Neurologic decompression illness: a gravity score

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Boussuges A, Thirion X, Blanc P, Molenat F, Sainty JM. Neurologic decompression illness: a gravity score. Undersea Hyperbaric Med 1996; 23(3):151–155.—Treatment of neurologic decompression accidents consists of various hyperbaric oxygen (HBO) protocols. To facilitate such comparisons between different protocols we developed a gravity score. A group of 96 divers was used to establish the score. On admission we first identified signs and symptoms that had possible predictive value (χ^2 test). The parameters included were repetitive dive, clinical course before HBO, objective sensory disorder, motor impairment, and urinary disturbances. Each parameter was assigned a coefficient. The sum of the coefficients for each accident, based on the most severe manifestations before decompression therapy, yielded a score for each diver. A multivariate analysis was used to evaluate the overall agreement between the model prediction and clinical observations, which was 78,7%. A second group (66 divers) was used to validate the score; this group showed a significant difference in the gravity score between the divers who had sequelae and those who did not (P = 0.0001), and between the divers who had incapacitating sequelae and those who had mild sequelae (P = 0.04). Eighty-six percent of the divers with a score above 7 developed sequelae. This index remains to be validated in a prospective multicenter study. If endorsed, valid comparisons can be made between the different therapeutic protocols.

decompression illness, gravity score, neurologic disorders, diving

With the growing popularity of diving, accidents are more frequent. Neurologic accidents are the most serious because they can lead to permanent neurologic disorders. Therapy is standard medical treatment and hyperbaric oxygen (HBO) (1). However, various HBO protocols exist, and it is difficult to assess their efficacy, given the different characteristics of the patients in published series. Previous studies have compared the results in different decompression centers or during different periods (2,3). Furthermore, depending on the geographic location of the decompression center, there can be significant differences in the type and depth of diving activity, the time lapse before treatment, and the initial treatment protocol. Finally, the term "neurologic accident" covers manifestations of varying gravity, ranging from transient subjective sensory disorders to quadriplegia (4).

The multiple therapeutic protocols used in this setting may reflect the absence of a reference treatment (1) and the impossibility of conducting comparative studies of heterogeneous populations. Gravity indices can be used to define homogeneous population groups with the aim of comparing and assessing therapeutic efficacy. Such indices are currently used, for example, in intensive patient management (5,6). They measure the likelihood of death or sequelae through a statistical analysis of the link with clinical and laboratory parameters (7,8).

No gravity index was previously available for neurologic decompression accidents. In 1985, Dick and Massey (9) proposed a severity scale based on 70 medullary decompression accidents. It was scored empirically from 1 to 10 according to sensory and motor impairments. However, it was not validated on an independent series of similar accident victims. It is now rarely used and has few advantages over a scale distinguishing between mild, moderate, and severe accidents (10).

With the aim of facilitating comparisons on homogeneous groups of injured divers, we developed a gravity score based on two series of neurologic decompression accidents. The first population consisted of 96 divers treated at the Salvator Hospital hyperbaric center and was used to establish the score. The second population was composed of 66 divers admitted to the Font-Pré Hospital hyperbaric center and was used to validate the score.

PATIENTS AND METHODS

Patients

Development of the gravity index: The index was based on findings in 96 divers (10 female, 86 male; mean age 35 ± 11 yr) admitted to Salvator Hospital for neurologic decompression accidents between 1985 and 1993. All the divers came to the hospital after a scuba dive, with clinical manifestations evocative of central nervous system injury or spinal cord injury suggesting a neurologic decompression accident.

