A scale for evaluation of spinal cord injury

BAHRAM CHEHRAZI, M.D., FRANKLIN C. WAGNER, JR., M.D., WILLIAM F. COLLINS, JR., M.D., AND DANIEL H. FREEMAN, JR., PH.D.

Department of Surgery, Section of Neurological Surgery, and Department of Epidemiology and Public Health, Yale University School of Medicine, New Haven, Connecticut

A scale has been developed for assessment of the severity of spinal cord injury and the prognosis for recovery. Based on neurological examination, this scale employs numerical grading of selected functions below the level of the injury. The scale is adaptable to prospective as well as retrospective studies, and provides a reliable estimation of prognosis and, therefore, a means of comparing the effectiveness of differing treatment modalities.

In relation to a group of 37 patients with cervical spinal cord injury treated under one protocol and assessed within 24 hours and again at 1 year from injury, a descriptive model of the patterns of recovery has been obtained. Relative recovery of the initial deficit measured as a “percentage recovery ratio” is presented as an analytical tool for comparison of effectiveness of different methods of therapy.

KEY WORDS • spinal cord injury • spinal trauma scale • assessment and therapy • prognosis

As awareness of the potential complications of a spinal cord injury and how they may be avoided has increased, so has the number of surviving patients with spinal cord injuries. What remains unclear is how early care may have affected the restoration of neurological function. An accurate method of assessing the degree of injury and the amount of recovery would be necessary to answer this question.

As part of a prospective study of spinal cord injuries in the State of Connecticut, a system of assessment of acute spinal cord injury has been reported previously from this center. Its short-term application to 133 patients during their primary hospitalization demonstrated the significance of sensory function for recovery when a large discrepancy was noted between initial sensory and motor functions. However, the clinical application of this system is rather cumbersome, and its clinical correlation may be confusing to various observers. With that in mind, a new method has been developed for evaluating neurological function in the patient with acute spinal cord trauma. The goals in designing such a system have been accuracy in the description of neurological impairment, reproducibility by multiple examiners, and ease of data analysis. This system is based on identifying the segmental level of injury and measuring clearly defined motor and sensory responses below this level. Responses are rated numerically, and the total score indicates the degree of retained function. Each patient is then reassessed at follow-up review, and the change in neurological status over the duration of study is reflected in the patient’s score.

Clinical Material and Methods

The level of the spinal cord injury is defined as the lowest spinal cord segment with intact sensory and motor function. This level is determined when the patient is first seen and is used for all subsequent evaluations. The score assigned to each patient is determined by grading the strength of selected muscles and the intactness of certain sensory modalities below the level of injury with overall motor strength and sensory function, each having a maximum value of 5.

Ten muscles were selected for possible examination (Table 1). These 10 muscles were selected because of the ease with which their strength can be measured, the spectrum of spinal cord segments they represent, and their functional significance. In each patient the strength of the selected muscles that were innervated by segments located below the level of injury is tested separately and graded from 0 to 5. An average is then obtained by dividing the sum of the graded muscle strengths by the number of muscles tested, and is rounded off to the nearest tenth.
Spinal cord injury scale

TABLE 1
Muscles tested for evaluation of motor strength

<table>
<thead>
<tr>
<th>Action to be Tested</th>
<th>Muscles</th>
<th>Nerves</th>
<th>Cord Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>abduction of arm</td>
<td>deltoid</td>
<td>axillary</td>
<td>C-5</td>
</tr>
<tr>
<td>flexion of forearm</td>
<td>biceps</td>
<td>musculocutaneous</td>
<td>C-6</td>
</tr>
<tr>
<td>extension of forearm</td>
<td>triceps</td>
<td>radial</td>
<td>C-7</td>
</tr>
<tr>
<td>flexion of digits 2, 3, 4 &amp; 5</td>
<td>flexor digitorum superficialis &amp; profundus</td>
<td>median, ulnar</td>
<td>C-8</td>
</tr>
<tr>
<td>opposition of metacarpal of thumb</td>
<td>opponens pollicis</td>
<td>median</td>
<td>T-1</td>
</tr>
<tr>
<td>hip flexion</td>
<td>iliopsoas</td>
<td>femoral</td>
<td>L-1, L-2</td>
</tr>
<tr>
<td>knee extension</td>
<td>quadriceps femoris</td>
<td>femoral</td>
<td>L-3</td>
</tr>
<tr>
<td>dorsiflexion of foot</td>
<td>tibialis anterior</td>
<td>deep peroneal</td>
<td>L-4</td>
</tr>
<tr>
<td>dorsiflexion of big toes</td>
<td>extensor hallucis longus</td>
<td>deep peroneal</td>
<td>L-5</td>
</tr>
<tr>
<td>plantar flexion of foot &amp; big toes</td>
<td>gastrocnemius flexor hallucis longus</td>
<td>tibial</td>
<td>S-1, S-2</td>
</tr>
</tbody>
</table>

