

- 21 Curley MD. US Navy saturation diving and diver neuropsychological status. *Undersea Biomed Res* 1988; 15: 39-50
- 22 Hodgson M and Golding JF. Psychometric evaluation of divers performing a series of heliox non-saturation dives. *Aviat Space Environ Med* 1991; 62: 407-13
- 23 Edmonds C and Hayward L. Intellectual impairment with diving. In *Underwater and Hyperbaric Physiology IX*. UHMS, Bethesda, Maryland, USA 1987: 877-86
- 24 Adkisson GH, MacLeod MA, Hodgson M, Sykes JJW, Smith F, Strack C, Torok Z and Pearson RR. Cerebral perfusion deficits in dysbaric illness. *Lancet* 1989; 2: 119-21
- 25 Adkisson GH, Hodgson M, MacLeod MA, Sykes JJW and Pearson RR. Cerebral perfusion deficits in dysbaric illness: follow up studies in 18 divers. *Proceedings of 15th EUBS Meeting (Eilat, Israel)*. 1989: 55-60
- 26 Hodgson M, Smith DJ, MacLeod MA, Houston AS and Francis TJR. Case control study of cerebral perfusion deficits using hexamethylpropylene amine oxime. *Undersea Biomed Res* 1991; 18 : 421-31
- 27 Yiannikas C, Beran R. Somatosensory evoked potentials, EEGs, and CT scans in the assessment of the neurological sequelae of decompression sickness. *Clin Exp Neurol* 1988; 25: 91-6
- 28 Overlock R, Dutka A, Farm F, Okamoto G and Suzuki D. Somatosensory evoked potentials in divers with a history spinal cord decompression sickness. *Undersea Biomed Res* 1989; 16(Supp): 89

*This paper was submitted as one of the requirements for the Diploma of Diving and Hyperbaric Medicine awarded to Dr Hodgson in 1992.*

*Dr Martin Hodgson's address is Medical Centre, HMAS CERBERUS, Western Port, Victoria, 3920, Australia.*

#### **NEUROPSYCHOLOGICAL PROBLEMS IN 25 RECREATIONAL DIVERS ONE YEAR AFTER TREATMENT FOR DECOMPRESSION ILLNESS**

Allan Sutherland, Andrew Veale and Des Gorman

#### **Abstract**

Twenty-five recreational divers were treated for decompression illness at the Royal New Zealand Naval Hospital in 1987 using the the United States Navy treat-

ment algorithm. Twenty-three of these divers were reviewed one year later. At discharge from hospital, 11 (48%) had obvious neuropsychological sequelae. None of these had recovered fully by one year. In contrast, 6 of the 12 who had no problems at the time of their discharge either developed or were noted to have problems during the next year. These late sequelae were mostly in the form of personality changes. The overall morbidity rate at one year was 74%. Alternatives to the United States Navy treatment algorithm should be developed and tested, and a review as late as one year after DCI may be needed to assess outcome accurately.

#### **Introduction**

The treatment of Australasian recreational divers with decompression illness (DCI) using the United States Navy (USN) treatment algorithm<sup>1</sup> is associated with treatment failure rates at discharge from hospital and one month later of between 32 and 45%.<sup>2-5</sup> However, it is believed that most sequelae of decompression illness will resolve during the subsequent year.<sup>3-6</sup> To test this belief, a defined population of recreational divers who were treated for DCI were surveyed one year later to determine the progression and prevalence of neuropsychological sequelae.

This survey was based on questionnaires and clinical examinations, as careful neurological examination appears a more sensitive measure of outcome than available evocative, recording or imaging techniques of the nervous system.<sup>7,8</sup>

#### **Methods**

In 1987, a total of 25 recreational divers were treated at the Royal New Zealand Naval Hospital (RNZNH) for DCI that developed after one or more air dives. The USN treatment algorithm was universally employed. One year after their discharge from RNZNH, letters were sent to all these patients, requesting general information about their invalidity, time off work, compensation or insurance claims, and, if any, specific disabilities. Any replies suggesting problems were followed by further contact with the patient (including an examination, if possible), their spouse, family, family doctor and/or diving physician.