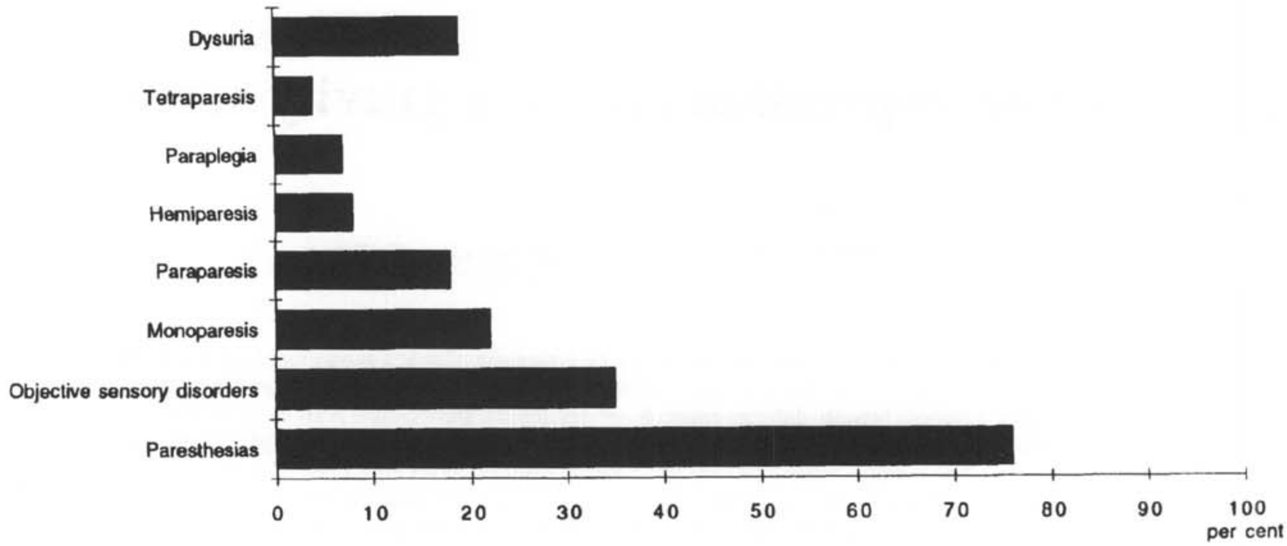

FIG. 1—Initial manifestations (96 divers admitted to the Marseille center).

Patients believed to have pulmonary barotrauma with cerebral air embolism were excluded. The mean maximum diving depth immediately before the accident was 41 ± 13 m. Some risk factors were identified for some divers: ignoring MN 90 recommendations (recommendations of the Marine Nationale 1990) (11), rapid ascent (>17 meters of sea water/min), repetitive dive (a second dive performed in 8 h or less after a first dive, according to the MN 90 recommendations).

Since 1985, our HBO procedure after admission is the same for all patients we suspect of neurologic decompression illness (DCI) (3). HBO therapy consists of recompression to 2 atm abs (203 kPa) with 100% oxygen for at least 2 h. Hyperbaric treatment is stopped when two successive examinations, 1 h apart, show no clinical progression, and is stopped in no more than 6 h in all cases. This HBO procedure prevents nitrogen saturation secondary to compression with air, and we have never observed neurologic aggravation during decompression (3). The therapeutic results seem comparable with those of traditional HBO procedures (12). HBO was given within 3 h of the accident in 50% of cases. In cases of residual signs or symptoms after the first hyperbaric course (58%), addi-tional courses of 1 h at 2.5 atm abs (253 kPa) ($Fi_{O_2} = 1$) are undertaken daily, until total recovery or stabilization of symptoms. The median number of additional courses was six. All the patients with motor disorders received physio-therapy.

Medical treatment consisting of aspirin (1 grain), and fluid loading according to the hematocrit value (500–1,000 ml of dextran or Ringer's lactate) was often included. Treatment with fluid loading and HBO therapy has proved to be associated with a better prognosis in animal victims of severe decompressions (13), so that a treatment including fluid administration, normobaric O_2 therapy, and aspirin is recommended by the Fédération Française d'étude des sports sous marins (French Federation for Underwater Sports and Study) for neurologic DCI (14), and is performed in France before any admission to a hyperbaric center. Eighty percent of our patients had received normobaric O_2 therapy, volemic expansion (500–1,000 ml), and antiplatelet drugs (1gram) before admission.

The gravity of the neurologic accident was assessed based on the persistence or not of sequelae 1 mo. after the accident. Sequelae were defined as persistent neurologic signs or symptoms, and incapacitating sequelae as persistent objective sensory, motor, or urinary signs. Poor outcome was defined as the persistence of sequelae. Longer-term outcome could not be determined because a large number of the divers were lost to follow-up.

Validation of the gravity index: To validate the gravity score, a second group of 66 divers (10 females and 56 males, mean age 34 ± 10 yr, and a mean maximum diving depth immediately before the accident of 39 ± 13 m) was used. These divers were admitted to the Font-Pré Hospital hyperbaric center for neurologic decompression accidents between 1991 and 1994. Since 1990, practitioners at the Font-Pré hyperbaric center have used the same HBO procedures as those at Salvator. Diagnosis of neurologic DCI was made using the same criteria as those of the first group. The hyperbaric and medical treatment protocols were identical to those used at Salvator Hospital. HBO therapy was started within 3.5 h in 50% of cases; 82% of this group received medical treatment before admission to the hyperbaric center. Treatment efficacy was assessed 1 mo. after the accident, using the same criteria as those applied to the first group.

METHODS

Development of the gravity index: We first identified signs and symptoms, before admission to the hyperbaric center, which had possible predictive values in a univariate analysis (χ^2 test).

We retained all parameters with P values of less than 0.10 in the univariate analysis, as well as clearly relevant clinical manifestations, and assigned them a coefficient. The sum of the coefficients for each accident, based on the most severe manifestations before recompression therapy, yielded a score for each diver. Next, a multivariate analysis (logistic regression model) was used to evaluate the overall agreement between the model prediction and clinical observations.