The sensory modalities of superficial pain, position sense, and deep pain are evaluated independently. Response to pinprick is graded between 0 to 2, with 0 indicating no sensation, 1 decreased or abnormal sensation, and 2 intact sensation. The average is obtained by dividing the sum of the responses in the dermatomes below the level of injury by the number of dermatomes tested and correcting to the nearest tenth. Posterior column function, as evaluated by position sense, is tested when appropriate in both the little fingers and big toes or in the big toes alone. As with superficial pain, a 0 to 2 grading system is used, and the mean is rounded off to the nearest tenth of either 2 or 4 measurements obtained. Deep pain is examined by compression of the Achilles tendon or by toe compression. A patient reporting any sensation and localizing it to the correct side receives a score of 1. If unable to do so, the patient receives a score of 0. The motor score and the three individual sensory scores are then added and the resulting number referred to as the “Yale Scale score” (Fig. 1). Each patient is thereby assigned a number ranging from 0 to 10. Zero indicates complete absence of motor and sensory function below the level of injury and 10 corresponds to intact function. Examination is repeated at the same interval from the date of injury for all patients. Comparison is made between each patient's admission and follow-up status by plotting the score at follow-up examination, for instance at 1 year, against the score on admission. In order to be able to assess the percentage of recovery of neurological deficit in each patient, a recovery ratio is constructed by dividing the actual change with time in a patient's score by the maximum improvement possible for that patient.

Application of the Scale

The method described above was applied initially to 37 patients admitted consecutively with cervical spinal cord injury and treated within 24 hours of their injuries at Yale-New Haven Medical Center between 1975 and 1978. During this period, a total of 54 patients with cervical cord injury were admitted. Of these, five had received their primary treatments elsewhere, three had only nerve root injuries, two had gunshot wounds, four died within 1 year, two were lost to follow-up review, and one patient was a “treatment failure;” all these were excluded from the series. The treatment of the remaining 37 patients with acute spinal cord injuries and fracture dislocations of the spine consisted of an immediate attempt at decompression of the spinal cord by alignment of the spinal column with skeletal traction. If this was not achieved within 1 hour, or if myelography demonstrated continued compression of the spinal cord, surgical decompression was carried out. In the patient who was excluded as a “treatment failure,” decompression with traction was unsuccessful, and she was not an operative candidate. This patient continued to have evidence of cord compression and showed little improvement. All patients were rated on admission and at 1 year ± 2 months after injury. No patient deteriorated. Nine patients had “acute complete” cord lesions, and it is of note that all nine patients had scores of less than 2 on admission and experienced little improvement.

Data Analysis

Analysis of scores at 1 year based on the value of the admission scores and the type of lesion as “complete” or “incomplete” was performed. The 1-year scores were regressed on the admission scores using ordinary least-squares procedure. Since the presence of a “complete” lesion was included in the analysis model, the technique is commonly referred to as analysis of covariance. Formally, the model may be written as the following equation:

$$Y = B_0 + B_1L + B_2X + B_3LX + E.$$  (1)
Here $Y$ is the score at 1 year, $X$ is the score at admission; $L = 1$ if the lesion is complete, $L = 0$ otherwise. The $B_i$'s ($i = 0, 1, 2, 3$) are called “parameters” of the model. These are generally estimated from the data using the method of ordinary least squares. The $E$ represents an unobservable error term about which the usual assumptions are made. \(^{10}\)

In this model, several hypotheses of interest may be tested by setting the individual $B_i$'s equal to 0. Specifically, $B_3 = 0$ would indicate that the effect of initial score is similar among the patients and independent of the type of lesions. Setting $B_2 = 0$ indicates lack of relationship between the admission score and the follow-up score, while the hypothesis that $B_1 = 0$ corresponds to lack of any difference between lesion type with respect to follow-up score.

