The SANDHOG criteria and its validation for the diagnosis of DCS arising from bounce diving.

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Submitted - 5-8-06; accepted - 11-15-06

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Grover I, Reed W, Neuman T. The SANDHOG criteria and its validation for the diagnosis of DCS arising from bounce diving. Undersea Hyperb Med 2007; 34(3): 199-210. Purpose: A three-point scale, the SANDHOG (SAN Diego Diving and Hyperbaric Organizations) criteria, was developed to diagnose DCS (decompression sickness), and then it was validated against a known database of diving related injuries. Introduction: There are currently no universally accepted diagnostic criteria for the diagnosis of DCS. The SANDHOG criteria were developed to address the need for a case definition of DCS. Methods: A point scale and entrance criteria were developed for the diagnosis of DCS. Once the entrance criterion had been met, points were awarded based upon the diver's symptoms and their time of onset. The point system and time limits (SANDHOG criteria) were determined based upon US Navy and Royal Canadian diving reports. The SANDHOG criteria were then applied on a *post hoc* basis to the Duke Hyperbaric database of diving injuries. Sensitivity and specificity were then calculated using three points as the cut off. The ROC (receiver operating characteristic) analysis was performed to determine the area under the curve (AUC). Results: The three point SANDHOG criteria had a specificity of 90.3% and a sensitivity of 52.7%. ROC analysis of the original SANDHOG criteria gave an AUC of 0.72. Using different point values for the diagnosis of DCS will subsequently affect the sensitivity and specificity of the SANDHOG criteria. Conclusions: The specificity of the SANDHOG criteria is good, and demonstrates that the SANDHOG criteria are a useful tool for the diagnosis of DCS.

INTRODUCTION

Sir Robert Boyle first suggested the etiology of decompression sickness (DCS) in 1670 when he produced bubbles behind the eyes of a snake that was placed in a vacuum chamber. The French mining engineer Triger first described the symptoms of decompression sickness in humans in 1841. With the advent of SCUBA (self contained underwater breathing apparatus) diving in the 20th century, and its dramatic increase in popularity over the last quarter of a century, diving injuries have become well known albeit infrequent medical disorders. Thus it seems peculiar that after over 100 years of experience with decompression sickness (DCS) we still have yet to establish a generally accepted case definition. This is even more remarkable when one considers that in the present day, when a new clinical syndrome is identified, one of the first things that the Center for Disease Control (CDC) does is to establish a case definition. AIDS (acquired immune deficiency syndrome) and SARS (severe acute respiratory syndrome) are just two examples of recent medical disorders that were given strict criteria to define the illnesses.

In the 1940's medicine was faced with the problem of diagnosing acute rheumatic fever (ARF). No sensitive or specific test existed for this illness. A series of "major" and "minor" criteria were established (Jones Criteria) to make this diagnosis (1). For research purposes, these criteria were highly

specific allowing the generation of case series that, for practical purposes, included only true cases of ARF. Conversely, interpreting these criteria more loosely helped practitioners make clinical diagnoses for treatment purposes or as an aid to advising patients. Other examples of diseases without a defining test that require clinical criteria to make the diagnosis are: systemic lupus erythematosus, Kawasaki's disease, and pelvic inflammatory disease.

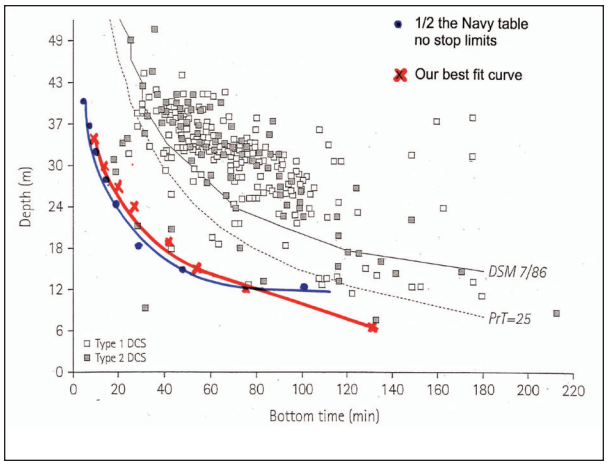
Diving medicine is not unique in the situation of being forced to make clinical diagnoses in the absence of a defining "test" to establish the diagnosis. However, its literature is almost unique in the repetitive presence of papers that define decompression illness based upon the clinical diagnosis of the author or based upon treatment records.

