG) and the event-related brain potential (P300) were recorded.*

Results: *One or more episodes of LOC were reported by 58 of 219 divers. LOC due to gas cut was reported by 27 of these. Divers having experienced LOC due to gas cut had lower SF-36 sub-scores then the rest of the diving population. EEG and P300 recordings did not differ between the groups.*

Conclusions: *A high proportion of former Norwegian North Sea divers reported episodes of LOC, for which gas cut was the most common cause. Both hypoxia and peritraumatic stress associated with the episode could have a long term impact on the quality of life. Neurophysiological functions, however, did not differ between the groups.*

(Int Marit Health 2013; 64, 3: 142–147)

Key words: diving, health-related quality of life, neurology, occupational risk

INTRODUCTION

Diving operations are technically complex and the underwater environment may pose an increased risk of accidents. The most common causes are equipment failure and supervisor/tender errors [1]. Human or technical error may lead to failure in gas supply, hot water supply, communication, etc. A Norwegian report from 2005 demonstrated an increased risk of death in divers compared to construction workers and electricians [2]. Similar data are reported from United Kingdom and Alaska [3, 4].

Non-fatal accidents are fairly common [5]. Several of these accidents may cause hypoxia and loss of consciousness (LOC), which in turn is associated with cognitive deficits or other neurological sequelae [6, 7]. The risk of anoxia, from the inhalation of gases not containing oxygen in commercial diving accidents, is not fully recognised [8]. LOC during diving is a serious hazard and the time between LOC and death may be no longer than 2.5 min [9]. Several previous studies [10–13] have demonstrated cerebral deficits and long-term reduction in health-related quality of life (HRQL)

Dr Endre Sundal, Department of Occupational Medicine, Haukeland University Hospital, N-5021 Bergen, Norway, tel: +47 55973863, telefax: +47 55975137, e-mail: endre.sundal@helse-bergen.no

Table 1. Diving experience among Norwegian North Sea divers having and not having experienced episodes of loss of consciousness (LOC)

	All divers N = 219		No LOC N = 161		LOC N = 58			
	Median	Range	Median	Range	Other causes		Gas cut	
					Median	Range	Median	Range
Age [years]	53	35–71	52	35–71	57	42–66	55	35–66
Years of diving	15	2–38	15	2–34	16.5	6–38	15	4–33
Years since last dive	15	1–34	14	1–34	18	3–32	17	1–23
Number of bounce dives	43	1–1200	28	1–1000	52	1–1200	55	2–600
Days in saturation	283	3–2500	265	3–1750	261	24–900	301	3–2500
Number of air dives	800	2–9000	800	2–9000	1000	150–5000	1001	110–5500
Maximum diving depth [msw]	177	50–504	176	50–504	183	100–500	174	100–450
Skin, joint DCS [%]	68		68		74		59	
Neurological DCS [%]	20		19		16		26	

DCS — decompression sickness

after drowning and cardiac arrest, both of which implying anoxia or hypoxia.

The aim of the present study was to investigate the prevalence and the causes of LOC during occupational diving in the North Sea before 1990 (pioneer diving). Furthermore, we wanted to explore the extent to which episodes of LOC may have influenced health status later in life.

MATERIALS AND METHODS

SUBJECTS

The present study was a part of a large clinical survey of health effects among former North Sea divers. According to official records obtained from the Norwegian Ministry of Labour and Social Affairs [14], a cohort of 365 Norwegian commercial divers worked in The North Sea before 1990. At the time of the present study, 46 of these had died. Eight additional divers were identified and included in the cohort (n = 373). They all had performed mixed gas bounce diving, or saturation diving, or both. Two hundred and twenty-one divers referred to the Department of Occupational Medicine, Haukeland University Hospital, for health complaints during 2000–2011 took part in the present study. All the participants were male, aged 35–71 years, and all signed a written informed consent. The Regional Ethical Committee for Medical Research and The Data Inspectorate approved the study (registration number 10721). Two participants requested withdrawal of their data from the analysis.