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**Table 2**

**Analysis of covariance for Yale Scale at 1 year**

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>Fisher’s F-test</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>model</td>
<td>2</td>
<td>391.69</td>
<td>195.85</td>
<td>569.34</td>
<td>0.0001</td>
</tr>
<tr>
<td>lesion ($B_1$)</td>
<td>1</td>
<td>117.04</td>
<td>117.04</td>
<td>340.23</td>
<td>0.0001</td>
</tr>
<tr>
<td>admission score ($B_2$)</td>
<td>1</td>
<td>7.41</td>
<td>7.41</td>
<td>340.23</td>
<td>0.0001</td>
</tr>
<tr>
<td>error</td>
<td>34</td>
<td>11.70</td>
<td>0.34</td>
<td></td>
<td></td>
</tr>
<tr>
<td>nonparallelism ($B_3$)</td>
<td>1</td>
<td>0.09</td>
<td>0.09</td>
<td>0.27</td>
<td>0.6068</td>
</tr>
<tr>
<td>residual</td>
<td>33</td>
<td>11.60</td>
<td>0.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>36</td>
<td>403.39</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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**Fig. 1.** Yale Scale for spinal cord trauma.
Spinal cord injury scale

<table>
<thead>
<tr>
<th>Source</th>
<th>Degrees of Freedom</th>
<th>Sum of Squares</th>
<th>Mean Square</th>
<th>Fisher's F-test</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>model</td>
<td>2</td>
<td>35631.85</td>
<td>17815.93</td>
<td>111.50</td>
<td>0.0001</td>
</tr>
<tr>
<td>lesion (B₁)</td>
<td>1</td>
<td>11619.34</td>
<td>11619.34</td>
<td>72.72</td>
<td>0.0001</td>
</tr>
<tr>
<td>admission score (B₂)</td>
<td>1</td>
<td>285.45</td>
<td>285.45</td>
<td>1.79</td>
<td>0.1905</td>
</tr>
<tr>
<td>error</td>
<td>33</td>
<td>5272.75</td>
<td>159.78</td>
<td></td>
<td></td>
</tr>
<tr>
<td>non-parallelism (B₃)</td>
<td>1</td>
<td>95.37</td>
<td>95.37</td>
<td>0.59</td>
<td>0.4481</td>
</tr>
<tr>
<td>residual</td>
<td>32</td>
<td>5177.38</td>
<td>161.79</td>
<td></td>
<td></td>
</tr>
<tr>
<td>total</td>
<td>35</td>
<td>40904.60</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

All analyses were performed using the general linear model procedure of the computer package SAS.

The statistical summary is shown in Table 2, where the model sum of squares (391) divided by the total sum of squares (403) indicates that the model explains 97.1% of variation in the scores at 1 year. Both parameters for the lesion type (B₁), and the admission score (B₂), were highly significant, p = 0.0001. It was noted that the effect of admission score was the same for both types of lesion, B₂ = 0. Finally, the procedure for least-squares estimation allowed the Yale Scale model to be written as YSS₁ = 7.67 – 6.31(L) + 0.24 (YSS₀) for this group of patients, with L = 0 for “incomplete” and L = 1 for “complete” lesions. The regression line and the 95% confidence limits were constructed on the data as shown in Fig. 2.

In order to relate the amount of recovery to the amount of functional loss due to injury, a recovery ratio was constructed in which actual change in score (YSS₁–YSS₀) was divided by the maximum improvement possible for each patient (10–YSS₀). The result was then multiplied by 100 to yield a percentage. A similar analysis of covariance for the percentage recovery ratio at 1 year (Table 3) demonstrated that Equation 1 accounts for 87.3% of the variation in the recovery ratio. Again, it was noted that the lesion types of interest, namely the complete or incomplete lesions, which corresponded to admission scores of below or above 2 were highly significant in predicting the outcome. As can be seen in Fig. 3, a graph of percentage recovery ratio (% RR) versus admission score (YSS₀), patients with initial scores of 2 or less demonstrated a mean recovery of 6% as compared to

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**FIG. 2.** Graph showing the relationship between admission scores (YSS₀) and scores at 1 year after injury (YSS₁). Circles are scores of individual patients. Line of least squares and the 95% confidence limits are drawn in heavy and light lines, respectively.

**FIG. 3.** Graph showing the relationship between admission scores (YSS₀) and percentage recovery ratios (% RR). Circles represent individual patients. The 95% confidence limits (light lines) of the line of least squares (heavy lines) are so wide that a significant relationship between admission score and the recovery ratio is not shown.

