Motor and Sensory Recovery Following Incomplete Tetraplegia

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Fifty individuals with incomplete tetraplegia due to trauma underwent serial prospective examinations to quantify motor and sensory recovery. None of 5 patients who were motor complete with the presence of sacral (S4-S5) sharp/dull touch sensation unilaterally recovered any lower extremity motor function. However, in 8 motor complete subjects having bilateral sacral sharp/dull sensation present, the mean lower extremity motor score increased to 12.1 ± 7.8 at 1 year. In 3 of the 8 cases, functional (≥3/5) recovery was seen in some muscles at 1 year. Though mean upper and lower extremity ASIA Motor Scores increased significantly (p < .001) between 1 month and 1 year for the entire sample, the annualized rate of motor recovery rapidly declined in the first 6 months and then subsequently approached plateau. Eighty-seven percent (20 of 23) of patients having a lower extremity motor score ≥ 10 at 1 month were community ambulators using crutches and orthoses at 1 year follow-up.

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In 1985, the Rancho Spinal Cord Injury Database was established to prospectively collect neurologic information on motor and sensory recovery following SCI. This is the fifth in a series of reports derived from a long-term, prospective study of the magnitude and rate of motor and sensory recovery, and the clinical predictors for functional motor recovery in individuals with traumatic SCI. The first report established a definition of complete injury for SCI. The second reported on recovery in patients with complete paraplegia, the third reported on complete tetraplegic patients, and the fourth reported on persons with incomplete paraplegia. This report describes the outcomes for patients who presented with incomplete tetraplegia upon admission to rehabilitation; it compares these findings to previously reported results.

METHODS

Examinations for motor and sensory function were performed on 50 consecutive patients with traumatic SCI who were admitted to Rancho Los Amigos Medical Center between 1985 and 1990. None of the patients had received methylprednisolone according to the regimen recommended by Bracken and colleagues. The Sacral Spared definition was used to define the completeness of injury.

Neurological examinations were performed upon admission, and subsequent examinations were repeated monthly and then annually from the patient’s date of injury by one examiner (JY). Each patient’s radiographs (plain films, computed tomography and magnetic resonance imaging where appropriate) were also examined to classify fracture type and bullet location in gunshot wound injuries.

The motor and sensory examinations were performed according to the Standards of the American Spinal Injury Association. The ASIA Motor Index Score uses standard manual muscle testing on a six grade scale. The key lower extremity muscles representing the five consecutive segments between C5 and T1 are elbow flexors, wrist extensors, elbow extensors, finger flexors, and hand intrinsics. The total possible bilateral upper extremity motor score (UEMS) is 50 points. The key lower extremity muscles representing the 5 consecutive neural segments between L2 and S1 included in the ASIA Motor Score are hip flexors, knee extendors, ankle dorsiflexors, long toe extensors, and ankle plantar flexors. The total lower extremity motor score (LEMS) is 50 points.

Both light touch and sharp/dull (pin prick) discrimination were tested for each sensory dermatome and graded on a three-point scale (Absent = 0; Impaired = 1; and Normal = 2). Numerically, the sensory scores total 116 points each for light touch and sharp/dull discrimination.

Although one examiner performed all examinations, inter-rater reliability between the primary examiner and back-up examiners was assessed periodically as a quality assurance measure for consistency and as a precautionary measure in the event that a back-up examiner might be required. Overall reliability for motor examinations was r = .99 for sharp/dull and light touch discrimination, the reliability figures were .94 and .93, respectively. In each instance the correlations were highly significant (p < .001).

The annualized rate of recovery was calculated by dividing the amount of recovery between two successive examinations by the time interval (days) between the examinations in order to quantify recovery per day. The resulting figure was multiplied by 365 to express the rate of recovery during a particular interval that would have been expected if it were
to have continued for 1 year. Measures of central tendencies, frequency distributions, and cross-tabulations were conducted to summarize attributes of the sample.

The scales of measurement used to assess both motor and sensory function are ordinal rather than true interval scales. Nevertheless, it has become common practice to apply parametric statistics to these scales, for example, in the methylprednisolone study conducted by Bracken. Although the use of parametric techniques with ordinal scales remains controversial, it is appropriate if the nature of the data and research process are kept in perspective.

RESULTS

First year annual examinations were performed on the 50 patients. Second year annual examinations were performed on 16, third year annual examinations on 8, fourth year examinations on 5, and fifth year examinations on 1 patient. This analysis was restricted to results at the first and second annual follow-up points because of the limited sample currently available with follow-up beyond 2 years.

