effect of the heat treatment was persisting. However, the pain in the scalp had spread to the neck probably though lymphatic spread. There was an intense burning, and a feeling as if my head was in a vice.

Hot towels were tried and a hot shower, but in the end I was subjected to lying prone on a bench with my head in a bowl of hot water. The relief was very rapid and after 20 minutes the pain had lessened to such a degree that treatment was ceased. Within an hour of being stung I was virtually pain free, and able to resume diving.

Discussion

The toxins of many marine species are known to be heat labile. These are principally members of the Scorpion Fish and Stingray families. Toxic spine injuries from these species are successfully treated with hot water.

This report suggests that the toxin of the jellyfish *Tamoya* is heat labile and able to be treated with local heat. This raises the question as to whether other species of jellyfish sting can be treated in this way.

The author is now resident in Busselton, Western Australia, on Geographe Bay. This area is well known for its summer plague of “stingers”; the principal species is thought to be the “Jimble” *Carybdea rastoni*. The severity of the sting received by subjects is very variable and some individuals seem to have a hypersensitivity to these stings, with the development of large wheals that take several days to resolve. Others only experience a transient stinging sensation and mild erythema.

Some hypersensitive individuals, who have been told of the benefits of immediate heat treatment, have reported to the author that heat treatment after being stung resulted in considerable improvement of their symptoms.

The Tamoya jellyfish is not a life-threatening species and stings with this species are rare. However, my own experience and the reported improvement in symptoms in sting-sensitive individuals who have used heat (hot water) treatment after being stung by unknown jellyfishes in Geographe Bay raises the question that perhaps the pain of more jellyfish stings might be alleviated by immediate heat treatment.

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Dr Geoff Taylor’s address is 6 Park Way, Busselton, Western Australia 6280. Phone/Fax +61-(0)8- 9754-2772. E-mail <jaqtayl@iinet.net.au>.

VALIDATION OF THE RNZN SYSTEM FOR SCORING SEVERITY AND MEASURING RECOVERY IN DECOMPRESSION ILLNESS

Tony Holley

Key Words

Decompression illness, risk, treatment sequelae.

Abstract

A retrospective study of 100 divers with a provisional diagnosis of decompression illness (DCI) admitted to the RNZN Slark Hyperbaric Unit from June 1995 to February 1997 inclusive, using the Royal New Zealand Navy (RNZN) scoring system for assessing the severity of DCI and recovery with treatment,[1] was carried out. Only 79 of the divers fulfilled the conditions of entry into the study, 21 being excluded because of doubtful diagnosis, inadequate case notes or a diagnosis of cerebral arterial gas embolism (CAGE). These latter, because of the Unit’s protocols, were kept horizontal until under pressure so could not have their standing and walking ability assessed.

The study showed that 59 out of 66 (89.4%) divers with a score of 25 or less (≤25) on admission had a symptom free recovery after treatment, or a sequelae rate of 10.6% (7 of 66). Of the 13 divers with an admission score of more than 25 (>25) only 3 were symptom free after treatment (23.1%) while 10 (76.9%) were left with sequelae.

The RNZN DCI scoring system has good prognostic power. The admission severity score correlates linearly with severity, as indicated by the number of treatments required to achieve maximum recovery, confirming that it is a useful index of severity when assessed at the time of presentation for treatment.

Introduction

There is a lack of information on prognostic factors in DCI, in contrast to many other conditions, such as the Critically Ill,[2] Head Injury,[3] Meningococcal Septicaemia,[4] Multiple Trauma[5,6] and Acute Pancreatitis,[7] in which epidemiological and clinical studies have elucidated prognostic indicators that have proved useful in the classification and treatment of the condition.

Although there have been a number of scoring systems devised for decompression illness[8-12] none of these meets the requirements of providing:

1 a universally applicable system for all forms of DCI;
2 a numerical severity index at presentation;
3 a numerical index of progress and recovery;
4 a methodology for comparing different therapies in different diver populations.

A scoring system for decompression illness (DCI) which aims to quantify relative severity of disease at presentation, and relative recovery after treatment was established by Mitchell et al. at the Royal New Zealand Navy (RNZN) Slark Hyperbaric Unit.[1] The prognostic validity of this system was assessed by this study.

