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RECOMPRESSION TREATMENT FOR DECOMPRESSION ILLNESS: 5-YEAR REPORT (2003-2007) FROM NATIONAL CENTRE FOR HYPERBARIC MEDICINE IN POLAND

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ABSTRACT

A serious diving accident can occur in recreational diving even in countries where diving is not very popular due to the fact that diving conditions there are not as great as in some tropical diving locations. The estimated number of injured divers who need recompression treatment in European hyperbaric facilities varies between 10 and 100 per year depending on the number of divers in the population, number of dives performed annually, and number of hyperbaric centres in the country. In 5 years of retrospective observation in Poland (2003-2007) there were 51 cases of injured recreational divers recorded. They either dived locally or after returning home by air from a tropical diving resort. All of them were treated with recompression treatment in the National Centre for Hyperbaric Medicine in Gdynia which has capability to treat any patient with decompression illness using all currently available recompression

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schedules with any breathing mixtures including oxygen, nitrox, heliox or trimix. The time interval between surfacing and first occurrence of symptoms was significantly lower in the group of patients with neurological decompression sickness or arterial gas embolism (median 0.2 hours) than in the group of patients with other types of decompression sickness (median 2.0 hours). In both groups, there were different types of recompression tables used for initial treatment and different number of additional sessions of hyperbaric oxygenation (HBO) prescribed, but the final outcome was similar. Complete resolution of symptoms after initial recompression treatment was observed in 24 cases, and this number was increased to 37 cases after additional HBO sessions (from 1 to 20). In the final outcome, some residual symptoms were observed in 12 cases. In 2 cases initial diagnosis of decompression sickness type I was rejected after initial recompression treatment and careful re-evaluation of diving profiles, risk factors and reported symptoms.

Keywords: decompression illness, arterial gas embolism, recompression treatment, hyperbaric oxygen therapy, diving accident

INTRODUCTION

Serious diving injuries in recreational diving are rare and often seem to be associated with hazardous conditions or unsafe behaviour. An estimated rate of decompression illnesses in recreational diving is a little less than 3.1 cases per 10,000 dives, as estimated from the Project Dive Exploration (PDE) by Divers Alert Network (1) or even less than 1.8 cases per 10,000 dives, as estimated by questionnaire survey in Germany (2). In tropical diving resorts, where there are thousands of dives conducted every day, as for example in Sharm el-Sheikh in Egypt, this can result in significant number of patients in a single hyperbaric centre, about 50 cases per year (3). But in countries, where diving conditions are usually not so great due to relatively low temperature of water, its poor visibility, strong currents and high probability of fishing nets covering ship wrecks, diving population is smaller and local morbidity of decompression sickness can be lower. For example, over last 30 years in the German Naval Medical Institute there were 267 cases of neurological decompression illness treated with recompression (4), which gives little more than 8 such cases per year. On the other hand, in some European countries the number of divers treated with hyperbaric recompression can be surprisingly high, as for example in Sweden an average 40 recreational divers are treated with recompression each year (5) and in UK there are about 100 cases of decompression illness treated annually (6). Nevertheless, every

country with a significant population of divers must be prepared for treatment of decompression sickness or arterial gas embolism, either experienced after diving in local waters or after flight home from tropical diving resorts. In Poland, there is one hyperbaric centre which is capable to treat any diver with decompression illness using all currently available recompression schedules with any breathing mixtures (oxygen, nitrox, heliox or trimix) and it is the National Centre for Hyperbaric Medicine in Gdynia. It is located in the northern part of Poland and the longest distance for medical air evacuation from all over the country is about 700 km. Every injured diver should be transported there (and in practice they are) in order to be recompressed in the hyperbaric chamber. The aim of this paper is to report cases of decompression illness treated in this Centre during 5-year observation.

MATERIAL AND METHODS

We retrospectively analyzed data on all cases of injured divers who were recompressed in the National Centre for Hyperbaric Medicine due to diving accidents from 2003 to 2007. During this period, there were 51 patients admitted for recompression treatment.