The two basic reasons for attempting to define criteria to establish the diagnosis of decompression sickness are to: (1) reach a treat-no-treat decision, and (2) include cases in a database for either clinical or research purposes. In both cases some sort of criteria or "case definition" for the diagnosis of dysbarism are necessary. In the former case the standards used to "establish" the diagnosis should result in a sensitive test, which would recognize most of the true cases that are present in the population. In the latter case it is desirable to have more specific case criteria. Unfortunately without the existence of a "gold standard" test, increasing the sensitivity of a case definition will invariably reduce its specificity and conversely, increasing the specificity will erode sensitivity.

The SANDHOG criteria were developed using the Jones criteria for acute rheumatic fever as a starting point. The method for the creation of this algorithm has previously been published (2). A point scale was used for making the diagnosis of DCS. This is advantageous because a point scale can be made more specific by raising the score needed to establish the diagnosis (i.e. for research purposes), but it can be made more sensitive by lowering the necessary score for a diagnosis (i.e. for clinical purposes). With the SANDHOG criteria, the goal was to keep the criteria specific enough for an uncorrupted database without unduly sacrificing sensitivity. The term SANDHOG was derived from the acronym for SAN Diego Diving and Hyperbaric OrGanizations for the group that helped to develop the criteria, and it is also a colloquial term used for caisson workers.

METHODS

The scoring system for the SANDHOG criteria was developed using data from numerous sources of diving injuries. To gain entrance into the scoring system, an exposure capable of producing DCS was defined, (just as an antecedent streptococcal infection is required for the diagnosis of ARF). Clearly not all exposures can cause DCS. In order to enter the SANDHOG algorithm, an exposure at least equal to the compartment loading achieved by a dive to 50% of the United States Navy (USN) '55 no stop limits was selected. The value of 50% of the no stop limits was selected for three reasons. Although it is a minimal exposure, occasionally severe cases of spinal cord DCS have been seen with such exposures (especially when associated with AGE). Secondly, analysis of North Sea Diving experiences demonstrates this will capture the vast majority of cases. (See Figure 1) (3) which represents a "best fit" curve drawn that includes all but 2 cases of DCS in North Sea divers and which coincides closely with 1/2 the Navy "no stop" limits).



Bottom Time (min)

Fig. 1. Depths and times at which DCS occurs in commercial offshore air-diving operation in the UK sector. Shields TG and Lee WB. "The incidence of Decompression Sickness Arising From Commercial Offshore Air-Diving Operations in the UK sector of the North Sea During 1982-1990."

Symptoms associated with exposures less than this are much more likely to be due to something other than DCS. These values were chosen because they would be easy for any clinician to use and apply to suspected DCS cases. Finally, a reliable way to estimate the severity of the exposure is generally available as most divers now use downloadable diving computers, providing the exact profile of the diver.

Table 1, opposite, provides the SANDHOG Criteria for the diagnosis of DCS and Appendix 1, at the end of this paper, further explains how the criteria were developed for DCS and the rationale for which they were given the particular point values.

The SANDHOG criteria were then validated against the Duke hyperbaric database of diving related injuries. The Duke Hyperbaric Database contains records on all patients evaluated and treated at the Duke University Medical Center Hyperbaric Medicine Center from 1997 onward. At the time of data collection the database was maintained on

SANDHOG Criteria for DCS

3 Points

1. Signs and symptoms of transverse myelitis with both sensory and motor changes within 2 hours of a dive
2. Monoparesis with pathological reflexes and associated sensory changes within 2 hours of a dive
3. Cutis Marmorata

2 Points

1. An exposure (without decompression) that is greater than the loading seen with exceeding the Navy no stop limits by 10% or missed decompression greater than 5 minutes
2. Any sign or symptom in the 3 point category occurring 2-6 hours after a dive
3. Syndrome of cough, substernal chest pain, and shortness of breath
4. The syndrome of inner ear (vestibular) DCS characterized by vertigo, tinnitus, and hearing loss occurring within 2 hours of a dive
5. Deep boring pain in a major joint within 2 hours of surfacing from a dive
6. Isolated sensory changes in a single limb or at a spinal cord level plus hyperreflexia within 2 hours of surfacing from a dive
7. Lymphedema occurring within 24 hours of a dive