Two patients who claimed significant neuropsychological disability were further assessed by extensive psychometric review<sup>9</sup> at Auckland Public Hospital's post-concussion clinic.

#### **Results**

Twenty-three of the 25 patients (92%) responded to the questionnaire. The 2 patients who could not be contacted had no overt problems when they were discharged

**TABLE 1**  
**SPECIFIC PROBLEMS AND DISABILITIES**  
**ONE YEAR AFTER TREATMENT FOR**  
**DECOMPRESSION ILLNESS.**

<b>Problem, disability</b>	<b>Number of patients</b>	
	<b>(% of total patients)</b>	
<b>Normal health</b>	<b>6</b>	<b>(26%)</b>
<b>With problems</b>	<b>17</b>	<b>(74%)</b>
Mood disorders *	14	(60%)
Impaired cognition (**)	12	(52%)
Headache	10	(43%)
Sensory disturbances	6	(26%)
Impaired balance	6	(26%)
Motor weakness	6	(26%)
Arthralgia & myalgia	4	(17%)
Visual disturbances	3	(13%)
Dysphasia, dyslexia	2	(9%)
Bowel & bladder problems	2	(9%)

\* Includes mood changes from uncontrollable irritability to depression, lassitude, and social withdrawal.

\*\* These patients had impaired short-term memory and often other problems such as difficulties with arithmetic etc.

form RNZNH. The dive profiles, presenting symptoms, time to treatment and other relevant history for these divers has been described previously.<sup>2</sup>

At the time of their discharge, 11 of these 23 patients (48%) had neuropsychological sequelae. None of the 11 had recovered fully by one year. In particular, focal neurological deficits did not change significantly. Of the 12 who were well on being discharged, 6 had deteriorated over the year and had obvious problems. At the one year review 17 of the 23 patients (74%) had sequelae of their episode of DCI. None of these 17 patients had any relevant past history.

The specific disabilities prevalent in these divers at the one year review are listed in Table 1. It is noteworthy that the personality problems (e.g. mood disorders) largely became evident after discharge, varied in severity from day to day and had a greater effect on family life, relationships and employment than the neurological deficits.

The 2 patients who underwent extensive psychometric assessment were both shown to have a considerable cognitive disorder typical of recent organic brain damage. Both have been the subject of individual case reports.<sup>10,11</sup>

### Discussion

The longitudinal study reported here shows that use of the USN treatment algorithm<sup>1</sup> in a group of Australasian recreational divers with DCI had an unacceptably high failure rate. This is consistent with other reviews of similar groups of divers.<sup>2-5</sup> It also underlies the urgent need to develop and test alternative methods of treatment.

However, our results contrast with those studies which show an continuing resolution of DCI sequelae during the subsequent year.<sup>3,6</sup> In this study, neurological deficits did not change significantly and many psychological/personality problems became apparent only after discharge. Indeed, six of the twelve patients who had no complaints at discharge, had overt problems after one year. This natural history is very similar to that described by Rozsahegyi<sup>12</sup> in a population of caisson workers who developed DCI and were given a single hyperbaric air treatment.

It follows that a late review, perhaps as much as one year after an episode of DCI may be needed to assess outcome and to determine if the patient is fit to return to diving.