CLINICAL INTERVIEW AND QUESTIONNAIRES

As a part of the comprehensive clinical evaluation, all the divers were interviewed by 1 of the medical doctors. The semi-structured interview included medical and work history, accidents, mishaps or other events. The divers responded to a questionnaire providing data on general socio-demographics, general and diving-related medical conditions and symptoms, as well as diving education and experience (Table 1).

The Medical Outcome Survey Short-Form 36 version 1 (SF-36), which is a multi-dimensional construct, was used to measure HRQL. Thirty-six items are scored on 8 scales representing different health dimensions: physical functioning (PF-scale), role physical (RP-scale), bodily pain (BP-scale), social functioning (SF-scale), role emotional (RE-scale), mental health (MH-scale), general health (GH-scale) and vitality (VT-scale). For each scale, raw scores are transformed to a 0–100 scale, with higher scores representing a better outcome [15]. SF-36 normative data from the general Norwegian population were used for comparison [16].

In the questionnaire, decompression sicknesses (DCS) was categorised into neurological, skin, joint or other. The data were aggregated into a single variable distinguishing between neurological DCS, other DCS or no DCS. Divers reporting both neurological and other types of DCS were categorised as neurological DCS.

NEUROPHYSIOLOGICAL ASSESSMENT

Electroencephalography (EEG) and event-related brain potentials. The EEG was a standard 21-channel recording at rest, after hyperventilation and during photo-stimulation [17]. All records were obtained by a Nervus EEG recorder (Taugagreining, Reykjavik, Iceland) and evaluated by a specialist in neurophysiology. The EEG records were categorised as normal or pathological (spikes, slow wave activity or theta activity).

The P300 component of the event-related brain potential was used as a measure of information processing. Recordings were performed using a standard method recommended by the International Federation of Clinical Neurophysiology [18, 19]. The equipment (Keypoint, Dantec, Copenhagen, DK) and the setup were the same for all the divers. There were 6 recording channels used: 2 frontal, 2 central and 2 parietal electrodes using the oddball paradigm methodology. The P300 amplitude and latency, i.e. the time from the signal to the peak response, were registered. The mean of the results from 2 electrodes in each region were used in the analysis. Motor reaction time was measured as the time from the oddball signal was given to the time it was identified by pressing a button with the dominant hand.

DATA PROCESSING AND STATISTICAL ANALYSES

As the study progressed, it became clear that many divers reported episodes of LOC during diving operations. Unfortunately, such information was not specifically asked for in the questionnaire or in the structured part of the interview. Hence, 2 observers (MG and ES), independently of each other, recorded the instances of LOC and their causes, through a systematic content analysis of the hospital records. The various causes of LOC are shown in Table 2. For group comparisons, divers were categorised into: no LOC, LOC due to gas cut, and LOC due to other causes. We distinguished between LOC due to gas cut and due to other causes, as the first one is associated with hypoxia.

For each scale of SF-36, divers who had reported LOC due to gas cut were compared to the group of divers with LOC due to other causes, and to the divers with no LOC. Differences in SF-36 scores, P300 amplitude and latency as well as motor reaction time were tested by General Linear Models Univariate Analysis, crude and adjusted for age and DCS. Risk of pathological EEG in divers who reported LOC due to gas cut was tested by exact odds ratio from 2 by 2 tables relative to no LOC and relative to LOC due to other causes. Differences in potential confounders were tested by non-parametric methods. Both descriptive analysis and statistical testing were performed by the IBM SPSS statistical software PASW version 18.0 [20].

RESULTS

Fifty-eight of 219 (27%) divers reported 1 or more episodes of LOC. A total of 75 episodes were reported. One episode was reported by 42 divers, 15 reported 2 episodes and 1 reported 3 episodes. LOC due to gas cut was reported by 27 (12%) divers (Table 1), while 31 (14%) divers had experienced LOC due to other causes. Number of episodes of LOC per year of active service had a mean of 0.11 ± 0.08 and 0.08 ± 0.04, respectively in these 2 groups.

