# THE OUTCOME OF 125 DIVERS WITH DYSBARIC ILLNESS TREATED BY RECOMPRESSION AT HMNZS PHILOMEL

Stefan Brew, Courtenay Kenny, Robert Webb and Des Gorman

## Summary

125 civilian sport scuba divers with dysbaric illness have been treated with recompression at HMNZS PHILOMEL over a 23 year period. A retrospective factorial analysis of the case records was carried out to identify the factors influencing outcome.

A significantly better outcome was noted in those divers who kept within conservative tables and in those whose dive profiles resulted in a low repetitive dive group.

The study also demonstrated the importance of obtaining adequate information at the time of treatment in order to facilitate prospective study.

## Introduction

Decompression sickness (DCS) and arterial gas embolism (AGE) are dysbaric illnesses amenable to treatment with hyperbaric oxygen (HBO). The clinical features of both include significant neurological abnormalities and the morbidity following treatment is unsatisfactorily high. In addition to obvious sequelae such as weakness, sensory deficit and cerebellar dysfunction, there may also be more subtle neuropsychologic abnormalities.[1,2] Such sequelae may nevertheless be distressing to the patient and highlight the need for early and adequate treatment.

The recompression chamber (RCC) at NMNZS PHILOMEL was established in 1959 to support Naval diving. However therapeutic recompressions have been predominantly for civilian sport scuba divers.

We report here a factorial analysis of all those divers treated by recompression and have used this to identify those factors associated with a poor outcome.

## Patients and Methods

The study includes all patients with a diagnosis of DCS or AGE and who were treated with recompression. Recompression includes all treatments undertaken in the RCC regardless of their duration or number.

Those patients who presented with a history and clinical features indicative of AGE but who also had dive profiles predisposing them to DCS were classified as AGE.

The data fields considered are listed in Table 1 with the proportion of data available for each field indicated.

This data was then entered on computer using the database programme dBase III plus. Programmes were designed to generate the descriptive data presented in Tables 1 to 4.

A further programme was developed to construct 2 x 2 contingency tables of outcome (complete or incomplete recovery) against the other factors in Table 1. This process was performed for outcome after first recompression, at discharge from hospital and at follow-up after one month. Complete recovery was considered to be the absence of any detectable neurological or other abnormality as indicated in the case notes. Incomplete recovery was taken as any comment in the case notes describing residual symptoms or signs related to the most recent episode of dysbaric illness. If the status of the patient was unclear, no outcome was assigned.

Patients with a diagnosis of AGE were considered separately from those with DCS.

Where a factor was not binomial, a range of values, including the mean, were used to divide the DCS and AGE populations into groups for comparison.

Although the original population consisted of 125 cases, when considered as two populations by diagnosis and excluding those cases of unknown outcome, some cells of the contingency tables were of such small size that Chi-square analysis was inappropriate. Therefore, Fisher's Exact test was performed and a p value of $< 0.01$ was considered significant.

Adjunctive treatment, if any, included combinations of aspirin, anti-coagulants, intravenous fluid, lignocaine, non-steroidal anti-inflammatory agents and steroids. Any treatment with one of these agents was recorded, regardless of its dose, frequency or duration.

## Results

A total of 125 patients were treated over a 23 year period. From 1967 until 1983 the average number of patients was less than 2 annually, but from 1984 onwards this increased to 15 per year.

The mean values and standard deviations of numerical data fields for DCS and AGE are shown in Table 2.

The ages of patients ranged from 16 to 58 years, with the average age for both groups being approximately 33 years. The average overall level of diving experience was 6.7 years. For DCS the average level of formal diver training was to the equivalent of PADI Advanced Open Water Diver

