Internat. Marit. Health, 2003, 54, 1 - 4

# CHANGE OF OCCURANCE OF TYPE 1 AND TYPE 2 DECOMPRESSION SICKNESS OF DIVERS TREATED AT THE CROATIAN NAVAL MEDICAL INSTITUTE IN THE PERIOD FROM 1967 TO 2000

DEJAN ANDRIĆ*, NADAN M.PETRI*, HRVOJE STIPANCEVIĆ*,
LENA VRANJKOVIĆ PETRI**, HASAN KOVACEVIĆ

**Key words: diving, decompression sickness, epidemiology**

Note:

The opinions expressed herein are of the authors and do not necessarily reflect the views of the Naval Medical Institute, Croatian Navy, or the Ministry of Defence of the Republic of Croatia

## ABSTRACT

A significant change of occurrence (p=0.0343) of type 1 and type 2 decompression sickness (DCS) of divers in Croatia was observed in the period from 1991 to 2002 (type

* The Naval Medical Institute, Department of Undersea and Hyperbaric Medicine, Split, Croatia,
** Clinical Hospital Split,
*** Oxyhyperbaric Medicine, Pula, Croatia
Address for correspondence:
Dr Nadan M.Petri, MD, PhD
Naval Medical Institute, Undersea and Hyperbaric Medicine Department
21000 Split, p/p 196 (HRM) Republic of Croatia

1: n=26, 37.68% and type 2: n=43, 62.32%) compared with the period from 1967 to 1990 (type 1: n=93, 52.84% and type 2: n=83, 47.16%).

The change was attributed to the extensive usage of diving computers and artificial gas mixtures which enable extended bottom times and deeper dives, thus putting divers at an increased decompression risk. The importance of the results of this report is in the fact that permanent neurological deficit occurs only after type 2 DCS. Injured divers with permanent loss after type 2 DCS are not fit for diving and require a long term medical care, thus becoming a significant public health problem.

## INTRODUCTION

Decompression sickness (DCS) is a specific health problem of all persons breathing compressed air or artificial gas mixture, but is most commonly encountered in diving, both recreational and professional. The disease is precipitated by gas bubbles that remain in tissues after a dive or pressure exposure. It is manifested by a variety of signs and symptoms ranging from pruritus to convulsions and death, as described in a classic work by Rivera (1).

Traditionally, the disease is classified as type 1 and type 2. Type 1 is considered to be less severe and includes musculoskeletal, cutaneous, and lymphatic form, and malaise/anorexia/fatigue. Type 2 is a more severe form and represents a significant health risk. It includes pulmonary and neurological forms, and hemoconcentration and hypovolemic shock (2).

In the recent years, recreational diving has become extremely popular and entry health criteria for the candidates have become less strict. An estimated number of divers in the United States of America at the beginning of this decade could be over 9 million (3).

Based on the Divers Alert Network (DAN) 2002 Report, the number of injured divers has been constantly increasing since 1987, when DAN started reporting diving injuries and fatalities. In the year 2000, DAN received 1042 reports on injured divers (4). In the 1980s, there were some 5 000 divers diving annually in Croatia. Nowadays, up to 100 000 divers, mostly foreign tourists, dive in the Croatian part of the Adriatic Sea each year, mostly in the period from June to September, during a week or two weeks holidays (Lukas N, Croatian Diving Federation, personal communication).

DCS symptoms vary so much from case to case, that it was said there is no DCS, but merely people who contract it. Of two divers diving together to the same depth, with the same bottom time, same ascent rate, and after same decompression, one diver could

get severe DCS and even die, while the other diver could be free of symptoms. Most often, in about 60% of the cases, DCS is manifested as "bends", a condition similar to unspecific rheumatoid problems (5). There are several excellent reviews on DCS (1,2,5,6,7) and hundreds of papers investigating this problem, but we still do not know enough about its pathophysiology, onset, treatment, and epidemiology. The delay of onset of symptoms after surfacing might vary, but in 95% of DCS cases the symptoms would manifest within 12 hours (1,2,4,5,6,7).