1 point

1. Deep boring pain in a major joint occurring 2-6 hours after a dive
2. Isolated sensory changes in a single limb or at a spinal cord level plus hyperreflexia 2-6 hours after a dive
3. Complete relief from joint pain within 10 minutes of the initiation of recompression therapy
4. Complete relief of motor and sensory changes within 40 minutes of therapeutic recompression, or a full number improvement in motor signs during the first two hours of recompression
5. Scintillating scotomata occurring after a dive in a patient without prior history of migraine headaches
6. A dive profile (without decompression stops) between the "no stop" limits of USN '55 and VVAL 18 or a properly conducted single dive requiring staged decompression

Half point

1. Isolated parasthesias or "tinglies" occurring after a dive
2. Fatigue, dizziness, headache, nausea, or vomiting

Minus one point

1. Presence of a fever
2. History of hypochondriasis or anxiety disorder

Filemaker Pro 6 software (FileMaker Santa Clara, CA). Records include demographic and billing information, initial evaluations, interval evaluation, follow up evaluations (when done), and technical information on the treatments done. The database contained information on 1919 patients at the conclusion of data collection.

IRB Approval

The data collection and analysis protocol was reviewed and approved by the Duke University Medical Center Institutional Review Board prior to the start of data collection.

Data Collection

Data were abstracted by one researcher. The database was queried for all patients treated for decompression illness. Cases were excluded if the case was caused by altitude exposure only, the cause was iatrogenic, or if the initial evaluation, recompression data, or follow up data were missing. The data were taken from the original evaluation by the attending physician at the time of the evaluation. Data were collected on basic demographic factors, relevant previous medical history, type of exposure, initial presentation, findings at initial evaluation, treatment, results of treatment, and type of residual symptoms, where present.

The Doubt Field

A case of DCS was classified as doubtful when the attending physician, at the time of the initial evaluation, expressed clear doubt about the diagnosis. This field, therefore, did not include the results of recompression therapy.

Application of Criteria

As the data fields were abstracted prior to the development of the criteria, the abstracted fields do not map directly to the SANDHOG criteria. In almost all cases by using a combination of data fields the SANDHOG criteria could be applied. The exposure fields however were unable to be included, due to a lack of reliable exposure data. A modified form of the SANDHOG criteria was developed with maximum dive depth and total days diving as proxies; this is termed the modified SANDHOG criteria. One point was given for a maximum depth of series of at least 60 fsw (18 msw). Two points were given for maximum depth of series of at least 100 fsw (30.5m) or more than 2 dives in a single day.

Statistical Analysis

Data were analyzed with Stata, version 8 (Stata Corporation, College Station, TX). Odds ratios, where reported, are uncorrected unless otherwise noted. Area under ROC curves were determined by the geometric method. Correction for specificity was done according to the method of Begg and Greenes (4). Briefly, this method attempts to correct for known biases in the "gold standard" tests. Using a standard 2x2 table set up as below:

	Ref Test Positive	Ref Test Negative
New Test Positive	a	b
New Test Negative	c	d

The calculated sensitivity of the candidate test is corrected for the non perfect specificity of the reference test as follows:

$$\frac{((a+b)*spec_{ref}) - b}{N(spec_{ref}-1) + (a+c)}$$

Where N is the total number of observations, a, b, and c correspond to the positions in the 2x2 table, and $spec_{ref}$ is the known or estimated specificity of the reference test.

RESULTS

There were a total of 128 cases with sufficient data to be eligible for review. Since hypobaric exposure following hyperbaric

exposures were not part of the SANDHOG criteria, all cases with hypobaric exposure (excepting for medical evacuation) were also excluded. This left a total of 86 cases available for review. The breakdown of cases by year is shown in Table 2.

Accident Year	No Doubt	Doubt	Total
1997	11	9	20
1998	7	8	15
1999	11	7	18
2000	14	4	18
2001	6	2	8
2002	6	1	7
Total	55	31	86

Table 2. Number of diving accidents per year.

There was a decline in the numbers of cases seen during the study period. This is partially explained by a decrease in the number of experimental hyperbaric only exposures at the study site in this period. The basic characteristics of the cases analyzed are shown in Table 3.