**TABLE 1**

**DATE FIELDS AND PERCENTAGE OF DATA AVAILABLE**

| Data Fields | Data Available % |
|---|---|
| Surname | 100 |
| Date of admission | 100 |
| Duration of stay | 96 |
| Sex | 100 |
| Age | 99 |
| Occupation | 71 |
| Diagnosis | 99 |
| Previous DCS or AGE | 56 |
| Diving experience in years. | 39 |
| Level of training | 38 |
| Training organisation | 20 |
| Diving activity | 76 |
| Number of divers | 46 |
| Maximum depth | 96 |
| Time underwater | 86 |
| Type of tables used | 27 |
| Complies with tables? | ? |
| Complies with DCIEM? | 86 |
| DCIEM repetitive group | 86 |
| Number of dives | 90 |
| Number of ascents | 90 |
| Number of days | 90 |
| Equipment failure | ? |
| Equipment misuse | ? |
| Ran out of air | ? |
| Alcohol/drugs use | 17 |
| Aggravated by altitude? | 98 |
| DES referral used | 98 |
| Retrieved or self-presentation | 98 |
| Retrieved in RCC | 100 |
| Cardiopulmonary symptomss | 98 |
| General symtoms | 98 |
| Musculoskeletal symptoms | 98 |
| Neurological symptoms | 98 |
| Dermatological symptoms | 98 |
| Time to symptom onset | 90 |
| Delay to recompression | 91 |
| Number of recompressions | 95 |
| Aspirin | 78 |
| Anticoagulants | 75 |
| Crystalloids | 76 |
| Colloids | 77 |
| Lignocaine | 78 |
| NSAID's | 78 |
| Steroids | 77 |
| Outcome after first recompression | 97 |
| Outcome at discharge | 94 |
| Outcome at one month | 47 |

while for AGE this was only to the equivalent of Basic Open Water Diver.

All cases were civilian divers and 80% were diving recreationally. 8 divers were undergoing diving training, and 4 were diving instructors. A further 8 were diving commercially, although not necessarily holding commercial diver qualifications.

There was a significant difference in mean time to onset of symptoms (10.5 hours for DCS, 0.1 hours for AGE, $p < 0.01$) and in average delay to recompression treatment (57 hours for DCS, 12.7 hours for AGE, $p < 0.01$) between the two groups.

Of those patients who ran out of air or experienced a failure of their air supply, 44% were diagnosed as having DCS and 56% as having AGE. In those reporting more than one ascent during their diving, 87% were diagnosed as having DCS and 13% as having AGE.

20% of those patients with DCS were considered from the case notes to have made a complete recovery after one recompression, compared with 28% of those with AGE. At the time of discharge, 40% of those with DCS were considered to be completely recovered, compared with 58% of those with AGE. Of those whose condition at one month after treatment was recorded (47% of the total), 49% of those with DCS and 50% of those with AGE were considered to have made a full recovery.

Presenting symptoms are listed in Table 3 and adjunctive treatment in Table 4.

Neurological symptoms were present in approximately 90% of patients in both groups. Nearly 50% of patients with AGE had cardiopulmonary symptoms (12% in DCS). In DCS, nearly half of patients had musculoskeletal symptoms, and a similar number had general symptoms including malaise, tiredness and aching or fullness in the head. Dermatological symptoms were present in 11% of those with DCS but not reported in any of those with AGE.

80% of those patients with AGE received intravenous crystalloid solutions as compared to 50% of those with DCS. Half those with AGE received at least one dose of steroids, as did one-third of those with DCS.

The significant factors influencing treatment outcome, together with their respective p values, are listed in Table 5.

Divers with DCS maintaining a DCIEM repetitive group less than or equal to group G was associated with a significantly better outcome at all times. Group F was associated with a better outcome at discharge and one month later.