For every case the following data was collected and described: age, sex, type of dive (single / repetitive), mode of dive (according to the plan / emergency event), breathing mixture (air / nitrox with or without oxygen / trimix with or without nitrox and/or oxygen), maximum diving depth, bottom time, total diving time, time interval between surfacing and symptoms occurrence, time interval between symptoms occurrence and start of recompression treatment, initial diagnosis at admission to the hyperbaric centre, type of recompression table used for initial treatment, clinical effects of recompression table, number of HBO sessions applied after initial recompression treatment, final diagnosis and final outcome after completing whole HBO treatment.

In two cases, the initial diagnosis of decompression illness was rejected after failure of initial recompression treatment to change any of symptoms. In those two cases further careful re-evaluation of risk factors and symptoms also did not support the initial diagnosis. In the second step of analysis, those two cases were rejected, so number of cases with confirmed final diagnosis of decompression illness was 49. Then this sub-population was divided into two groups: the DCS1 group with patients with decompression sickness type I which included 37 cases with skin, muscular, lymphatic or joint presentation of symptoms and the DCS2AGE group with patients with decompression sickness type II or arterial gas embolism (AGE) which included 12 cases

with neurological symptoms of cerebral or spinal decompression sickness or cerebral AGE. Both groups were then compared in the univariate mode using all collected data.

Statistical data was evaluated with Pearson chi2 test with Yates' continuity correction and Mann-Whitney's test using statistical software Statistica 8 (StatSoft, Inc. 2007). The results are reported as mean ± standard deviation (SD) with median and range of values. A P value < 0.05 was considered statistically significant.

RESULTS

In total, in five years of observation (2003-2007) there were 51 divers, including 47 males (92.2%) and 4 females (7.8%), which were treated using hyperbaric recompression in the National Center for Hyperbaric Medicine in Gdynia, Poland. In 2003 there were 8 cases, in 2004 – also 8 cases, in 2005 – 10 cases, in 2006 – 14 cases and in 2007 – 11 cases.

The mean age of divers was 34.6 ± 9.6 [SD] years (median 32; range 18 – 63). Divers' age distribution is presented on.

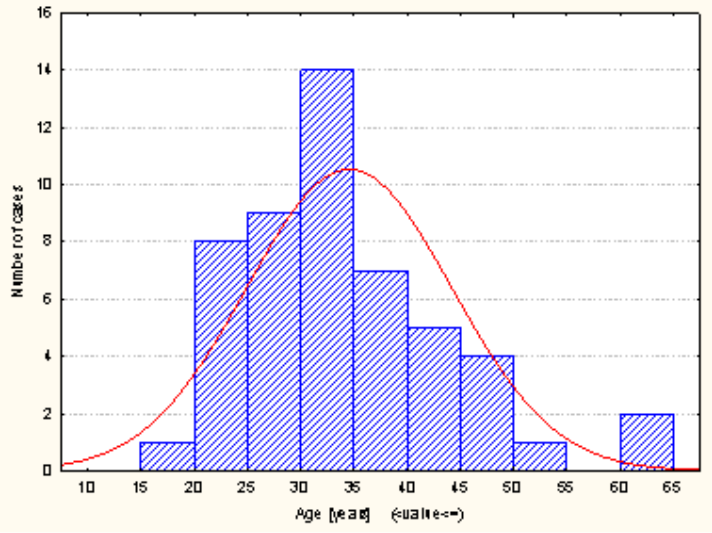

Figure 1. Divers' age distribution.

Description of dives which preceded the admission to our Centre is presented in Table 1 and the maximum diving depth distribution is presented on.

Table 1. Dive parameters for all divers.