Table 2. Causes of loss of consciousness reported in medical records of 58 former North Sea divers

Gas cut	27
Wrong gas mixture	19
Polluted breathing gas	5
Hyperventilation	5
Oxygen swimming	3
Low temperature	3
Heavy effort	2
Injuries trauma	1
Decompression sickness II	1
Other*	4
Unknown	5

*Includes current surge, fast compression, loss of diving mask, rapid ascent

Exposure variables did not differ between divers with LOC due to gas cut and divers with no LOC, or between divers with LOC due to gas cut and divers with LOC due to other causes (Table 1). The prevalence of neurological DCS was: 4.3% in divers with LOC due to gas cut, 7.1% in divers with unconscious due to other causes, and 6.4% in those with no LOC.

The divers who experienced LOC due to gas cut had numerically lower scores on all SF-36 subscales compared to the divers who had been unconscious due to other causes, and to divers without LOC (Fig. 1). The differences were significant for the subscales: physical function (PF), bodily pain (BP), general health (GH) and vitality (VT) (Table 3). Divers who had been unconscious due to other causes had higher scores on all SF-36 scales compared to those not reporting episodes of LOC. There were no differences between groups on EEG or P300 variables, as shown in Table 3. Only results of the central electrode of P300 recordings are shown.

DISCUSSION

One or more episodes of LOC during diving operations were reported by 58 out of 219 professional divers in this study. LOC was most commonly caused by faulty gas supply. Those having experienced episodes of LOC due to gas cut reported lower quality of life, as assessed by SF-36. There were no differences between groups on neurophysiological measures, no differences in cumulative diving exposure, and no differences in reported DCS.

Two thirds of the official number of former Norwegian divers, having performed offshore diving in the North Sea before 1990, have been examined and included in this study. It is a well-defined population and the divers have been examined in a standardised program. The study sample was, however,

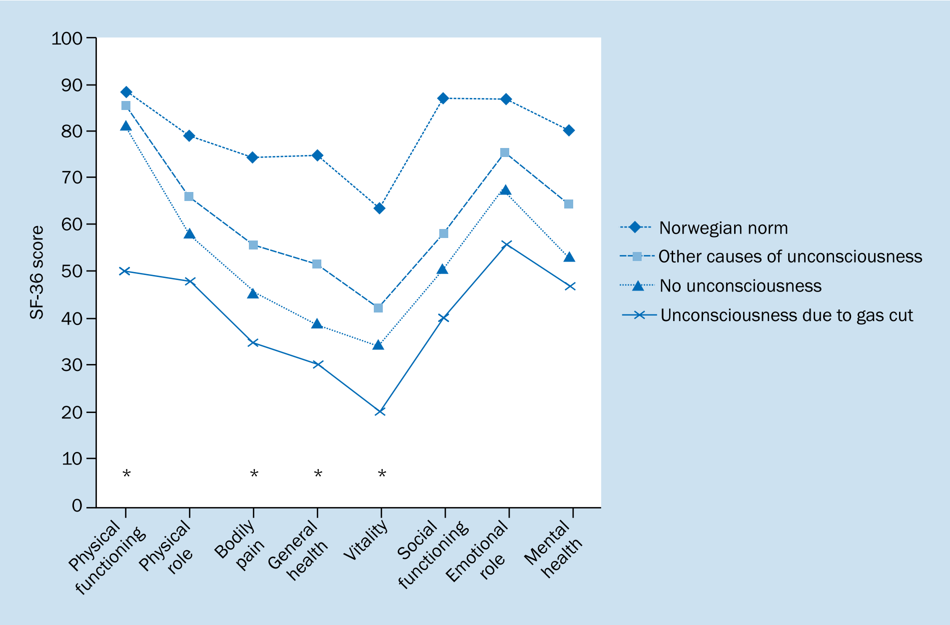

Figure 1. Mean scores on the SF-36 scales for the Norwegian normative sample, for divers without episodes of loss of consciousness (LOC), for divers with LOC due to gas cut and for divers with LOC due to other causes. The asterisks indicate subscales that are significantly different ($p < 0.05$) between divers having experienced LOC due to gas cut and divers not having experienced LOC

Table 3. Evoked related potential P300 and electroencephalogram (EEG) by groups of divers having experienced loss of consciousness (LOC) due to gas cut, due to other causes and not having experienced unconsciousness during diving