In the recent years, our impression was that clinical manifestations of DCS have become more serious in Croatia than previously observed (8,9,10). We also felt that DCS was manifested more often as type 2 or mixed form (type 1 plus type 2). Besides, establishing the diagnosis of DCS represented sometimes an intriguing diagnostic problem (11). We speculated that changes in diving pattern which occurred in Croatia during the last 10 or 12 years could be responsible for that.

In the period from 1967 to 1991, diving was almost exclusively based on conservative United States Navy (USN) air diving decompression tables (8,9). Since 1991, divers in the Croatian Adriatic have been using artificial gas mixtures more frequently. Besides, the usage of diving computers has become extremely popular, enabling less conservative decompression procedures (10). The fact is that gas mixtures and diving computers enable deeper dives and extended bottom times in comparison with decompression procedures found in air decompression tables (4,5,6,7). We noticed that erroneous use of diving computer algorithms also contributed to the occurrence of diving injuries, for example when a computer was used for more than two successive dives or when air dives were accomplished to the depths greater than 50 meters.

Thousands of unexperienced summer divers, tourists mostly from non-maritime European countries, arrive to the Croatian Adriatic every year. They represent a significant challenge to the national sea rescue network because there are hundreds of remote dive resorts and we have only two recompression centers, in Pula and Split. Although both centers are within a range of one hour helicopter flight from every site in the Croatian Adriatic, each rescue action necessarily results in an engagement of numerous people participating in first aid, urgent helicopter or sea transport, medical evaluation of a diver, and his/her recompression treatment.

Till the year 1990, an average number of treated divers for the entire Croatian Adriatic was up to 10 per year (8,9), while nowadays it is up to 60 (12). Up to 15 DCS cases are now treated per year at the Undersea and Hyperbaric Medicine Department of the Naval Medical Institute of the Croatian Navy in Split (NMI), while the remaining cases are treated in a recompression chamber in Pula, which became operational in 1996. Th explanation for this difference is that up to 85% people dive in the North Adriatic.

The objective of this paper is to demonstrate the change of occurrence of type 1 and type 2 DCS observed at the NMI in the period from 1991 to 2002 as compared with the period from 1967 to 1990.

## MATERIALS AND METHODS

The data from the archives of the NMI covering the period from 1967 to 2002 were analysed. We compared the data from 1967 to 1990 with the data from 1991 to 2002. The data from the first period included DCS cases for the entire Croatian Adriatic. The data from the second period included DCS cases only from Middle and South Adriatic, because in that period a new recompression chamber in Pula became operational. In statistical analysis, Chi-square test was used. P-values less than 0.05 were considered significant.

## RESULTS

A total of 245 divers with DCS were treated at the NMI from 1967 to 2002. The distribution of DCS types is presented in Table 1.

Table 1. Comparison of distribution of types of decompression sickness of divers treated at the Naval Medical Institute of the Croatian Navy in Split in the period from 1967 to 1990 and 1991 to 2002 (n=245).

| Period/Type of DCS | Type 1 | Type 2 | Total |
|---|---|---|---|
| 1967 - 1990 | 93 (52.8%) | 83 (47.2%) | 176 |
| 1991 - 2002 | 26 (37.7%) | 43 (62.3%) | 69 |
| Total | 119 | 126 | 245 |

Cumulative distribution of numbers of DCS cases and delay of onset of symptoms for type 1 and type 2 DCS for both periods are presented in Table 2.