### References

- 1 *USN diving manual*. NAVSEA 0994-LP-001-9010.
- 2 Brew SK, Kenny CT, Webb RK and Gorman DF. A factorial analysis of 125 diving accidents treated at HMNZS PHILOMEL. *SPUMS J* 1990; 20(4): 226-230.
- 3 Gorman DF, Edmonds CW, Parsons DW et al. Neurologic sequelae of decompression sickness: a clinical report. In: Bove AA, Bachrach AJ and Greenbaum LF Jr, Eds. *Underwater and hyperbaric physiology IX*. Undersea and Hyperbaric Medical Society, Bethesda, 1987: 993-998.
- 4 Gorman DF, Peace A and Webb RK. Dysbaric illness in South Australia, 1987. *SPUMS J* 1988; 18(3): 95-101.
- 5 Weinmann M, Tuxen D, Scheinkestel C and Millar I. Decompression illnesses. 18 months experience at the Alfred Hospital Hyperbaric Unit. *SPUMS J* 1991; 21(3): 135-143.
- 6 Hodgson M, Anderson TA, Gorman DF, Edmonds, CW, Dillon TA, Green Rd, Beran RG, Firman J and Loxton MJ. *Neurological sequelae of dysbaric illness*. RAN SUM Report, SUM 85/2, 1987.
- 7 Curley MD, Schwartz HJ, Zwingleberg K. Neuropsychologic effects of cerebral decompression.

- sion sickness and gas embolism. *Undersea Biomed Res* 1989; 16: 223-236.
- 8 Moon RE and Gorman DF. Treatment of the decompression disorders. In: Bennett PB and Elliott DH. *The physiology and medicine of diving*. Fourth edition. Balliere-Tindall, London 1992, in press.
  - 9 Gromwell D, Wrightson P. Memory and information processing capacity after closed head injury. *J Neuro Neurosurg Psychiat* 1981; 44: 889-899.
  - 10 Sutherland AFN. Diving accident cases treated at HMNZS PHILOMEL in 1988. *SPUMS J* 1990; 20(1): 4-9.
  - 11 Sutherland AFN. Late sequelae of decompression sickness. A case report. *SPUMS J* 1991; 21(2): 76-77.
  - 12 Rozsahegyi I. The late consequences of the neurological forms of decompression sickness. *Br J Ind Med* 1959; 16: 311-317.

### Appendix 1

A letter from the wife of one of the patients describing the sort of personality changes discussed in the paper.

Dear Dr Sutherland

I am hoping you will remember treating my husband approximately a year ago at the Naval Base. I am writing to you as I am still rather anxious and concerned about him.

He still suffers from frequent depression, mood changes, lack of concentration, and occasionally his memory is quite bad even after a short time of me telling him something. These symptoms can occur months apart or as often as 3 to 5 times a week. I notice they are worse when he is tired or under stress.

I finally persuaded him to go along to his GP and he has prescribed him some anti-depressants. He has been taking these for 8 weeks now and when he got adjusted to the tablets I found his moods were much happier but still some of the other symptoms are present. Now he is sleeping better and is more motivated in activities which he hasn't been for a long while e.g. running, indoor cricket and general household chores etc.

My husband is usually a quiet, placid person and I definitely know that he is not the type to complain but I can see that he gets very frustrated with not being able to cope with his symptoms. I feel that you are in the best position to advise me on this matter and I would be very grateful if you could give me some guidelines on what and where do we go from here.

I am writing this letter in the strict confidence as for some reason my husband wasn't too keen on me writing to

you when I approached him on this matter.

I realise it is very difficult for you to assess him through a letter and I would be happy to give you any further details if I haven't been specific enough.

As this confidential, could you please send a reply to my work address.

Thank you for your time which I realise is very limited and I understand that correspondence takes second place.

### Appendix 2

These two case reports are based on the neuropsychological assessment reports and illustrate the disabilities patients are suffering. Both men were severely disabled by their residual brain damage.

#### Case A

A sustained 2 episodes of decompression illness (DCI). The first mentally muddled him up, and the second physically damaged him. After the first episode he lost his way a lot, was forgetful, had to write everything down, found it hard to concentrate on things, mentally blacked out during conversations or if things were happening fast and had difficulty sleeping and was very irritable and argumentative. He found irritability difficult to cope with as he had been previously very easy-going. It has had a detrimental effect on his relationship (his partner and 2 sons).