**TABLE 2**

**AVERAGES AND STANDARD DEVIATIONS OF NUMERICAL DATA FIELDS**

| DATA FIELDS | DCS | | | AGE | | |
|---|---|---|---|---|---|---|
| | Cases | Average | Standard Deviation | Cases | Average | Standard Deviation |
| Age | 92 | 33.7 | 7.8 | 32 | 32.7 | 9.9 |
| Duration of stay (days) | 89 | 4.8 | 6.4 | 31 | 6.3 | 10.1 |
| Diving experience (years) | 35 | 7.4 | 6.8 | 7 | 9.9 | 5.9 |
| Level of diving training* | 34 | 1.9 | 1.2 | 10 | 0.9 | 0.5 |
| Maximum depth (M) | 89 | 28.0 | 13.0 | 31 | 23.4 | 10.0 |
| Time underwater (MIN) | 81 | 34.0 | 17.0 | 26 | 33.2 | 11.4 |
| Number of dives | 85 | 3.8 | 6.8 | 26 | 1.4 | 1.0 |
| Number of ascents | 84 | 5.6 | 13.0 | 26 | 1.9 | 1.5 |
| Number of days diving | 85 | 2.0 | 2.5 | 26 | 1.2 | 0.6 |
| Time to onset (hours) | 90 | 10.5 | 41.0 | 32 | 0.1 | 0.5 |
| Delay to recompress (hours) | 86 | 57.0 | 87.0 | 28 | 12.7 | 17.2 |
| Number of recompressions | 88 | 3.3 | 3.5 | 30 | 3.1 | 5.0 |

* level 1 equivalent to PADI basic open water diver
* level 2 equivalent to PADI advanced open water diver

**TABLE 3**

**PRESENTING SYMPTOMS AS PERCENTAGE OF CASES**

| Diagnosis | General | Dermatalogical | Musculoskeletal | Cardiopulmonary | Neurological |
|---|---|---|---|---|---|
| DCS | 41 | 11 | 48 | 12 | 88 |
| AGE | 13 | 0 | 9 | 47 | 91 |

**TABLE 4**

**ADJUNCTIVE THERAPY**
**(PERCENTAGES OF CASES WHERE DATA WAS AVAILABLE)**

| Diagnosis | Aspirin | Anti-coagulant | Crystalloid | Colloids | Lignocaine | NSAID | Steroids | Other |
|---|---|---|---|---|---|---|---|---|
| DCS | 32 | 1 | 54 | 0 | 8 | 40 | 37 | 39 |
| AGE | 21 | 17 | 80 | 21 | 13 | 24 | 54 | 58 |

**TABLE 5**

**SIGNIFICANT OUTCOMES OF 2 X 2 CONTINGENCY TABLES FOR 125 CASES**

**Decompression Sickness**

| FACTOR | POOR OUTCOME after 1st RCC | POOR OUTCOME at time of discharge | POOR OUTCOME at 1 month follow-up |
|---|---|---|---|
| Repetitive DCIEM Group greater than F | 0.054 | 0.010 | 0.008 |
| Repetitive DCIEM Group greaterthan G | 0.008 | 0.00006 | 0.002 |
| Non-Adherence to DCIEM Tables | 0.014 | 0.005 | 0.006 |

**Arterial Gas Embolism**

| FACTOR | POOR OUTCOME After 1st RCC | POOR OUTCOME at time of discharge | POOR OUTCOME at 1 month follow-up |
|---|---|---|---|
| Non-Adherence to DCIEM Tables | 0.008 | 0.011 | 0.012 |

Adherence to DCIEM tables was associated with a significantly better outcome in both DCS and AGE. Compliance with the diver's own tables or computer did not appear to be a significant factor, nor did the number of dives or ascents.

The time to onset of symptoms and the delay to recompression did not appear to have any significant influence on outcome.

## Discussion

As in most retrospective studies absent or incomplete records led to many data fields being inadequate for analysis.

The epidemiology of these civilian diving accidents is similar to other regional experience.[3] While the preponderant neurological involvement is different from early studies of DCS,[4,5] it supports many other recent surveys.[3,6]

The most interesting finding is, however, the significantly better outcome in those divers who kept within conservative tables such as the DCIEM tables and those whose diving profiles resulted in a DCIEM repetitive group lower than group G. Adherence to DCIEM tables was also shown to be a significant outcome factor in those patients with AGE and this may be explained by the likelihood of their having concurrent DCS.

The lack of any correlation between time to onset of symptoms and outcome may be due to those with mild symptoms failing to recognise them and presenting relatively late for treatment. Animal studies have shown that there is an inverse relationship between latency of onset and the severity of disease.[7] The delay to recompression was not shown to be a significant factor. Since mild disease tends to be treated less urgently any difference in outcome may have been obscured.

Given the findings of previous surveys of this type[3] it is surprising that the number of ascents is not a significant outcome factor. It may be the result of divers in this series under-reporting the number of ascents which occurred.