The mean age of the total sample (41 men and 9 women) was 32.2 ± 11.1 years at the time of injury (range, 18 to 59 years). The average time from injury to admission was 27.4 ± 17.1 days (range, 7 to 64 days). Twenty-six percent of the injuries (13 cases) were the result of penetrating injuries (11 gunshot wounds and 2 stabs). The remaining 37 cases were caused by motor vehicle accidents (16 cases), motorcycle accidents (4 cases), falls (9 cases), and other causes (8 cases).

In 9% (1 case) of gunshot wound injuries, the bullet traversed and lodged outside the canal; in 64% (7 cases) the bullet never entered the canal, and in 18% (2 cases) the bullet remained within the canal. In one case bullet excursion could not be verified radiographically. The bullets were removed in both cases where they had lodged in the spinal canal.

In nonpenetrating injuries, a distractive flexion mechanism accounted for 29% (11 cases), compressive flexion for 21% (8 cases), vertical compression for 8% (3 cases), compressive extension for 5% (2 cases) and distractive extension for 3% (1 case). Eleven percent (4 cases) could not be classified and an additional 24% (9 cases) were associated with spondylosis. Of the cases with nonpenetrating injuries, 32% (12 cases) underwent surgery for spinal fusion only, 3% (1 case) had spinal fusion and decompression procedures, 11% (4 cases) had anterior decompression without fusion, and 11% (4 cases) had laminectomy. Seventy-three percent of all injuries (27 cases) had no surgical intervention.

Neurologic Level of Injury

The NLI on admission ranged from C3 to C7. There were 24 cases with examinations at 30 days as well as examinations prior to 30 days. The average number of days from injury to examination for these earlier admissions was 12.3 ± 4.3 days (range, 7 to 21 days). In 83% (20 cases) of these cases, there was no change in NLI between the initial (<30 days) and 30 day postinjury point, in 3 cases the NLI improved by one level, and in 1 it improved by three levels.

There were 42 cases with both 30 day and 1 year postinjury examinations. In 69% (29 patients) of the these cases, the initial NLI did not change at first annual follow-up. Twenty nine percent (12 patients) had one level NLI change, and 2% (1 case) gained two levels from the initial NLI. There were 16 cases for which 1- and 2-year examinations were available. In one of these cases the NLI improved by one level; however, the rest remained unchanged with regard to NLI.

In 5 of 8 cases that had an initial examination at 60 days and a 1 year follow-up examination, the NLI remained the same at 1 year as it was at 60 days; in 2 cases it improved one level, and in 1 case it improved two levels. Altogether 66% (33 cases) showed no improvement in NLI from the 30 or 60 day examination to 1- or 2-year follow-up examination.

Motor Complete Sensory Incomplete (Frankel B) Cases

There were 13 patients having zero lower extremity motor function 1 month after injury with NLIs from C3 to C6. In five, light touch sensation was present but bilateral sharp/dull sensation absent at the S4-S5 dermatome and remained so throughout follow-up. None of these five experienced any lower extremity motor recovery. In the following assessment of lower extremity motor score recovery these five cases are excluded from analysis.

All of the remaining 8 cases who were initially motor complete but retained presence of bilateral S4-S5 sharp/dull sensation experienced some lower extremity motor recovery. In 3 of the 8 cases, functional (≥3/5) recovery was seen in some muscles at 1 year. The mean LEMS at 1 year was 12.1 ± 8.3 (range, 1 to 26 points). Thus, a zero LEMS in an incomplete SCI patient 1 month after injury is not an absolute indicator of poor motor recovery if bilateral sharp/dull sensation at S4-S5 is present.

Upper Extremity Motor Recovery

UEMS recovery is shown in figure 1. Most recovery occurred in the first 6 months after injury. The rate of recovery was highest during the first 3 months after injury and approached plateau in the second half year interval following injury (fig 2). Variance in the rate of recovery was also greatest during the initial measurement intervals. The following equation characterizes the curve ($r^2 = .94$) for the annualized upper extremity rate of motor recovery:

$$\text{UEMS} = k \times (1 - e^{-t/r})$$

where $k$ is the maximum upper extremity rate of motor recovery, $t$ is the time in months, and $r$ is the rate constant. The rate constant $r$ is estimated to be 3.3 months for the time interval following injury.
Motor recovery rate = \((14.19 - 2.07 \ln(t))^2\) (Eq 1)

where \(t\) is the time (days) since injury.