	No Doubt	Doubt	p
Female Gender	18%	16%	0.81
Age	39	37.3	0.48
Back Problem	3.64%	9.68%	0.057
Past MS Problem	3.64%	9.68%	0.051
Experimental Dive	14.5%	9.68%	0.52
Dive Comp Use	67.92%	64.52%	0.75
Days Diving	1	1	0.32
Dive in Series	2	2	0.24
Depth of Last Dive	103	75	0.005
Depth of Deepest	113	97	0.03

Table 3. Dive accident case characteristics.

There was no difference in the gender, age, or dive planning method used between the doubt and no-doubt groups. The age and gender distribution were similar to that found in the much larger DAN accident database. The doubtful cases had a higher frequency of both musculoskeletal problems and back problems than did the no-doubt cases, although this difference did not reach statistical significance (p=0.051 and p=0.057 respectively). The number of days diving and number of dives per series was similar in both groups. The median depth of the dive immediately preceding the accident, and the median deepest depth of the dive series was slightly more in the no-doubt group. Deeper depths of dives, both immediately prior to the accident and deepest dive of the series, made for increased confidence in the diagnosis by the treating physicians.

SYMPTOMS

The presenting symptoms of the two groups are shown in Table 4.

	No Doubt (n=55)	Doubt (n=31)	p
Cognitive	5.45%	0.00%	0.26
Pulmonary	1.82%	3.23%	0.59
Cardiovascular	3.53%	0.00%	0.64
Pain	54.55%	61.29%	.054
Rash	5.45%	0.00%	0.19
Vision	5.45%	0.00%	0.26
Coordination	**23.64%**	**0.00%**	**0.003**
Weakness	**21.82%**	**0.00%**	**0.005**
Paresthesia	60.00%	70.97%	0.309
Numbness	**32.73%**	**6.45%**	**0.001**
Headache	12.73%	6.45%	0.479
Constitutional	7.27%	12.9%	0.451
Vertigo	**12.73%**	**0.00%**	**0.046**
Dizziness	14.55%	6.45%	0.318
Tinnitus	1.82%	0.00%	1.00
Consciousness	1.82%	0.00%	1.00
Reflex	10.91%	0.00%	0.083

Table 4. Presenting symptoms.

There were relatively few statistically significant differences in the two groups. The presence of demonstrable signs of neurologic deficits in strength, sensation, and coordination was associated with confidence in the diagnosis of DCS. Vertigo was the only other symptom which was statistically significant between the two groups. The strictly subjective symptoms of both pain and paresthesia were the most commonly reported, although were both slightly more common in the doubtful group.

Symptom onset

The time to symptom onset of the different groups is shown in Figure 2.

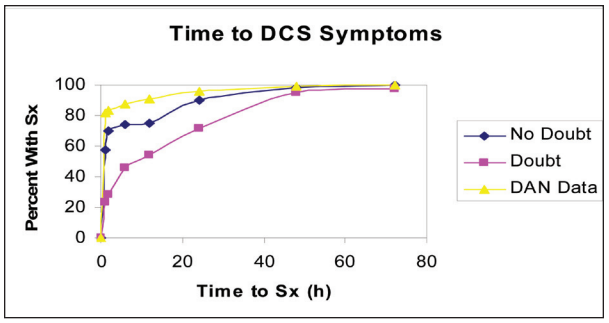


Fig 2. Time to onset of DCS symptoms

The median time to symptom onset for the doubtful group was 9 hours; the median time to symptom onset on the no-doubt group was 24 minutes ($p<0.0001$ by Wilcoxon rank sum test) (5). In order to account for possible confounding a Cox proportional hazards model was used (6). The initial model included all factors identified as being potentially significant in the bivariable analysis; the model was then reduced stepwise. When controlled for deepest depth of dive series, symptoms of weakness and numbness, the symptom onset time was still statistically different between the doubt and no-doubt groups. Shorter symptom onset times were more associated with less doubt of the diagnosis; longer symptom onset times were associated with more doubt. Despite the difference in symptom onset time, there was no difference in the delay to treatments. Both groups had a median time from onset of symptom to start of recompression therapy of 12 hours.

Application of the SANDHOG Criteria

The initial SANDHOG criteria were applied to the cases collected from the Duke Hyperbaric Database. The quality of the exposure data was such that no points were allocated for the hyperbaric exposure. The median score in the doubt group was 1.5, and the median score in the no-doubt group was 3.5. The resultant scores after the application of the SANDHOG criteria are shown in Figure 3.