On the dive which caused his second episode of DCI he became disorientated at the end of the dive, came straight to the surface, and has no memory of the following events. Apparently he was pulled from the water and taken to the Naval Hospital. His problems, which persist, include severe pain in the back, hips, shoulders, and headaches. The cognitive difficulties that he experienced following the first episode persisted and added to the severe physical pain of the second episode, caused him to feel irritable and to have increased difficulty controlling his anger. He had difficulty with relationships, coping with noise, and family relationships. Not surprisingly he became depressed and this further affected his sleep. He has dreams. Anti-depressants did not assist him and he had bad days most days of the week.

The neuropsychologist's report included the paragraphs below.

"This man's neuropsychological profile is not straightforward with considerable variability within the test

limits. These are caused because physical pain and depression are present as well as the cognitive difficulties. The neuropsychological profile does resemble that found in individuals who have an organically-based dysfunction of the brain. There were some tasks on which his performance fell well in the average range for the population. In contrast, he had slowed reaction times which reflected a slowing down of the cognitive process, a markedly reduced rate of information processing, and a reduced ability to concentrate over time. This was consistent with his subjective complaints and is consistent with the kind of profile found in individuals who have diffuse brain damage.

The findings have direct implications as to the patient's ability to cope with daily activities, including his home environment, and his ability to resume work. With cognitive problems of this type, any situation that is noisy, requires quick thinking, doing several things at once, or concentrating over long periods of time, will pose major difficulties. One direct example of this is his inability to tolerate much of the behaviour of the children, which is caused, to a large extent, by his deficits in information processing ability.

Recovery from deficits of this sort is hindered when an individual is regularly in situations where he becomes over-loaded and unable to cope. Appropriate management and strategies within the home and work environments are essential, involving:

- a Physical, especially pain;
- b Cognitive deficits;
- c Depression

These areas inter-react with each other and thus it is best to deal with each problem in isolation from the others.

Although the factors contributing to the neuropsychological profile are complex in this case, I have no doubt that there is an organic dysfunction to the brain similar in its effect to the closed head injury which underlies the patient's performance."

A was re-assessed 19 months later which was two and a half years after suffering his second episode of DCI. As most recovery of cognitive function occurs in the 2 years post-injury, with other forms of non-progressive injury (e.g. closed head injury and carbon monoxide poisoning), it is appropriate to investigate any residual cognitive disability.

At the time of this assessment, the patient "claimed he still had a lot of difficulty concentrating and was unable to cope very well with any situation where things are happening fast. Such situations included those where there was a lot noise, several people talking, or more than one thing happening at once. This difficulty affects his family relationship, social relationships, and has implications on

his ability to work. When his children are noisy, or racing around, he gets very irritated and can't handle it. Similarly, in many social situations, he is unable to follow conversations and just switches off. Consequently there are many social contacts he now avoids.

The patient has expressed a wish to write, but after a short period finds that it all gets jumbled up and that words he has written down get messed up and parts do not make sense. This is most likely related to impaired concentration ability, rather than a language deficit. Although he is able to drive a car, he does not do it often as he has to put a lot of effort in and after driving feels like a "wreck". A significant change for someone who had a commercial drivers licence.

He continues to have difficulty sleeping and usually feels worn out even after sleeping. His ability to handle alcohol is markedly reduced from before his diving accident. Now he becomes drunk very quickly on little alcohol. The intense frustration and anger that concerned him during the first assessment occurs less frequently because he has adapted to the changes, using the words "I don't care" more frequently. He has developed a strategy of removing himself from situations which frustrate him."

The results of the neuropsychological tests were similar to that achieved previously. "The patient has had some relief from pain and this has significantly reduced his irritability and depression and changed his lifestyle and expectation of his abilities. He will have to be involved in a process of grieving for his major loss of lifestyle before he will be able to construct a life that adapts to such changes. There has been some improvement in his cognitive abilities, giving some capacity to develop strategies to cope with his many difficulties.