To further assess the amount of motor recovery and to determine whether initially spared motor function influenced recovery, subjects were partitioned in five groups based on the initial UEMS: 0, 1-9, 10-19, 20-29 and \(\geq 30\) points (table 1). The five patients lacking S4-S5 sharp/dull sensation and having no motor recovery were excluded from this analysis.

Between 1 month and 1 year, there was a significant (\(p < .001\)) change in the UEMS across all groups averaging 10.6 ± 6.9 points. In addition, the groups partitioned by 1 month UEMS differed significantly in the amount of change averaging 9.2 ± 5.0, 9.3 ± 6.2, 14.5 ± 7.2, 10.7 ± 5.0 and 4.0 ± 4.0 points, respectively (\(p < .02\)). However, post hoc analysis revealed the only truly significant difference occurred when those who had an initial UEMS between 10 and 19 points were compared to those who had an initial score \(\geq 30\). In this regard the difference may be due to ceiling effect pertaining to the latter group. Although most cases with second year follow-up underwent further motor change between the first and second year postinjury, the amount of recovery in LEMS was small, 1.8 ± 3.1 points, and not significant in relation to the amount observed in the first year.

Figure 1 depicts lower extremity motor recovery as a function of time since injury. The motor recovery curves for the upper and lower extremities were approximately the same and did not differ significantly.

The rate of lower extremity recovery is depicted in figure 2. As with the upper extremities (fig 3), the rate of recovery was highest during the first 3 months after injury and leveled off in the second half year interval following injury with variance in the rate of recovery also greatest during the initial measurement intervals. The following equation characterizes the curve (\(r^2 = .92\)) for the annualized lower extremity rate of motor recovery:

Motor recovery rate = \((13.68 - 1.98 \ln(t))^2\) (Eq 2)

where \(t\) is the time (days) since injury

**Lower Extremity Motor Recovery**

As with the assessment of UEMS, subjects were partitioned in five groups based on the initial LEMS: 0, 1-9, 10-19, 20-29 and \(\geq 30\) points (table 2). Between 1 month and 1 year, there was a significant (\(p < .001\)) change in the LEMS across all groups averaging 13.5 ± 7.0 points. However, the groups partitioned by 1 month LEMS did not differ significantly in the amount of change averaging 12.1 ± 8.3, 15.6 ± 8.0, 15.4 ± 6.3, 11.4 ± 4.4, and 9.9 ± 4.2 points, respectively. Nevertheless, the lowest amount of change was seen in the group with the highest initial scores as it was in the assessment of UEMS. As with UEMS, although most cases with second year follow-up underwent further motor change between the first and second year postinjury, the amount of recovery in LEMS was small, 1.8 ± 3.1 points, and not significant in relation to the amount observed in the first year.

**Table 1: Upper Extremity Motor Scores**

<table>
<thead>
<tr>
<th>Initial Range</th>
<th>1 Year Range</th>
<th>Initial Mean</th>
<th>1 Year Mean</th>
<th>Initial to 1 Year Mean Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>2-14</td>
<td>0</td>
<td>9.2 ± 5.0</td>
<td>9.2 ± 5.0</td>
</tr>
<tr>
<td>2-8</td>
<td>4-22</td>
<td>4.0 ± 2.1</td>
<td>13.3 ± 7.0</td>
<td>9.2 ± 6.2</td>
</tr>
<tr>
<td>10-18</td>
<td>14-40</td>
<td>13.5 ± 3.5</td>
<td>28.0 ± 6.8</td>
<td>14.5 ± 7.2</td>
</tr>
<tr>
<td>20-28</td>
<td>26-40</td>
<td>24.0 ± 4.0</td>
<td>34.7 ± 7.6</td>
<td>10.7 ± 5.0</td>
</tr>
<tr>
<td>30-40</td>
<td>36-50</td>
<td>36.3 ± 4.3</td>
<td>40.3 ± 5.1</td>
<td>4.0 ± 4.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>13.2 ± 11.9</td>
<td>23.8 ± 12.3</td>
<td>10.6 ± 6.9</td>
</tr>
</tbody>
</table>