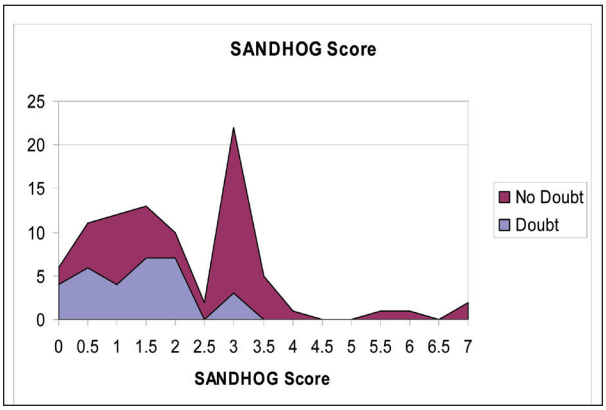


Fig. 3. Scores for the two groups after application of the SANDHOG criteria.

As initially presented, with a score of 3 to make the diagnosis of decompression sickness, the criteria are 52.73% sensitive and 90.32% specific. Since the SANDHOG criteria is a score based system, it allows altering the threshold for diagnosis. The sensitivity of the criteria ranged from a low of 9% with a score of 4, to a high of 61.8% with a score of 2. Specificity was inversely related to sensitivity (as expected) ranging from a low of 61.8% with a score of 2, to a high of 100% with a score of 4. The Receiver Operator Characteristics (ROC) graphically quantitates the performance of a diagnostic test. The ROC curve for the original SANDHOG criteria is shown in Figure 4, opposite.

The area under the ROC curve for the original SANDHOG criteria is 0.73. In the initial evaluation of the SANDHOG criteria there were no points given for exposure. This was due to the poor quality of the recorded exposure data, and difficulties in correctly evaluating gas loading where reliable exposure

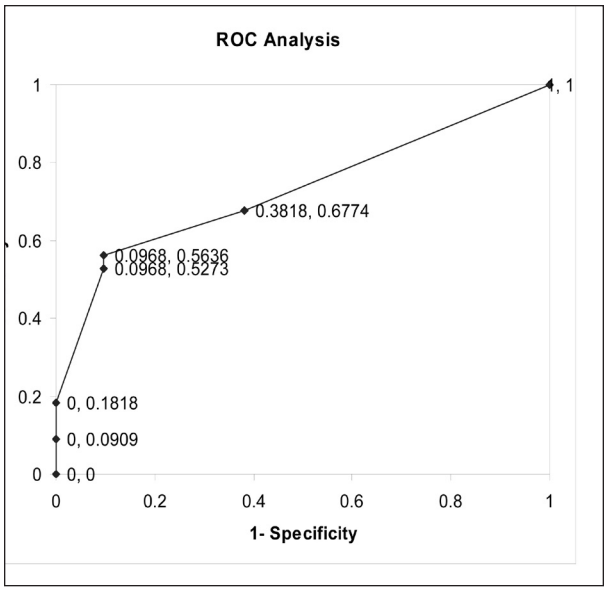


Fig 4. ROC analysis of the SANDHOG criteria.

data did exist. The modification allowed one point for maximum depths of series of 60 fsw (18 msw) or greater, and two points for maximum depths of series of greater than 100 fsw (30.5 msw) or greater than 2 dives per day.

Overall there was some improvement of the sensitivity of the modified SANDHOG criteria, with sensitivities ranging from a low of 52.7% to a high of 70.9%. This came, however, at a very significant loss of specificity, which ranged from 48.4% to 93.6%. The overall performance of the modification was slightly worse than the original, with the AUC of 0.697. The calculation of the performance of the SANDHOG criteria assumes a 100% sensitivity and specificity of the clinical standard. The clinical standard is likely to be nearly 100% sensitive, or if not the nature of the data collection ensures that clinical false negatives will not be included in the dataset (a diagnosis of decompression illness and recompression were required for entry). Given the nature of the doubt field it is likely that the specificity of the diagnosis was less than 100%, and might be considerably less than that. Using the method of Begg and Greenes we estimated the true sensitivity of the test. These estimates are shown in Table 5.