The RNZN scoring system is complex in its derivation, but simple and convenient to employ clinically.[1] Numerical analogue scales were derived for each symptom or sign. An "importance" conversion factor for each potential manifestation was derived by ranking each symptom or sign on scales for four parameters (specificity for DCI, natural history of that manifestation if untreated, potential for incapacity and a co-dependence compensation). A second conversion factor accounts for the time course of any particular disease manifestation, and was generated by arbitrarily allocating a numerical weighting to the descriptive terms used by Francis and Smith (static, remitting, relapsing and progressive).[13] Assessment of the clinical course before and after treatment, allows calculation of a "severity" index and a "recovery" index for any patient.[1] The RNZN scoring system will be useful, as both a research tool in comparing therapeutic modalities and for the assessment of disease severity and the effects of treatment in the individual diver.

Scoring systems are generally constructed by identifying (either by clinical consensus or statistical analysis) variables which are best related to outcome. Weights are then attributed to those variables to generate a score, as was the case for the RNZN system. Before adopting a prediction rule or scoring system, clinicians must evaluate its applicability to their patients.[14]

In this study the RNZN DCI scoring system was evaluated by assessing the prognostic value of the severity score at admission in a large, heterogeneous population of injured divers.

Method

The RNZN decompression illness severity scoring system was validated by reviewing the case notes for all divers presenting with DCI treated at the RNZN Slark Hyperbaric Unit from June 1995 to February 1997 inclusive.

This retrospective review yielded 100 cases. Twenty one were excluded from the study. Exclusion criteria were:

1 equivocal diagnosis;
2 inadequate documentation in the clinical notes to allow for reliable severity score calculation;
3 patients treated for cerebral arterial gas embolism, as it is unit policy to keep these patients in the supine position until recompression therapy has been commenced.

The study population had a diverse spectrum of disease including neurological, musculoskeletal, constitutional and cutaneous decompression illness.

Admission severity scores were retrospectively calculated for those patients meeting the inclusion criteria. Severity scores were also calculated from the clinical records at discharge. Each patient's recovery index was calculated by subtracting the discharge score from the admission score. Admission scores were also correlated with the number of once daily hyperbaric treatments required to achieve maximal recovery (defined as either full recovery or failure to record sustained improvement over two consecutive days). The predictive values of scores >25 and ≤25 at admission were compared for incomplete recovery at discharge from hospital to give a negative (sequelae present) prediction rate and a positive (complete cure) prediction rate. The prognostic value of the new scoring system was determined by calculating the positive and negative predictive values for a score of less than, equal to or greater than twenty five.

Demographic data for all 79 patients included were recorded (Table 1). There were 71 males and 8 females, the mean age was 33.5 (± 9.1) years. For all cases the time from the last dive to presentation was established. There was a mean delay of 53 (±71) hours and objective signs were detected in 61 patients (77%). The mean number of treatments was 5.2 (± 4.2). In 62 patients (78.5%) full recovery was documented. Seventeen patients (21.5%) were discharged with sequelae.

TABLE 1

STUDY POPULATION

Diver total	79
Males	71
Females	8
Mean age	33.5 (± 9.1) years
Objective signs at presentation	61 (77%)
Complete recovery	62 (78%)
Mean delay to presentation	53 (±73) hours
Hyperbaric treatments per diver (mean)	5.2 (±4.2)

Microsoft Excel software was used to establish the distribution of the severity scores for the study population. For each score, the number of patients demonstrating recovery or sequelae were compared. Using a linear regression analysis model, the relationship between the initial severity score and the number of treatments required to achieve full or maximal resolution for individual patients was established. At the RNZN Slark Hyperbaric Unit patients are treated on a daily basis until full resolution or until, despite two further treatments, a clinical plateau is achieved. In the absence of a single marker for the severity of decompression illness, the number of treatments required to achieve "best" resolution provides a useful retrospective indicator of disease severity.