	Cause of LOC	Mean measurement	Mean measurement difference	Crude (p)	Adjusted (p)*
P300 central, latency [ms]	Gas cut	362	4.5	0.69	0.74
	Other causes	366			
	Gas cut	362	3.6	0.71	0.68
	No LOC	365			
P300 central, amplitude [µV]	Gas cut	10.7	1.6	0.32	0.37
	Other causes	12.3			
	Gas cut	10.7	2.1	0.16	0.17
	No LOC	12.8			
Motor reaction time [ms]	Gas cut	537	–63	0.15	0.24
	Other causes	474			
	Gas cut	537	–31	0.32	0.31
	No LOC	505			
Pathological EEG		**N (%)**	**Crude OR****	**95% CI**	
	Gas cut	4 (14.8)	2.25	0.42–15	
	Other causes	2 (6.5)	1		
	Gas cut	4 (14.8)	1.25	0.39–4.0	
	No LOC	19 (12.2)	1		

*Adjusted for age and decompression sickness; **Exact from 2 by 2 tables; None: divers reporting no episodes of LOC; OR — odds ratio; CI — confidence interval

not randomised. A governmental, financial compensation to injured North Sea divers was an issue at the time of the study. The divers involved in our study must have been aware of this and, accordingly, open to unwitting influences regarding their own state of health. These influences cannot, however, explain the differences within the group of divers.

The questions related to LOC were not included in the questionnaire or structured part of the interview. The divers told about their experiences while they were interviewed. The investigators were not blinded and an observer bias might lead to underreporting of the episodes. The recall bias must be considered as well, since the time elapsed between the episodes and the interview, being at least 15 years on average. Experiencing breathing problems under water is, on the other hand, quite dramatic and likely to be remembered and reported.

Todnem et al. [21] reported that 14% of the North sea divers in their sample had been unconscious during diving. The occurrence in our sample was 26%. The Norwegian divers in Todnem's sample belong to the same cohort as ours do, but were younger and professionally active during the investigation. At the time of our study most of the divers were retired, and our participants were referred for health complaints. Assuming that all the divers not included in our sample (108 out of 327) had no episodes of LOC, the prevalence is 18%. At the time of Todnem's study, reporting health complaints and episodes of LOC might jeopardise the divers' professional career. Hence the divers had more incentive for underreporting than for overreporting events at that time.

The reduction in HRQL compared to the Norwegian norm for SF-36 scores, may in part be explained by other factors, including additional factors associated with diving. Many divers (30–50%) do not fully recover after DCS [22]. In an earlier study we found that DCS, and neurological DCS in particular, was significantly associated with lower HRQL scores [23]. In the present study we adjusted for age and DCS in the statistical analyses.

Several studies have demonstrated long-term reduction in quality of life after episodes of hypoxia/anoxia due to drowning and cardiac arrest [10–13]. Except for Moulaert et al. [10], these studies have employed instruments other than SF-36 for assessing HRQL. When comparing to Moulaert et al.'s [10] patients with cardiac arrest, divers having experienced gas cut had lower scores on the SF-36. In divers breathing hyperoxic gas mixture, time from event to LOC is most likely longer because of the higher oxygen reserve in body. This oxygen reserve may have protected against serious brain injury. On the other hand, the lasting experience of not being able to breathe may have caused serious peritraumatic fear, which in turn may have a significant impact on long term HRQL. HRQL is a highly subjective measure and correlation to objective measures of disease severity is generally low.

The evoked related potential P300 is a measure of information processing and is sensitive to cerebral dysfunction [18]. Motor reaction time reflects the duration of at least 2 distinct stages. Stimulus evaluation and response occur serially, and the integrated response is dependent on adequate functioning in different regions of the brain. There were no differences between groups in P300, motor reaction time or EEG. Thus, the lower SF-36 scores are probably not related to cerebral dysfunction.

The present study demonstrates an unacceptably high prevalence of LOC during diving in this cohort of former North Sea divers who started diving before 1990. These results are important in understanding the different hazards and health risks among divers in general. LOC during diving is preventable, contingent upon the diving industry's focus on health and safety issues. Even though there were no differences in neurophysiological functioning between those unconscious during diving and those not, the quality of life issue is of concern and further studies should address the reasons for the lower scores.