There was, as expected, a significant but not overwhelming improvement in the estimated sensitivity of the SANDHOG criteria. Generally, there was an improvement of 10 percentage points when the estimated specificity of the clinical criteria was decreased from 100% to 75%. This represents a significant, although not overwhelming, improvement in the performance of the criteria. The AUC was not calculated using the new sensitivity because the correction for altered specificity gives an idea of what the sensitivity may be with the assumed change in specificity. This new sensitivity is a derivative value, so there is a large amount of error associated with this number. Since the AUC is a value derivative from the new sensitivity, the calculation would be so far removed from the actual data and thus the calculation would be of questionable utility.

	Clinical Specificity	1	0.95	0.90	0.85	0.80	0.75
SANDHOG 3	Corrected Sensitivity	0.527	0.540	0.553	0.575	0.598	0.626
SANDHOG 2	Corrected Sensitivity	0.618	0.627	0.638	0.651	0.667	0.686
SANDHOG 2.5	Corrected Sensitivity	0.564	0.578	0.595	0.615	0.640	0.672
SANDHOG 3.5	Corrected Sensitivity	0.182	0.187	0.194	0.202	0.212	0.224
SANDHOG 4	Corrected Sensitivity	0.091	0.093	0.096	0.099	0.103	0.108
Modified SANDHOG 3	Corrected Sensitivity	0.618	0.627	0.6379	0.6508	0.667	0.6866
Modified SANDHOG 2.5	Corrected Sensitivity	0.709	0.715	0.722	0.730	0.741	0.753
Modified SANDHOG 3.5	Corrected Sensitivity	0.5636	0.5789	0.5970	0.6188	0.6455	0.6791
Modified SANDHOG 4	Corrected Sensitivity	0.5273	0.5414	0.5582	0.5784	0.6032	0.6343

Table 5. Corrected sensitivity for SANDHOG scores.

DISCUSSION

The SANDHOG criteria were developed to provide a case definition for DCS for scientific studies. The criteria will also help clinicians identify cases of decompression sickness for a treat-no-treat decision. The criteria are limited in this regard because points can be awarded for response to treatment. The point system allows clinicians to adjust the cut-off values for the diagnosis of DCS which will affect the sensitivity and specificity depending on whether the criteria are going to be used for research purposes or to suggest a treat-no-treat decision. The benefit of the SANDHOG criteria for research purposes would be that it would generate a database of true DCS cases. This database would likely be uncontaminated with a significant number of false positive cases (i.e.non DCS related clinical entities). This highly specific database of true positives could be used for research and long term analysis which could lead to adjunctive treatments or alternative treatment regimens for DCS. The importance of this increases as underwater development and exploration continues and as more people take to the water to enjoy SCUBA diving.

In this study the criteria were applied by one physician to the different cases, but the criteria were developed to be generalizable. Based on the application of the SANDHOG criteria against a database of diving related injuries, we found the criteria to have a high specificity. The area under the ROC curve (AUC) shows that the criteria are a useful test. The AUC tells us about the accuracy of the criteria. An area under the curve of .90-1.0 is an excellent test, 0.80-0.89 is a good test, 0.70-0.79 is a fair test, and 0.60-0.69 is a poor test. As examples, the AUC for the Walsh clinical prediction rules for streptococcal pharyngitis is 0.71, the AUC for BNP for the diagnosis of heart failure has been shown to be between 0.82 and 0.90, and the AUC for d-dimer for the diagnosis of deep venous thrombosis has been shown to be 0.72 (7,8,9).

The sensitivity of the criteria clearly should be improved, but we were comparing the criteria to a "doubt" field that was not a true "gold standard". Even outlying cases of decompression sickness were not doubtful unless the treating physician expressed doubt. The sensitivity did improve when the estimated specificity of the clinical criteria was decreased from 100% to 75%. Another confounding factor is that these criteria were applied retrospectively and no points were given for exposure because dive times were not recorded in the database. Exposure information is important and would likely add to the sensitivity of the criteria.

Symptoms of decompression sickness may progress or improve prior to the patient being examined by a physician. If symptoms did resolve prior to examination or treatment, then inclusion in a research database would have to be defined by the researcher ahead of time. Further comparisons are required because in this database, there were no clear cases of vestibular, pulmonary, or lymphatic decompression sickness.