Results

The study showed that those with a score of 25 or less (≤25) on admission had a symptom free recovery rate after treatment of 59 out of 66 or 89.4%, or a sequelae rate of 10.6% (7 of 66) (Table 2). Of the 13 divers with an admission score of more than 25 (>25) only 3 were symptom free after treatment (23.1%) while 10 (76.9%) were left with sequelae. These results show that for an admission score of ≤25 the likelihood of positive result (complete recovery) is 89% and for an admission score of >25 the likelihood of a negative result (incomplete recovery) is 77%.

TABLE 2

PROGNOSTIC VALUE

Score	Sequelae	Recovery	Total
>25	10	3	13
<25	7	59	66
Totals	**17**	**62**	**79**

Positive predictive value = 77%
Negative predictive value = 89%

There was a strong linear correlation between admission severity score and number of treatments (multiple r = 0.80; $r^2 = 0.64$). Table 3 (page 78) shows the discharge score ranges of the divers left with sequelae, their individual discharge scores and their symptoms and signs. It is clear that those with a discharge score of 25 or less were less handicapped than those with scores of 36 or over.

Discussion

This study of a large population of divers who presented with heterogeneous manifestations of DCI has tested RNZN DCI severity scoring system and demonstrated that it can be used to follow the progress of patients in response to hyperbaric treatment and to predict the likelihood of permanent sequelae after treatment to "no further improvement".

Other authors have proposed gravity or severity scoring models, but none of the systems has been applicable to a wide range of clinical presentations.[8-12]

Ball et al.[10] produced a model which was intended for use specifically in neurological DCI and included historical, therapeutic and clinical parameters. The authors stated "this gravity index is in no way intended for application to individual cases". In addition to exclusion of the common musculo-skeletal DCI, this system is insensitive to those divers with primarily dorsal column spinal lesions and those divers who lack objective neurological findings. This alone would preclude their system's use in excess of 50% of patients presenting to Australasian hyperbaric facilities.[15]

Boussuges et al.[11] devised a scoring system which is useful for "assessing the gravity of a population with a view to comparing the efficiency of different therapeutic protocols". However, this system again effectively disregards a large subgroup of patients with neurological symptomatology in the absence of objective neurological findings.

Valuable work by Kellher et al.[12] produced a system capable of predicting the probability of incomplete resolution after the first recompression intervention. The authors, however, excluded cognitive disorders, abnormalities of special senses and sphincter dysfunction, claiming they were infrequent and hence unlikely to facilitate development of a model. In Australasian experience these presentations are not infrequent.

The RNZN DCI scoring model, subjected to validation in this study, encompasses a wide range of potential presentations. The model is highly inclusive and it is simple and time efficient to implement.

Demographic data obtained from the study population revealed a mean age of 33.5 (±9.1) years and 9:1 male to female ratio. The marked male predominance and age distribution is common in Australasian facilities treating recreational divers.[15-18] However, this study has a higher male predominance than most other series, where the male predominance is usually in the order of 70%. There is no obvious explanation for the male bias in this study sample.

The mean delay to presentation was 53 (±73) hours, which is significant in that it reflects the inclusion of very mild or subtle disease. One would expect that there would be very little delay in presentation in the presence of severe

TABLE 3

Scores and Sequelae at Discharge

Score Range	Number of divers	Individual Scores	Sequelae
6-10	2	9	Musculoskeletal pain
		10	Musculoskeletal pain
11-15	1	11	Paraesthesiae hand
16-20	1	20	Mild cognitive impairment
21-25	3	21	Objective sensory deficit foot
		23	Diffuse musculoskeletal pain
		25	Paraesthesiae arm
26-30	2	27	Mild facial paraesthesiae
		29	Tinnitus right ear
36-40	1	37	Bilateral lower limb weakness (able to ambulate without assistance)
41-45	1	45	Bilateral thigh paraesthesiae
46-50	1	48	Mild cognitive impairment
51-55	2	51	Mild cognitive impairment, musculoskeletal pain
		54	Lower limb weakness (unable to walk without assistance)
			Objective sensory deficit in lower limbs
56-60	2	56	Gait disturbance (ataxic), musculoskeletal pain,
		59	Paraesthesiae
			Labile affect, moderate cognitive disturbance
66-70	1	71	Paraplegia, bladder dysfunction, lower limb sensory loss

symptomatology, and what delay did occur would be a function of transportation times. Unfortunately this is not always so. It would seem likely that those with mild disease, or that which was perceived to be insignificant, might well delay their presentation.