Validation of the gravity index: We compared the gravity scores between the divers who made a full recovery and those who had sequelae, and then between the divers with incapacitating sequelae and those with mild sequelae. The Mann–Whitney U test was used to compare gravity scores because values were not distributed normally. Differences with P values of less than 0.05 were considered significant. Statistical tests were run on SAS software (Cary, NC).

RESULTS

Development of the gravity index

Univariate analysis: Initial manifestations and progression before HBO therapy: Seventy percent of the divers developed symptoms within 10 min of diving and 91% within 1 h. A repetitive dive had been performed by 18% of divers. Initial manifestations consisted of sensory disorders (88%), motor (59%), and urinary (19%). Sensory and motor disorders were both present in 49% of patients. Sensory disorders were of a subjective (paresthesia or pain) or objective nature (alterations of the superficial, the deep, or the thermo-analgesic sensibility). Motor disturbances ranged from monoparesis to paraplegia. Figure 1 shows the initial manifestations in the 96 divers. During transport to the hospital, 52% of the patients improved, 41% remained stable, and 7% deteriorated.

Therapeutic results: After the first HBO session, 55% of the divers were asymptomatic. One month after the accident, 71% of the divers were asymptomatic and 29% had sequelae; 19% of the total were incapacitated.

Conclusion of the univariate analysis: A repetitive dive was not associated with a poor prognosis in the univariate analysis ($P = 0.09$). The delay between emerging from the water and compression was not different in divers without sequelae (median = 185 min) when compared with divers with sequelae (median = 203 min) ($P = 0.44$; Mann–Whitney U test).

The progression of the clinical manifestations before hospital admission provided prognostic information: a rapid amelioration carried a good prognosis ($P < 0.005$) whereas a deterioration was associated with a poor outcome; all divers had sequelae 1 mo. after the accident.

The onset of motor disorders correlated with the presence of sequelae ($P < 0.05$), of which paraplegia was the most serious ($P < 0.0001$). Initial urinary disorders were also associated with sequelae ($P < 0.0001$). Sensory alterations were classified into two categories: subjective disorders alone carried a good prognosis (correlation with complete recovery, $P = 0.03$), whereas objective disorders carried a poor prognosis ($P < 0.0001$).

No significant difference was observed in the time to onset of clinical manifestations between the divers who recovered completely and those who had sequelae ($P = 0.20$).

Attribution of a coefficient: On the basis of the results of this statistical analysis and expert knowledge, we attributed a coefficient to each sign and symptom that seemed to be predictive of outcome.

Calculation of the gravity index: The gravity index was the sum of the coefficients for each diver. The coefficient retained was based on the most severe manifestation before HBO therapy (Table 1).

Multivariate analysis: The logistic regression model, based on the clinical study and the results of the univariate analysis, was used to identify links between sequelae and the following variables: clinical improvement or deterioration

Table 1: Calculation of the Gravity Index

Score		0	1	2	3	4	5	6
Repetitive dive	no	X						
	yes			X				
Clinical course beore HBO_2	improvement	X						
	stability				X			
	deterioration						X	
Objective sensory disorder	no	X						
	yes					X		
Motor impairment	no	X						
	monoparesis, paraparesis, or tetraparesis					X		
	paraplegia							X
	hemiplegia				X			
Urinary disturbances	no	X						
	yes						X	