CONCLUSIONS

The specificity of the SANDHOG criteria is very high, and it suggests the SANDHOG criteria are a useful tool for the diagnosis of DCS. A score based system represents a practical method to establish inclusion criteria for trials and epidemiological studies involving DCS. Further research is required to apply the SANDHOG criteria for DCS in a prospective fashion.

Appendix 1

DCS Criteria

Three Points are awarded for each of the following:

1. *Signs and symptoms of a transverse myelitis with both sensory and motor changes (weakness rated as 3/5 or worse; not just isolated sensory changes) within 2 hours of a dive*. The motor exam is scored on the 5 point scale where 0 is no movement at all, 1 is a muscle twitch but no actual movement, 2 is movement, but not strong enough to overcome gravity, 3 is movement strong enough to overcome gravity but not any other resistance, 4 is movement strong enough to overcome gravity and some resistance, but not normal, and 5 is full strength. The reasoning for this is that a transverse myelitis with motor changes is an unusual diagnosis for things other than DCS. Such findings are likely to be highly *specific* for DCS. Based on review of type II DCS cases, two hours was selected because the overwhelming majority of neurological DCS occurs within 2 hours of a dive. When such symptoms begin further out from a dive the specificity for DCS decreases. See Figure 5, page 209 (10).
2. *A monoparesis worse than or equal to 3/5 with pathological reflexes and associated sensory changes (not isolated sensory changes) within 2 hours of a dive*. The reasoning behind this is the same as # 1 above.
3. *Cutis Marmorata, not an erythematous rash, but true marbling of the skin.* Linear streaking is not cutis marmorata. Although cutis marmorata can rarely be seen in other conditions it is generally only associated with shock like states, except in DCS. Therefore, if it occurs after a dive, the finding is specific enough to be diagnostic of DCS.

Two Points are awarded for each of the following:

1. *An exposure (without decompression) that is greater than the loading seen with exceeding the Navy no stop limits by 10% (i.e. a 60 foot dive for 66 minutes, a 70 foot dive for 55 minutes, an 80 foot dive for 44 minutes etc.) or missed decompression greater than 5 minutes.* These would be highly provocative profiles and "soft" signs or symptoms after such a dive must be considered much more likely to be DCS than after a trivial exposure.
2. *Any sign or symptom in the three point category occurring 2-6 hours after a diving exposure.*
3. *Chokes, which is defined as the syndrome of cough, substernal chest pain and shortness of breath*. This syndrome was only assigned two points because of possible confusion with immersion pulmonary edema, aspiration etc. Chokes are most frequently associated with a heavy load of venous gas embolism (VGE) and therefore will be associated with a heavy gas load as in #1 above or #6 under the 1 point category.
4. *The syndrome of inner ear (vestibular) DCS characterized by vertigo, tinnitus and hearing loss that lasts more than 5 minutes accompanied by an abnormality of tandem gait or an abnormal Romberg (not sharpened Romberg), occurring within 2 hours after a dive*. This was not given three points because people who are simply "dizzy" should not enter the database, as this is too subjective a symptom. Otic barotrauma can be easily confused with this syndrome so it was

assigned only two points. Once again most true vestibular DCS is associated with significant and/or provocative exposures.

5. *Deep boring pain in a major joint within 2 hours of surfacing from a dive.* Too many alternative diagnoses can cause pain in the joints. Therefore, this syndrome was only assigned 2 points. Again, based on extensive review of DCS cases, two hours was selected because two-thirds of all DCS occurs within this time period. The further from the dive, the less likely the symptoms are likely to be DCS related. See Table 6 (11,12).
6. *Isolated sensory changes in a single limb or at a spinal cord level plus hyperreflexia within two hours of surfacing from a dive*. There is always concern about isolated subjective (symptoms) complaints. The presence of hyperreflexia makes the likelihood that a true pathophysiologic abnormality exists greater and therefore the sensory changes are more likely to represent DCS. That it occurs within two hours of surfacing also increases the likelihood of DCS. Isolated paresthesias without any other findings are not highly specific enough to be routinely considered DCS.
7. *Lymphedema occurring within 24 hours of a dive*. This is quite specific for DCS. However, one must make sure to differentiate this from hives and swelling due to trauma, stings etc.