Dive parameter	Value
Type of dive (single / repetitive)	14 (27.5%) / 37 (72.5%)
Mode of dive (conducted with the plan / emergency event*)	34 (66.7%) / 17 (33.3%)
Breathing mixture (air / nitrox** / trimix ***)	37 (72.5%) / 9 (17.6%) / 5 (9.9%)
Maximum diving depth (m)	41.1 ±20.4 SD (median 40; range 15-137)
Bottom time (min)	24.2 ±13.4 SD (median 24; range 4-56)
Total diving time (min)	40.9 ±22.4 SD (median 37; range 10-110)

* Emergency event includes emergency surfacing or omitted decompression stop

** Nitrox includes also usage of oxygen for decompression

*** Trimix includes also usage of nitrox with or without additional oxygen for decompression

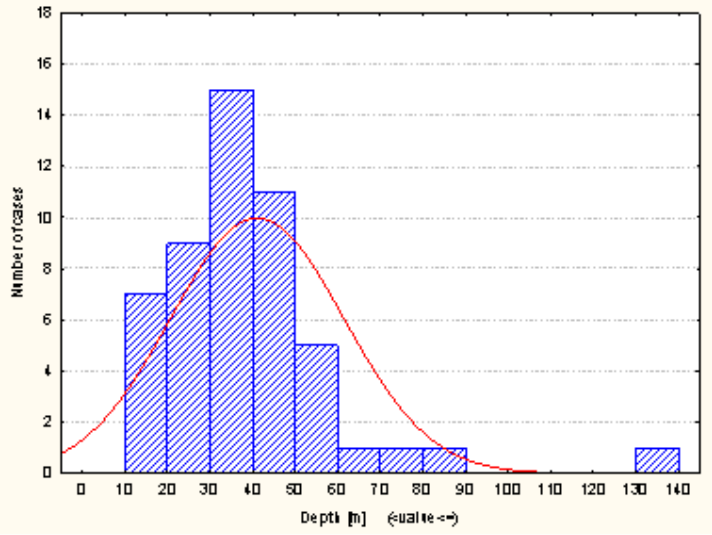

Figure 2. Maximum diving depth distribution.

The median time interval between surfacing and first occurrence of symptoms was about 1 hour and the median time interval between first symptoms occurrence and start of recompression was 32.5 hours (**Table 2**). Distributions of both time intervals are presented on **Figure 3** and **Figure 4**.

Table 2. Time intervals between surfacing and first occurrence of symptoms or start of recompression for all divers.

Time interval	Value
Between surfacing and first symptoms (hours)	10.9 ±21.2 SD (median 1,0; range 0.0-96.0)
Between first symptoms and start of recompression (hours)	54.5 ±56.1 SD (median 32.5; range 2.0-193.5)

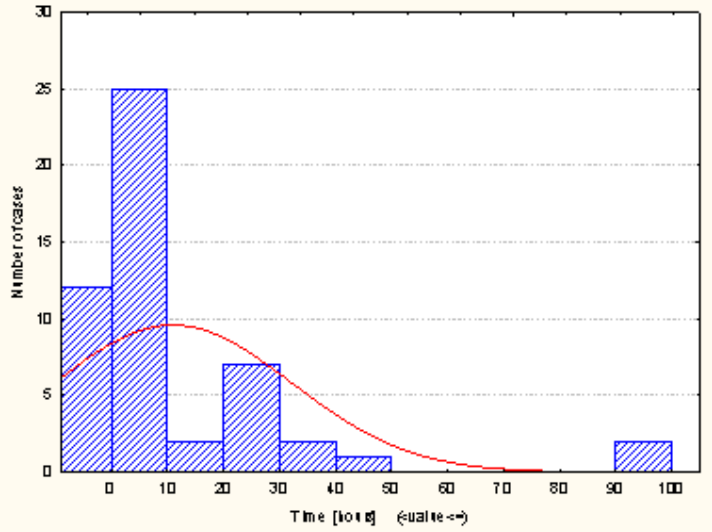

Figure 3. Distribution of time interval between surfacing and first occurrence of symptoms.