The findings of the second assessment were much more clear-cut than on the previous occasion. "The patient being left with the kind of cognitive impairments that frequently follow other forms of diffuse brain damage and the pattern of his neuropsychological profile is strongly suggestive that he has organic dysfunction of the brain. This continues to have a profound impact on his family relationships, his ability to work, and his ability to enjoy life.

## Case B

B's first assessment described him as having a gross problem with attention and memory. "The difference between his average to his above-average performance on the vocabulary and perception tests, and his poor performance on these measures, is strong evidence that the deficits have resulted from some CNS insult. They are consistent with the history of the diving accident last year."

When re-assessed a year later, it was reported that it was "a pleasure to see and test this man again because he had made so much progress. He had improved on almost all measures and although he said that he still gets tired and has lots of headaches, he seemed to be managing his taxi run well."

Three tests had improved. The digit span reaction time and word fluency to within the normal range. Tests which had improved, but still demonstrated an impaired score, were visual memory and verbal memory. It is unlikely that this man would make as much progress in the next 2 years as he has in the last, but even if he makes no

progress at all, his cognitive function is now at a level where he should be able to cope reasonably well."

*Drs Allan Sutherland, Dip DHM, and Andrew Veale, FRACP, Dip DHM, are associated with the Royal New Zealand Navy Hyperbaric Unit, HMNZS PHILOMEL, Devonport, Auckland, New Zealand. Dr Des Gorman is Director of the Unit.*

*Address for correspondence.*

*Dr Allan Sutherland, 4 Dodson Avenue, Milford, Auckland 10, New Zealand.*

## THE WORLD AS IT IS

### CALCULATING DIVER NUMBERS: CRITICAL INFORMATION FOR SCUBA SAFETY AND MARKETING PROGRAMS

Jeffrey Wilks

#### Introduction

A question frequently asked of the recreational scuba diving industry is "How many active divers are there?" The answer to that question is, of course, that "there are no reliable estimates of active divers within Australia".<sup>1</sup> While the question is asked by different people, for different reasons, two broad interest groups can be identified.

The first group is interested in establishing the size of a potential customer market. This group may include tourism authorities, insurance agents, equipment wholesalers and retailers, training agencies, the media and various government departments. In fact, marketing enquiries form the majority of requests for diving statistics.

The second group seeks information on the number of active scuba divers to provide a background or perspective on safety. This group may include medical practitioners, health and safety authorities, dive industry associations, lawyers and the scuba training agencies. To some extent there is an overlap between the groups as those concerned with marketing will also be interested in safety, since it is an important component of the diving product.

Obtaining accurate estimates for the number of certified divers is a difficult process, as evidenced by the continuing debate in the United States.<sup>2,3</sup> One of the main barriers to calculating accurate figures is the fact that scuba

certification cards do not expire. Once a diver has completed his or her entry level qualification there is no easy way to determine whether they continue on as an active diver or drop out from the sport. Even the definition of an "active diver" varies, though the accepted consensus, used in this paper, seems to be "at least one dive in the previous 12 months".<sup>4,5</sup> There are some who consider that the figure should be 5 to 10 dives a year as fewer dives would fail to maintain the diver's skills.

#### Identifying groups of divers

One approach to the question of diver numbers is first to identify unique groups, then attempt to count participants. Ten separate groups have been identified in Queensland. A brief description of each group follows, along with initial attempts to determine the number of dives made by the groups during 1991.

The intention of this project was to estimate the number of dives made in Queensland over a one year period, rather than the number of divers. Pilot studies had clearly shown that it would be impossible to track individual divers, especially if they were members of groups which had no contact with training agencies or commercial dive facilities. In addition, the total number of "safe" dives completed was considered a more appropriate figure for the purpose of placing accident statistics in their proper perspective.

1 NEW DIVERS TRAINING FOR ENTRY LEVEL CERTIFICATION

The first group consists of new divers who have recently completed an open water course. Confidential figures were obtained from all four Australian training agencies on the number of open water courses conducted in