The distribution of the injured diver population according to the admission severity index score, and post treatment sequelae (Figure 1), provides a useful tool. The significant difference in the severity score between the divers with sequelae and those who recovered completely is the first step toward validation.

The prognostic value of the severity score above 25 was established by calculating the positive and negative predictive values. Ten (76.9%) of the 13 divers with a score above 25 developed sequelae (Table 2). Conversely 59 (89.4%,) of the 66 divers with a score less than or equal to 25, did not develop sequelae. Analysis of the prognostic value of scores higher than 25, therefore confirms the validity of this severity index. A negative predictive value for a score of equal to or less than 25 is useful in advising patients as to the probability of full recovery.

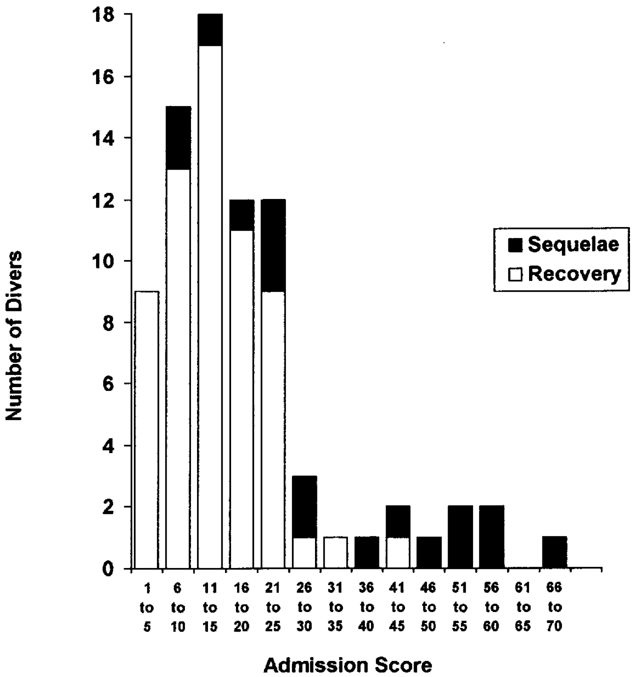

Figure 1. Distribution of admission scores.

Admission score versus number of treatments (Figure 2) provides a linear relationship, with a correlation coefficient of 0.80. In the absence of a single marker for the severity of DCI, the number of treatments received by the patients has been utilised to best reflect severity. The RNZN Slark Hyperbaric Unit treats all injured divers until full resolution, or until a clinical plateau is achieved (as determined by two further treatments failing to demonstrate

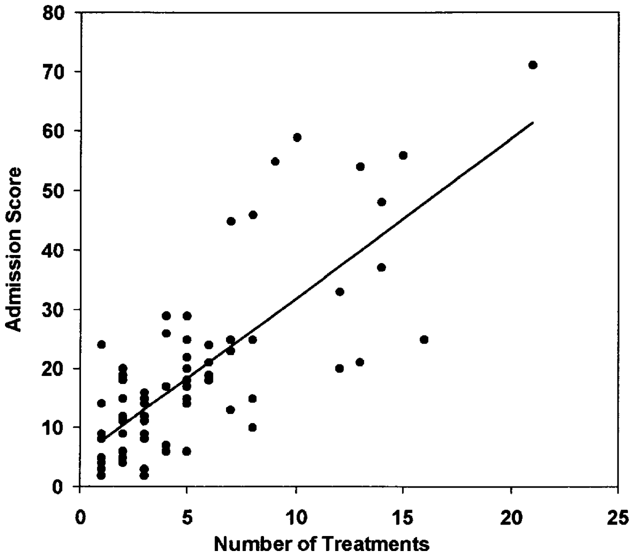

Figure 2. Admission score verus treatment number ($r=0.80$, $r^2=0.64$)

any improvement). The Undersea and Hyperbaric Medical Society Therapy Committee Report[19] provides upper threshold limits for therapy in DCI and indicates therapy should be continued until "improvement plateaus or 14 days". No patients who did not improve with treatment received more than two such "failed" treatments. Patients in this study received a mean number of treatments of 5.2 (±4.2), with three patients receiving in excess of 14 days therapy (receiving 15, 16 and 20 treatments respectively). These three patients were treated beyond the 14 day recommendation as they continued to improve. If these three patients are excluded from the study, the correlation coefficient is 0.74 . The implication of the linear relationship between admission severity score and number of treatments, is that for an individual patient for whom a severity score is calculated, the number of treatments required may be reliably estimated. This information will not only be useful for the physician's treatment planning, but also for the divers and their families, who are often resident in different geographical locations to the hyperbaric facility.