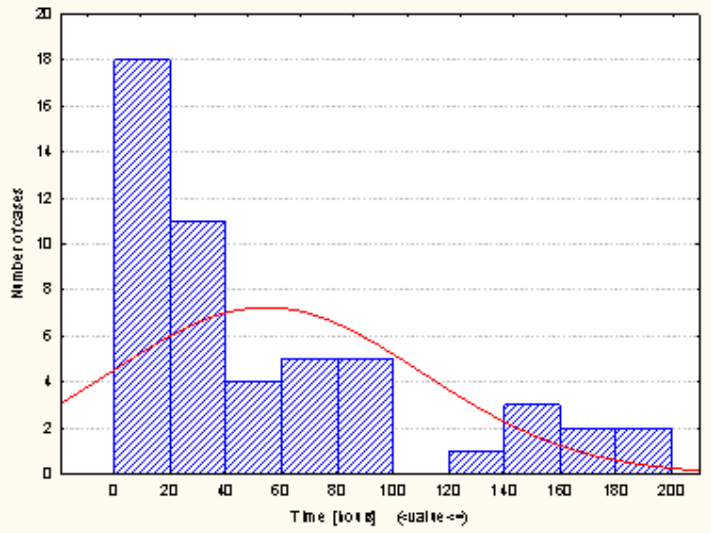

Figure 4. Distribution of time interval between first occurrence of symptoms and start of recompression treatment.

At admission, the initial diagnosis was: decompression sickness type I (DCS1) in 39 cases (76.5%), decompression sickness type II (DCS2) in 10 cases (19.6%) - including 5 cases of spinal cord decompression sickness and 5 cases of cerebral decompression sickness - and arterial gas embolism (AGE) in 2 cases (3.9%).

For recompression, the following recompression schedules were used

- in 36 cases (including 33 cases of DCS1) – United States Navy (USN) table 5,
- in 9 cases (including 7 cases of DCS2) – USN table 6,
- in 3 cases – USN table 5 with at least one extension,
- in 1 case – USN table 6 with extensions,
- in 1 case – USN table 5 followed by USN table 6,
- in 1 case – USN table 6 followed by USN table 6 with extensions then followed by Comex Cx30 with heliox (50% helium and 50% oxygen).

In three cases, after the first recompression schedule, the initial diagnosis made at admission was changed. In two cases with initial diagnosis of decompression sickness type I there was failure of recompression treatment to induce any change of symptoms and further careful re-evaluation of diving profiles and risk factors caused change of the

final diagnosis into 'negative observation toward the decompression sickness'. In one case after post-recompression review of available data the initial diagnosis of 'AGE' was changed to 'cerebral decompression sickness'. In order to analyze the recompression effects and the final outcome of HBO treatment, as well as to make comparisons between different diagnoses, those two cases of negative observations were rejected from further analysis and one case described above was recoded from "AGE" to "DCS2CEREBRAL", but this did not cause change of the final group designation (DCS2AGE).

In this sub-population of 49 cases, the complete resolution of symptoms after the initial recompression treatment was observed in 24 cases (49.0%), significant improvement was observed in 16 cases (47.0%) and in one case (2.0%) there was no change in clinical symptoms.

In 12 cases (24.5%) adjunctive pharmacological treatment, other than fluids for hydration, was used. This included lidocaine, low-molecular-weight heparin, non-steroidal anti-inflammatory drugs, steroids, piracetam, diuretics, osmotic diuretic agents, proton pump inhibitors and/or vitamins. In 7 cases (14.2%) the initial recompression was the only hyperbaric treatment. In all other cases (N=42, 85.8%) the additional HBO treatment was conducted with the median number of 4 HBO sessions (range from 1 to 20 sessions) and in 13 cases this treatment resulted in complete resolution of symptoms (as added to those cases where complete resolution of symptoms was observed already after initial recompression treatment), in 8 cases in further improvement and in 3 cases there was no change in symptoms.