REFERENCES

1. Bradley ME. Commercial diving fatalities. Aviat Space Environ Med 1984; 55: 721–724.
2. Scanpower Risk Management Report nr.27.207.307/R2, 4. Oslo: Scanpower 5 A.D. August 2005.
3. Lusby N. Diving statistics: a tool for improvement. Proceeding of the Norwegian underwater Intervention. Diving Seminar, Bergen 2011. http://www.nui.no/sitefiles/22/Dykkeseminar/2011/pdf/NLusby-esesjon 1.pdf (01 February 2013, date last accessed), 2011.
4. OSHA. Deaths associated with occupational diving: Alaska, 1990–1997. MMWR Morb Mortal Wkly Rep 1998;47: 452–455.
5. Denoble PJ, Caruso JL, Dear GL et al. Common causes of open-circuit recreational diving fatalities. Undersea Hyperb Med 2008; 35: 393–406.
6. Vaernes RJ, Eidsvik S. Central nervous dysfunctions after near-miss accidents in diving. Aviat Space Environ Med 1982; 53: 803–807.
7. Nolan JP, Neumar RW, Adrie C et al. Post-cardiac arrest syndrome: epidemiology, pathophysiology, treatment, and prognostication. A Scientific Statement from the International Liaison Committee on Resuscitation; the American Heart Association Emergency Cardiovascular Care Committee; the Council on Cardiovascular Surgery and Anesthesia; the Council on Cardiopulmonary, Perioperative, and Critical Care; the Council on Clinical Cardiology; the Council on Stroke. Resuscitation 2008;79: 350–379.
8. James PB, Calder IM. Anoxic asphyxia: a cause of industrial fatalities. A review. JR Soc Med 1991; 84: 493–495.
9. Craig AB, Jr. Summary of 58 cases of loss of consciousness during underwater swimming and diving. Med Sci Sports 1976; 8: 171–175.
10. Moulaert VR, Wachelder EM, Verbunt JA et al. Determinants of quality of life in survivors of cardiac arrest. J Rehabil Med 2010; 42: 553–558.
11. Choi SP, Youn CS, Park KN et al. Therapeutic hypothermia in adult cardiac arrest because of drowning. Acta Anaesthesiol Scand 2012; 56: 116–123.
12. Ballesteros MA, Gutierrez-Cuadra M, Munoz P et al. Prognostic factors and outcome after drowning in an adult population. Acta Anaesthesiol Scand 2009; 53: 935–940.
13. Sunnerhagen KS, Johansson O, Herlitz J et al. Life after cardiac arrest; a retrospective study. Resuscitation 1996; 31: 135–140.
14. The Norwegian Ministry of Labour and social Affairs.http://www.regjeringen.no/nb/dep/ad.html?id=165. 2012.

15. Ware JE, Jr., Sherbourne CD. The MOS 36-item short-form health survey (SF-36). I. Conceptual framework and item selection. Med Care 1992; 30: 473–483.
16. Loge JH, Kaasa S. Short form 36 (SF-36) health survey: normative data from the general Norwegian population. Scand J Soc Med 1998; 26: 250–258.
17. American Electroencephalografic Society. Guidelines in EEG. J Clin Neurophysiol 1994; 11: 1–39.
18. Goodin D, Desmedt J, Maurer K et al. IFCN recommended standards for long-latency auditory event-related potentials. Report of an IFCN committee. International Federation of Clinical Neurophysiology. Electroencephalogr Clin Neurophysiol 1994; 91: 18–20.
19. Duncan-Johnson CC, Donchin E. The P300 component of the event -related brain potential as an index of information processing. Biol Psychol 1982;14: 1–52.
20. SPSS Inc. Released 2009. PASW Statistics for Windows, Version 18.0. Chicago: SPSS Inc. 2009.
21. Todnem K, Nyland H, Kambestad BK et al. Influence of occupational diving upon the nervous system: an epidemiological study. Br J Ind Med 1990;47: 708–714.
22. Barratt DM, Harch PG, Van MK. Decompression illness in divers: a review of the literature. Neurologist 2002; 8: 186–202.
23. Irgens A, Gronning M, Troland K et al. Reduced health-related quality of life in former North Sea divers is associated with decompression sickness. Occup Med (London) 2007; 57: 349–354.