Table 2. Cumulative distribution of divers treated for type 1 and type 2 decompression sickness at the Naval Medical Institute of the Croatian Navy in Split and delay of onset of symptoms in the period from 1967 to 2002 (n=245).

| Period/Delay of onset of symptoms | During ascent | In 30 min. | In 1 hr | In 3 hrs | In 6 hrs | In 12 hrs | In 24 hrs | More than 24 hrs |
|---|---|---|---|---|---|---|---|---|
| 1967 to 1990<br>Type 1<br>Type 2 | 6 (6.5%)<br>9 (10.8%) | 45 (48.4%)<br>69 (83.1%) | 60 (64.5%)<br>75 (90.4%) | 74 (79.6%)<br>80 (96.4%) | 84 (90.3%)<br>81 (97.6%) | 88 (94.6%)<br>83 (100%) | 91<br>(97.8%) | 93 (100%) |
| 1991 to 2002<br>Type 1<br>Type 2 | 4 (15.4%)<br>8 (18.6%) | 17 (65.4%)<br>28 (65.1%) | 21 (80.7%)<br>37 (86%) | 24 (92.3%)<br>40 (93%) | 26 (100%)<br>40 (93%) | 41 (95.3%) | 43 (100%) | |

In only one case the diver was sent for the recompression treatment with the wrong diagnosis, but in 66 cases (27%), the physicians at various diving sites reached the diagnosis with difficulties and after prior consultations with the NMI. 86 divers (35%) came to the NMI directly, without first seeing a doctor at the diving site or in a medical institution located near to the site.

## DISCUSSION AND CONCLUSIONS

Type 2 DCS, observed per total number of DCS cases, occurred more often (Table 1) in the period from 1991 to 2002 (n=43, 62.33%) compared with the period from 1967 to 1990 (n=83, 47.16%). This difference was statistically significant (p=0.0343). The percentage of type 2 in the second period was basically similar to the percentages previously reported in the literature (4,13,14,15,16,17,18,19,20,21).

We attribute this finding to the increased number of unexperienced recreational divers, increased popularity of the usage of diving computers, and increased usage of artificial gas mixtures.

However, for the reasons beyond the scope of this paper, a 20-fold increase in the total number of divers did not result in the same increase of number of DCS cases. This relative decrease was also observed in the literature (4). Nowadays in Croatia, even beginners dive up to the depths of 50 or 60 m, most often on compressed air, which is much deeper than could have been imagined before the year 1991, thus putting themselves at an increased decompression risk. In our group of divers, the first symptoms of DCS were manifested within 12 hours in 97.1% of cases, which is basically the same as previously reported (1,2,4,5,6,7).

The comparison of number of cases of both types of DCS in both periods, which occurred after the same delay of onset of symptoms (Table 2), did not show statistically significant differences ($p>0.05$).

The incidence of DCS in the diving community is generally low, ranging from 0.013% to 1.25% (22,24,24). Since divers, for various reasons, often tend to neglect minor symptoms, the number of divers treated for DCS never represents the number of divers who really had DCS. In recreational divers, type 2 DCS is far more frequent than type 1 DCS, comprising up to 80% of reported cases. In commercial and military diving, type 1 DCS occurs in 86% of symptomatic decompression.

It could be assumed that recreational divers make more errors in diving than professionals, which results in more serious type of DCS (5). The occurrence of DCS depends on numerous risk factors (25), but the most important of them are the basic determinants of decompression stress, i.e. depth, bottom time, and ascent rate (1,2,3,4,5,6,7).

The importance of DCS is not in its occurrence per number of pressure exposures, but in the fact that it might be a cause of permanent invalidity and, in rare cases, even of fatal outcome. Thus, even minor symptoms require recompression treatment. According to the 2002 DAN Report based on the year 2000 data, the proportion of injured divers using dive computers (73% in the year 2000) continues to increase over previous years, although this may reflect the continued growth in popularity of the use of dive computers rather than the increased risk over dive tables (4). However, it was estimated that the use of the 40 feet of seawater (fsw) for 200 minutes schedule in a decompression computer is likely to result in DCS incidence 2.5- to 70-fold greater than that observed in diving using United States Navy table-based procedures (23).