The final outcome, including both recompression treatment and all HBO sessions, was positive (with complete resolution of symptoms) in 37 cases (75.5%) and fairy good (improvement, but with some residual symptoms) in 12 cases (24.5%). There was not any single case with negative effect of combined recompression and HBO treatment defined as no change of symptoms or deterioration in clinical status.

In two cases during the recompression schedule there were oxygen toxicity symptoms (loss of consciousness and generalized convulsions) which developed while patients were breathing 100% oxygen under pressure of 2.8 ATA; both resolved without any further residual symptoms and pre-planned recompression and HBO treatment were completed in both cases.

The comparison of dive profiles between two groups (DCS1 versus DCS2AGE) is summarized in Table 3.

Table 3. Comparison of dive parameters between group of DCS1 and DCS2AGE.

Dive parameter	Group DCS1 N=37	Group DCS2AGE N=12	P
Age (years)	33.9±8.4 SD (median 32.0; range 23.0-61.0)	35.0±13.1 SD (median 31.0; range 18.0-63.0)	0.09
Sex (female / male)	2 (5.4%) / 35 (94.6%)	2 (16.7%) / 10 (83.3%)	0.53
Type of dive (single / repetitive)	7 (18.9%) / 30 (81.1%)	6 (50.0%) / 6 (50.0%)	0.08
Mode of dive (conducted with the plan / emergency event*)	26 (70.3%) / 11 (29.7%)	6 (50.0%) / 6 (50.0%)	0.35
Breathing mixture (air / nitrox** / trimix***)	26 (70.3%) / 7 (18.9%) / 4 (10.8%)	10 (83.4%) / 1 (8.3%) / 1 (8.3%)	0.64
Maximum diving depth (m)	41.8±22.2 SD (median 40.0; range 16.0-137.0)	38.0±16.4 SD (median 40.0; range 15.0-75.0)	0.70
Bottom time (min)	24.3±11.8 SD (median 24.0; range 4.0-40.0)	23.6±20.3 SD (median 24.0; range 5.0-56.0)	0.83
Total diving time (min)	42.7±22.8 SD (median 40.0; range 10.0-110.0)	35.9±21.8 SD (median 28.5; range 10.0-85.0)	0.27

* Emergency event includes emergency surfacing or omitted decompression stop

** Nitrox includes also usage of oxygen for decompression

*** Trimix includes also usage of nitrox with or without additional oxygen for decompression

The median time interval between surfacing and first occurrence of symptoms was about 12 minutes in the DCS2AGE group and it was significantly shorter than in the DCS1 group, where it was 2 hours (**Table 4**). The difference of time intervals between first symptoms and start of recompression treatment between both groups did not reach statistical significance (P=0.08).

Table 4. Time intervals between surfacing and first symptoms and start of recompression in two groups.

Time interval	Group DCS1 N=37	Group DCS2AGE N=12	P
between surfacing and first symptoms (hours)	12.3±186.2 SD (median 2.0; range 0.0-96.0)	8.6±27.5 SD (median 0.2; range 0.0-96.0)	0.03
between first symptoms and start of recompression treatment (hours)	60.1±53.5 SD (median 48.5; range 4.0-193.5)	43.4±66.6 SD (median 14.3; range 2.0-192.5)	0.08

The usage of recompression tables was different between both groups (P<0.001), where in the DCS1 group there was significantly higher rate of usage of USN table 5 (with different extensions) and in the DCS2AGE group there was statistically significantly higher rate of usage of USN table 6 (with different extensions). Also number of HBO sessions was different between two groups (P=0.003) and it was higher in the DCS2AGE group than in the DCS1 group, with median number of 8.0 (range 2.0-20.0) and 3.0 (range 0.0-10.0), respectively. Nevertheless, there was no statistically significant difference of final outcomes between both groups (P=0.55).