This study strongly suggests that divers should both keep within conservative tables, such as the DCIEM tables, and ensure that repetitive diving is conservative.

It also demonstrates the need to elicit adequate and appropriate information from the patient during the hospital admission so as to facilitate subsequent prospective study.

The widely varying HBO schedules and adjunctive treatment used resulted from changing ideas about the treatment of dysbaric illness since 1967 and the differing preferences of individual practitioners. Nevertheless, the prevalence of incomplete recovery is in keeping with other reports [3,6] and shows that there is little room for complacency in the current treatment of divers with either DCS or AGE.

## References

1 Curley MD, Schwartz HJC and Zwingelberg KM. Neuropsychologic assessment of cerebral decompression sickness and gas embolism. *Undersea Biomed Res* 1988; 15 (3): 223-236

2 Levin HS. Neuropsychological sequelae of diving accidents. In: Hong SK. ed. *International symposium on man in the sea.* Bethesda, Maryland: Undersea Medical Society, 1975: 233-241

3 Gorman DF, Pearce A and Webb RK. Dysbaric illness treated at the Royal Adelaide Hospital 1987; A factorial analysis. *SPUMS J* 1988; 18 (3): 95-102

4 Slark AG. *Treatment of 137 cases of decompression sickness. R.N. Personnel Research Committee Report 63/1030.* London: Medical Research Council, 1962.

5 Rivera J.C. *Decompression sickness among divers: an analysis of 935 cases. US Navy Experimental Diving Unit Research Report 1-63.* Washington Navy Yard, 1963.

6 Gorman DF, Edmonds CW, Parsons DW, et al. Neurologic sequelae of decompression sickness: a clinical report. In: Bove A.A., Bachrach A.J., Greenbaum L.J. eds. *Underwater and Hyperbaric Physiology IX* Bethesda, Maryland; Undersea Medical Society, 1987: 993-998.

7 Francis TJR and Dutka AJ. The influence of latency on the outcome of spinal cord decompression sickness. *Undersea Biomed Res.* 1988; 15 (Suppl.): 77.

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*S K Brew MHB, CT Courtenay Kenny MB ChB, RK Webb MB BS, FFARACS, and DF Gorman MB ChB, FACOM, PhD are associated with the Diving and Hyperbaric Medicine Unit, Royal New Zealand Navy and the Department of Anaesthetics and Intensive Care, the Royal Adelaide Hospital and the University of Adelaide.*

*Address for Correspondence: Dr Des Gorman, Diving and Hyperbaric Medicine Unit, Royal New Zealand Naval Hospital, Naval Base, Auckland, New Zealand.*

# BOOK REVIEW

**DEEPER INTO DIVING.** John Lippmann
1990. Illustrated, 610 pages. J.L.Publications, P.O.Box 381, Carnegie, Victoria 3163, Australia.
Price $ 45.00 (including postage)

John Lippmann is an enthusiastic diver and writer and consequently his two previous books on diving have been successful. This book will have a similar fate as it is well researched and written and will satisfy the needs of many involved in diving activities.

The book is divided into sections of physics and physiology, decompression tables, altitude diving, multilevel diving, decompression diving, administration of oxygen and a miscellaneous final section. There are also several appendices. The strength of this book is the simple translation and practical examples given to explain extremely difficult and confusing phenomena. Such explanations are necessary to an increasingly better informed recreational diving community and essential given the active marketing of new decompression tables and decompression computers. A healthy cynicism needed in reviewing these products and this is apparent in John Lippmann's writing.

Purists may object to the frequency of personal communications and unpublished observations cited in this book, but this is the cost of trying to describe what medical practitioners think and believe rather than what they have written. The nature of these citations then is a reflection on both diving and those involved and on the recent changes in understanding of the diving illnesses.

"Deeper into diving" is a logical progression from John Lippmann's earlier books and, although it is written primarily for dive masters and diving instructors, it would be a useful addition to the diving library of serious recreational divers, navy divers, commercial divers and general medical practitioners interested in learning more about decompression and diving medicine.

Des Gorman.