The importance of the change of occurrence of type 1 and type 2 DCS observed in this report is in the fact that permanent neurological deficit occurs only after type 2 DCS. Injured divers with permanent loss after type 2 DCS are not fit for diving and require a long term medical care, thus representing a significant public health problem (3).

## REFERENCES

1. Rivera JC. Decompression sickness amongst divers: An analysis of 935 cases. Milit Med 1963;129:314-34.
2. Elliott DH, Kindwall EP. Manifestations of the decompression disorders. In: Bennet PB, Elliott DH, eds. The physiology and medicine of diving. London. Bailliere-Tindall, 1982:461-72.

3. Newton HB. Neurologic complications of scuba diving. Am Fam Physician 2001;63:2211-8.
4. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 2002.
5. Dutka AJ, Francis TJ. Pathophysiology of decompression sickness. In: Bove AA, ed. Diving medicine. 3rd ed. Philadelphia: WB Saunders, 1997:159-75.
6. Edmonds C, Lowry C, Pennefather J. Decompression sickness: clinical manifestations. In: Diving and subaquatic medicine. 3rd ed. Oxford: Butterworth-Heinemann, 1992:159-78.
7. Elliott RE, Moon RE. Manifestations of the decompression disorders. In: Bennett PB, Elliott DH. The physiology and medicine of diving, 4th ed. London: WB Saunders, 1993:481-505.
8. Kovacevic H, Denoble P, Gosovic S, Runje M, Zivkovic M. Clinical manifestations and results of treatment of decompression sickness and barotraumatic gas embolism in recompression chambers of the Navy from 1982 to 1985. In: Agolli B, ed. Book of proceedings of the 4th Congress on maritime medicine. Belgrade: Mornaricki glasnik. 1987:315-22 (in Croatian).
9. Kovacevic H, Gosovic S, Denoble P, Zivkovic M, Andric D. Experience in the treatment of 154 cases of decompression sickness contracted in standard compressed air diving from 1967 to 1988. In: Agolli B, ed. Book of proceedings of the 4th Congress on maritime medicine. Belgrade: Mornaricki glasnik. 1990:269-77 (in Croatian).
10. Andric D, Petri NM. Cases of decompression sickness treated at Naval Medical Institute of the Croatian Navy in Split from 1991 to 1997. In: Petri NM, Andric D, eds. Book of proceedings of the 1st Croatian congress on maritime, undersea, and hyperbaric medicine. Split: Croatian Maritime, Undersea, and Hyperbaric Medicine Society. 1998:125-34 (in Croatian).
11. Petri NM, Andric D. Differential diagnosis problems of decompression sickness. Examples from a diving medicine specialist's experience and case reports. Arch Med Res 2003;34(1):26-30.
12. Andric D, Petri NM, Stipancevic H. Diving accidents in the Middle and South Adritic in the year 2002. In: Materljan E, ed. Book of proceedings of primary health care symposium. Labin: Dom zdravlja. 2002:260-8 (in Croatian).
13. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1993.
14. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1994.
15. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1995.
16. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1996.

17. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1997.
18. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1998.
19. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 1999.
20. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 2000.
21. Anonymous. Report on diving accidents and facilities. Durham: Divers Alert Network, 2001.
22. Arness MK. Scuba decompression illness and diving fatalities in an overseas military community. Aviat Space Environ Med 1997;4:325-33.
23. Ball R, Parker EC. A trial to determine the risk of decompression sickness after a 40 feet of sea water for 200 minute no-stop air dive. Aviat Space Environ Med 2000;71:102-8.
24. Berghage TE, Durman D. US Navy air decompression table and risk analysis. Naval Medical Research Institute Technical Report 80-1, 1980.
25. Gorman DF, Pearce A, Webb RK. Dysbaric illness treated at the Royal Adelaide Hospital 1987: A factorial analysis. South Pac Underwater Med Soc J 1988;18:95-101.