The purpose of the RNZN DCI scoring system is to assign a numerical index of severity, rather than attempt to describe the exact character of any sequelae.[1] For completeness, the sequelae experienced by the study population have been included (Table 3). Only one diver, of those individuals presenting with an admission severity score ≤25, was discharged with potentially disabling sequelae (headaches and mild cognitive impairment). All patients with an admission severity score of 48 and above were discharged with potentially severe disabilities.

Clarification of the prognosis of DCI treated with standard therapies is important for several reasons. Firstly, education of the patient during treatment is important. Some divers have the misinformed belief that DCI is easily treatable and always cured with recompression therapy and, thus, expect complete resolution following treatment.[12] Secondly, the estimated likely number of treatments until full recovery or plateau will be useful to the patients and their families. Thirdly, identification of patient sub-groups with a poor response to standard therapy could be useful in the initiation of early adjuvant therapies.

Finally, a reliable classification of the prognosis allows for comparison of injured diver populations. The Slark Hyperbaric Unit at the RNZN Hospital has initiated a randomised, prospective, controlled, double blind trial of lidocaine as an adjuvant to recompression therapy in the treatment of DCI. For the purposes of this trial, a scoring system, which provides an effective and quantitative method of tracking progress and assessing recovery is required.

Boussuges et al.[11] state that the use of clinical criteria alone in a severity score could limit its reproducibility and hence suggest the inclusion of objective criteria such as haematocrit (which they believe to correlate with prognosis in decompression illness). The RNZN DCI severity index includes a wide range of clinical parameters, but also clearly defines how each should be applied with the intention of retaining reproducibility.

While the results of this validation study suggest the severity index is a good predictor of improvement with treatment, the likelihood of sequelae and a useful tool for research, several caveats must be recognised before attempting to generalise these results.

The clinical-descriptive classification of decompression illness[13] refers to the full spectrum of disease that results from decompression and the consequent lowering of ambient pressure. This descriptive classification therefore, includes Cerebral Arterial Gas Embolism (CAGE). At the RNZN Hyperbaric facility, those patients suspected of recent CAGE are not tested for gait or balance, for fear of posturally induced arterial gas embolism, but are maintained in the supine posture until under pressure in hyperbaric therapy. The RNZN scoring system has, therefore, not been applied to this sub-group of patients and cannot be considered a useful entity in the assessment of CAGE on admission.

The large proportion of cases (21%) that were excluded from analysis because of incomplete notes, equivocal diagnoses or inadequate clinical examination and CAGE, increases the probability that the conclusions drawn from the sample population are biased. This would be the case if the study variables in the missing records should differ from those in the study population. It is impossible to use missing records and it is normal practice to base conclusions on those records which are complete. The solution is better recording by medical staff of all aspects of treatment so that fewer patients have to be excluded.

As symptoms, signs and recovery were recorded together in the medical records, it was not possible to blind the severity scoring process. Furthermore, all scoring and data collection were performed by the same researcher, which could possibly bias the results. This is an unavoidable problem with retrospective research.

Conclusion

Validation of the RNZN scoring system, using a retrospective review of 100 cases, has demonstrated that it has good prognostic capability and is useful for research. The RNZN index now ready to be validated in a prospective, multicentre study.

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Dr A D Holley MB BCh, Dip DHM, was a Naval Medical Officer in the Royal New Zealand Navy. When this paper was submitted he was Emergency Medicine Registrar, Townsville General Hospital, Townsville, Queensland 4810, Australia. His present address is 12 Willowbrook Place, Titrangi, Auckland 1007, New Zealand.

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