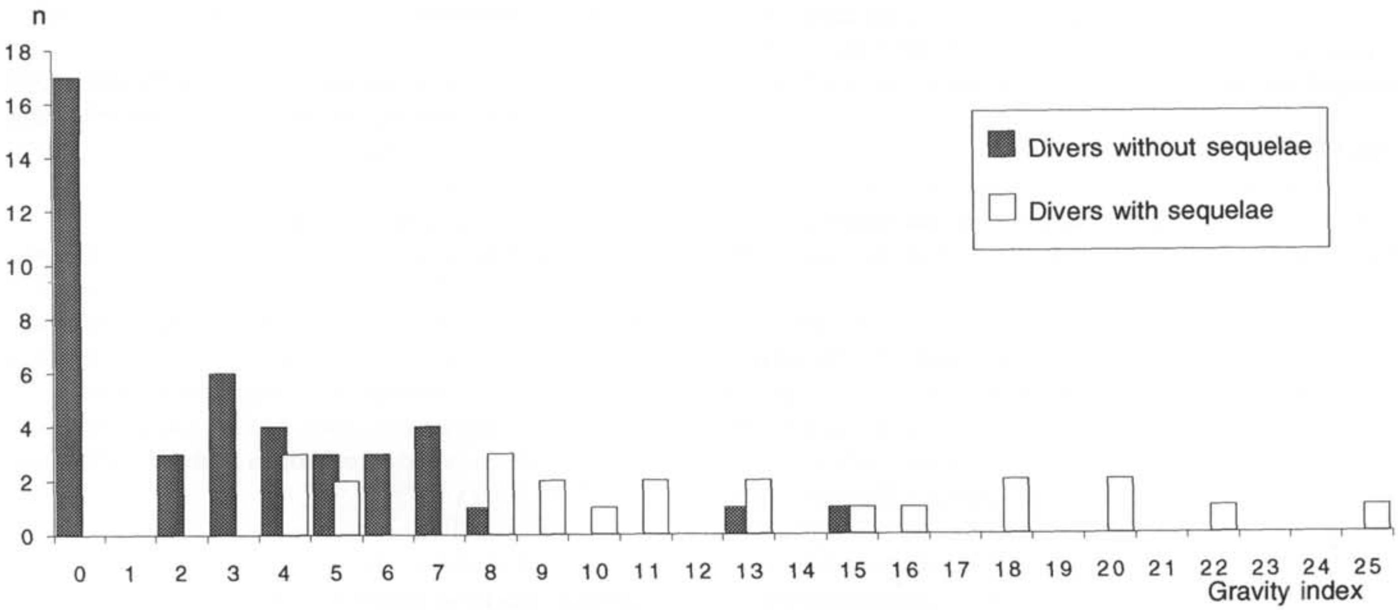

FIG. 2—Validation of the gravity index in the 66 divers admitted to the Toulon center.

before admission, objective sensory disorders, paraparesis, paraplegia, hemiparesis, and urinary disorders. Repetitive dive was also included in the multifactorial analysis. The overall agreement between the model prediction and clinical observations was 78.7%.

Validation of the gravity index

The gravity index was validated on the population of 66 divers with neurologic manifestations of decompression injury admitted to Font-Pré Hospital; none of these divers was included in the population used to develop the index; 21% had performed a repetitive dive. Initial symptoms consisted of sensory disorders (94%), motor (45%), and urinary (20%). During transport to the hospital, 70% of the patients improved, 24% remained stable, and 6% deteriorated. One month after the accident, 65% of the divers had made a full recovery and 35% had sequelae, including 24% of the total who had incapacitating sequelae.

We noted a significant difference in the gravity score between the divers who had sequelae and those who did not (P = 0.0001) (Table 2), and between the divers who had incapacitating sequelae and those who had mild sequelae (P = 0.04). Figure 2 shows the distribution of the population according to the gravity scores.

We studied the prognostic value of a gravity score above 7 by calculating the sensitivity, specificity, and positive and negative predictive values. As shown in Table 3, 86% of the divers with a score above 7 developed sequelae.

Table 2. Significant Differences in the Gravity Index Between the Divers With and Without Sequelae[a]

	n	Median	Minimum	Maximum
Recovery	43	3	0	15
Sequelae	23	11	4	25

[a]P = 0.0001.

Table 3: Prognostic Value of a Score Greater than 7[a]

	Sequelae	Recovery	
>7	18	3	21
≤7	5	40	45
	23	43	66

[a]Sensitivity 78%; specificity 93%; positive predictive value 86%; negative predictive value 89%

DISCUSSION

The study of a large population of divers who experienced a neurologic decompression accident enabled us to develop a statistically sound gravity index. The clinical parameters used are simple, meaning that the score should be reproducible. In the univariate analysis, initial neurologic status provided a number of prognostic criteria. We also found the initial clinical course to be predictive of the longer-term outcome; Francis and Smith (15) used this criterion in their new classification. The multivariate analysis also identified a repetitive dive as being associated with a poor prognosis. Contrary to several experimental or clinical studies (16,17), we found that the time lapse to the onset of symptoms had no prognostic value.

The use of clinical criteria alone in a gravity index could limit its reproducibility, and it would thus be valuable to include objective criteria in our scale. In particular, the hematocrit on admission seems to correlate with the prognosis in decompression accidents (18). We were unable to include this parameter in our index because these data were unavailable, but the continuation of this study should determine the prognostic value of the hematocrit level.

To validate the index, we applied it to a different population of 66 divers suffering from neurologic decompression accidents, who were admitted to another hyperbaric center using the same therapeutic protocols. The significant difference in the gravity score between the divers with sequelae and those who recovered completely is the first step toward validation. Analysis of the prognostic value of scores higher than 7 confirmed the validity of this gravity index. However, secondary deteriorations have been noted in divers who have equivocal neurologic signs and symptoms on admission (19). Thus, a low score does not necessarily mean that the patient will not develop sequelae because the negative predictive value of a score below 7 was 89%. Therefore this gravity index is in no way intended for application to individual cases. Indeed, it is aimed solely at assessing the gravity of a population with a view to comparing the efficiency of different therapeutic protocols. The index now remains to be validated in a prospective, multicenter study.

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