<u>One Point is awarded for each of the following:</u>

1. *Deep boring pain in a major joint from 2-6 hours after surfacing from a dive*. The reasoning again is that as more time elapses after a dive a non-specific symptom becomes increasingly less likely to represent DCS. Therefore, as one gets further from the dive non specific symptoms must be worth fewer points.
2. *Isolated sensory changes in a single limb or at a spinal cord level plus hyperreflexia 2-6 hours after surfacing from a dive*. The reasoning behind this is the same as #1 above.
3. *Complete relief from joint pain within 10 minutes of the initiation of recompression therapy.* Many things improve in a chamber over a 6-hour period. The placebo effect is both real and considerable. True "pain only" bends usually responds quickly to recompression. Although cases may respond slowly, too many of those will likely be false positives thus increasing the likelihood of an incorrect diagnosis.
4. *Complete relief of motor and sensory changes within 40 minutes of therapeutic recompression, or a full number improvement in motor signs during the first 2 hours of recompression, i.e. a change from 3/5 to 4/5, or from 2/5 to 3/5*. Again, the reasoning behind this is the same as #3 above.
5. *Scintillating scotomata occurring after a dive in a patient without a prior history of migraine headaches.* This symptom is too subjective and too non-specific to be weighted heavily. When it occurs without a significant exposure or without any other signs or symptoms, there should be concern with the diagnosis of DCS.
6. *A dive profile (without decompression stops) between the "no stop" limits of USN '55 and VVAL 18 or a properly conducted single dive requiring staged decompression.* These are still

rather benign exposures with a very low incidence of DCS. Symptoms following such a dive might represent DCS, however these profiles cannot be considered very provocative (13).

Half Point is awarded for each of the following:

1. *Isolated paresthesias or "tinglies" occurring after a dive.* Many people have minor non-progressive, highly subjective symptoms that are very non-specific. If isolated "tinglies" are considered DCS the database will be significantly corrupted.
2. *Fatigue, dizziness, headache, nausea, or vomiting*. Only half a point can be awarded for any combination of these symptoms. The reasoning for this is the same as #1 above. However, if these symptoms are associated with "harder" signs or symptoms they will be considered in the diagnosis.

Minus One Point for each of the following:

1. *Presence of fever*
2. *History of hypochondriasis or anxiety disorder* (14, 15)

Fig. 5

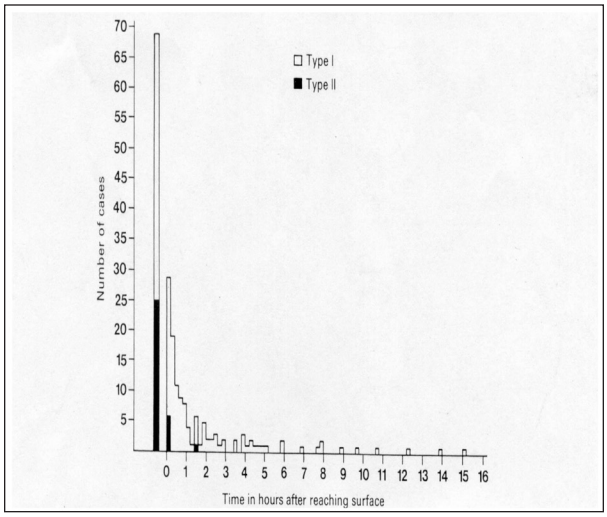


Fig 5. Decompression sickness-time of onset of cases in relation to the time of reaching surface. 196 cases from the Canadian Forces Institute of Aviation Medicine and Royal Canadian Navy Diving Establishments, July 1963 to October 1968. The cases, which occurred during decompression, are shown together before the time of surfacing.

Table 6. Kelley, Berghage and Summit. NEDU Research Report 10-68. 1968.

CUMULATIVE PERCENTAGE OF CASES HAVING ONSET OF SYMPTOMS BEFORE GIVEN TIME AFTER SURFACING FROM A DIVE				
Year		1997	1961-66	Rivera (1963)
During Dive		**11%**	**12%**	**9.1%**
	20	41%	40%	
	40	56%	50%	
1 Hr.	60	59%	56%	54.7%
	80	59%	60%	
	100	67%	61%	
2 Hr.	120	69%	65%	66.8%
	140	74%	66%	
	160	79%	68%	
3 Hr.	180	82%	71%	
4 Hr.	240	85%	78%	
5 Hr.	300	87%	84%	
6 Hr.	360	90%	90%	86.2%
	400	95%	93%	
	400	(5%) 100%	(7%) 100%	

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