DISCUSSION

During 5 years of observation there were 51 divers treated in our Centre using hyperbaric recompressions, which gives average number of 10 cases of diving accidents per year. This rate is quite similar to reports from other countries which are comparable to Poland in environmental and diving conditions.

In the whole group of all divers being admitted to our Centre for hyperbaric treatment, most divers (72.5%) did dives using compressed air. This reflects the extensive usage of compressed air by recreational divers, regardless of increasing popularity of other breathing mixtures (nitrox, heliox and trimix). More than 70% of patients did repetitive dives before symptoms occurred and indeed a repetitive exposition is a well recognized risk factor for decompression illness (7).

On the other hand, only in one third of cases, there was an emergency event during dives (emergency surfacing or omitted decompression stop) and in two third of cases dives were conducted according to the diving plan and all instructions of decompression tables or diving computers were followed.

Statistical comparison of two groups (DCS1 versus DCS2AGE) showed no significant difference between them at least for basic dive parameters, but it must be emphasized that this was a univariate analysis. Unfortunately small number of cases precluded from using the multivariate analysis to verify the influence of all parameters on final outcome of treatment.

There was statistically significant difference in time intervals between both groups. Time interval between surfacing and first occurrence of symptoms was shorter in divers in the DCS2AGE group, where in 50% of cases time interval was shorter than 12 minutes, as compared with the DCS1 group, where in 50% of cases time interval was 2 hours. There was also 4-fold difference (but still not significant probably due to small

number of cases in the DCS2AGE group) in median time interval between first occurrence of symptoms and start of recompression, which is estimation of transportation time to the hyperbaric centre. Not surprisingly this time interval was shorter in the DCS2AGE group, where neurological manifestation of symptoms usually urged immediate transportation to hyperbaric centre. But even in such cases, the longest noticed delay reached almost 8 days.

Usage of recompression schedules applied for injured divers was different in both groups, but this is not surprising as prescription of recompression treatment strongly depends on initial diagnosis. In most cases with neurological decompression sickness or AGE the initial recompression schedules is based on the USN table 6 (with or without extensions) and in some patients with decompression sickness type I the USN table 5 can still be used if symptoms are mild and disappears after the first oxygen breathing period. Also number of additional HBO sessions prescribed to injured divers after completing the initial recompression treatment was different between both groups, and it was statistically significantly higher in the DCS2AGE group. Nevertheless, the final outcome was good in both groups with no statistically significant difference. This confirms that regardless of severity of symptoms, where symptoms of patients with decompression sickness type II or AGE are generally expected to be more serious than in patients with decompression sickness type I, the algorithm of choosing the recompression schedule is appropriate and final outcome is similar.

In one case of 53-year-old male diver who dived to maximum depth of 46 meters with compressed air for 25 minutes of bottom time and 37 minutes of total diving time, first symptoms of spinal decompression sickness occurred after 15 minutes of uneventful decompression. Recompression treatment using USN table 6 (total recompression time of 4 hours 50 minutes) started after 1.5 hours after symptoms; however there was no change in clinical symptoms. Therefore the second recompression schedule was initiated using USN table 6 with 4 extensions (two at 2.8 ATA and two at 1.9 ATA with total recompression time of 8 hours 10 minutes), but also without any improvement. Then the Comex Cx 30 with heliox 50% oxygen and 50% helium was conducted (total recompression time of 7 hours 30 minutes) with only slight improvement of clinical status. After 20 additional HBO sessions patient was discharged from hyperbaric centre with persistent neurological deficits of spinal cord for further rehabilitation. This case confirms that in decompression illness of spinal cord, even if extensive recompression treatment is initiated shortly after occurrence of symptoms, the prognosis is poor and residual symptoms can be serious.

To conclude, this paper reports the rate of decompression illness and recompression treatment in Poland, time intervals between surfacing, occurrence of symptoms and start

of recompression treatment, as well as final outcome of treatment of divers by recompression schedules.

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