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the remainder of the group with mean recovery of 80%. The relative recovery of deficit (percentage recovery ratio), however, showed no statistically significant dependence on the value of the admission score for patients within the two lesion types examined. The prediction equation for this group of patients was given by the equation

\[ \%RR = 70.21 - 64.40(L) + 1.61(YSS_o). \]  

Here \( B_2 = 1.61 \) and is not statistically significant. Again, \( L = 0 \) for “incomplete” and \( L = 1 \) for “complete” lesions.

**Discussion**

A variety of methods have been employed previously for the purpose of assessing the patient with a spinal cord injury and evaluating the usefulness of various modes of therapy. In general, these methods have placed patients into categories on the basis of their neurological signs and/or functional capabilities. When reviewing these studies, determining the precise neurological status of the patient is often difficult. Furthermore, the tendency for spontaneous improvement after spinal cord trauma and selection of arbitrary categories to fit the available data in retrospective studies has made it hard to compare the effectiveness of various treatments with any degree of certainty.

An acute complete spinal cord injury is a well defined category. It would seem possible to readily compare the outcome in this group of patients. Most investigators, however, have noted little recovery in these patients regardless of mode of therapy. Patients with partial lesions have been regarded as having the best outlook for neurological recovery. However, the concept of partial sensory motor paralysis covers a wide range of neurological function. Attempts to fit this continuum into discrete categories has resulted in artificial and indistinct boundaries. Heiden, et al.,

Classifications that have been based on the presumed strength and direction of the force of injury or the pattern of skeletal injury have, in general, been limited in predicting neurological function and recovery.

Attempts to classify patients according to various traumatic syndromes with emphasis on the anatomical pattern of injury as in the central cervical cord, the anterior cervical cord, and the Brown-Séquard syndromes appear to have three drawbacks: 1) the degree of damage is not controlled for, other than in a descriptive manner; 2) individual patients may demonstrate fragments of a number of syndromes; and 3) a patient’s disorder may resolve into a syndrome other than what he presented.

Classifications in which only a portion of the neurological examination, such as the motor strength, is evaluated have been presented. Although these methods have simplified neurological assessment, it has been pointed out that other aspects of neurological status, such as the sensory function, may have more significant correlation with prognosis.

Methods that assess functional capabilities tend to rely on descriptive categories that may be unclear, such as “community walker.” Patients with similar capabilities, but with differing neurological signs, tend to be placed in the same groups, resulting in lessened likelihood of demonstrating effectiveness of a particular treatment. Furthermore, the emphasis on ambulation in grading of patients has resulted in underestimating the deficits of patients with “central cord” syndrome, and is confounded by the effects of physical therapy and rehabilitation, especially since patients with acute injury are not tested for ambulation during the initial evaluation. In the present model, a comparison of scores at a specified interval with initial scores enables a recovery line to be constructed. Patients treated in different ways may then be compared by superimposing their lines of recovery. There seems to be a correlation between the initial and the follow-up scores. As has been surmised previously, patients with less initial neurological deficit appear to do better. Whether these patients actually recover a greater percentage of their deficit than the patients with lower initial scores is uncertain. The recovery ratio, as originally used by Lucas and Ducker and employed by us, is an attempt to address this question. The finding of no statistically significant difference in recovery ratio in the present study between patients with initially high scores and those with intermediate scores suggests that these patients have a similar potential for recovery. Lucas and Ducker, however, considered only the motor function above and below the level of injury, whereas, in this study, both the sensory and motor function below the level of injury were measured. The calculation of recovery ratio on the basis of function above and below the level of injury makes the outcome dependent on the level of injury.

The preliminary application of the Yale Scale has generated a descriptive model in which the type of lesion (\( YSS_o < 2 \) compared with \( YSS_o > 2 \)) is important in predicting both actual and relative recovery of neurological deficit. Furthermore, the initial score is of significant value in predicting actual score at 1 year for each lesion type. The relative recovery of neurological deficit, however, is independent of this initial score for scores of greater than 2.

Whether the recovery from the initial neurological deficit as measured by the recovery ratio is a more sensitive and accurate way of determining the effects of different methods of treatment will require further testing.
References


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Address reprint requests to: Bahram Chehrazi, M.D., Section of Neurological Surgery, Yale University School of Medicine, New Haven, Connecticut 06510.