**Lower Extremity Motor Scores**

<table>
<thead>
<tr>
<th>Initial Range</th>
<th>1 Year Range</th>
<th>Initial Mean</th>
<th>1 Year Mean</th>
<th>Initial to 1 Year Mean Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>1-26</td>
<td>0</td>
<td>12.1 ± 8.3</td>
<td>12.1 ± 8.3</td>
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<tr>
<td>1-8</td>
<td>9-36</td>
<td>4.6 ± 2.0</td>
<td>20.2 ± 8.7</td>
<td>15.6 ± 8.0</td>
</tr>
<tr>
<td>10-19</td>
<td>23-40</td>
<td>12.5 ± 2.8</td>
<td>30.9 ± 5.5</td>
<td>18.4 ± 6.5</td>
</tr>
<tr>
<td>20-29</td>
<td>31-40</td>
<td>23.6 ± 3.9</td>
<td>35.0 ± 4.3</td>
<td>11.4 ± 4.4</td>
</tr>
<tr>
<td>30-40</td>
<td>39-50</td>
<td>34.3 ± 4.4</td>
<td>44.1 ± 5.5</td>
<td>9.9 ± 4.2</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>13.0 ± 12.5</td>
<td>26.5 ± 12.9</td>
<td>13.5 ± 7.0</td>
</tr>
</tbody>
</table>

**Figure 3**—Annualized upper extremity recovery rates: motor function, light touch and sharp/dull sensation. - , motor; - , Sharp/dull; X, light touch.
of the 15 patients with a LEMS equal to or greater than 20 points at 1 month. Ambulation status closely correlated with the 1 year LEMS scores, which averaged 9.7 ± 8.2 for nonambulators, 25.6 ± 5.1 for household ambulators, and 36.9 ± 7.6 for community ambulators with a significant difference between the means of the three groups (p < .0001).

Ambulation success depended not only on the LEMS but also on the UEMS. When partitioned according to their ambulation status, patients able to ambulate on a household or community ambulation basis had a higher (p < .0005) mean UEMS than nonambulators, which signifies the importance of upper extremity strength and crutch use in ambulation success (table 5). Overall the UEMS averaged 16.1 ± 9.6 for nonambulators, 22.3 ± 9.6 for household ambulators and 30.3 ± 10.8 for community ambulators.

Sensory Recovery

Average sharp/dull and light touch score changes between 1 month and 1 year were 3.0 and 2.9, respectively, for the upper extremity and 3.0 and 5.0 for the lower extremity. The shapes of the annualized rate of recovery curves for sharp/dull and light touch sensation and motor function are similar, the rate of recovery being highest in the first months after injury and subsequently reaching a plateau prior to the second year postinjury. However, the rate for both types of sensation levels off much earlier than the rate for motor recovery at about 3 months after injury (fig 4).

DISCUSSION

Forty-six percent of the incomplete tetraplegic patients recovered sufficient upper and lower extremity strength to reciprocally ambulate in the community using conventional orthoses and crutches. In contrast, 6/6% of incomplete paraplegic patients reported previously achieved community ambulation status; whereas only 5% of the complete paraplegic

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**Table 3: Upper Extremity Muscles (Elbow Flexors, Wrist Extensors, Elbow Extensors, Finger Flexors, Intrinsic)**

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>One month</td>
<td>0</td>
<td>85</td>
<td>44</td>
<td>19</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>10</td>
<td>28</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>15</td>
<td>14</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>12</td>
<td>85</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>≥4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>41</td>
</tr>
<tr>
<td>Total</td>
<td>85</td>
<td>51</td>
<td>29</td>
<td>80</td>
<td>175</td>
</tr>
</tbody>
</table>

muscles (29 of 29) that were 2/5 at 1 month recovered ≥3/5 at 1 year (table 3). Seventy-three percent (45 of 62) of muscles which were 1/5 at 1 month recovered ≥3/5 at 1 year. Of those muscles that were 0/5 at 1 month, 54% (100 of 185) recovered some volitional control (≥1/5) but only 20% (37 of 185) recovered to ≥3/5.

The chance for lower extremity recovery to ≥3/5 strength followed a similar pattern. Ninety-seven percent of lower extremity muscles (28 of 29) that were 2/5 at 1 month recovered ≥3/5 at 1 year (table 4). Seventy-seven percent (59 of 77) of muscles that were 1/5 at 1 month recovered ≥3/5 at 1 year. Of those muscles that were 0/5 at 1 month, 64% (125 of 196) recovered some volitional control (≥1/5) but only 24% (48 of 196) recovered to ≥3/5.

**Ambulation**

Forty-six percent of patients (23 of 50 cases) were able to ambulate in the community at 1 year follow-up. All patients used a reciprocal gait. Seven walked with bilateral knee-ankle-foot-orthoses (KAFO); 3 walked with a combination of one KAFO and one ankle-foot orthosis (AFO); 3 with one AFO; and 10 ambulated without lower extremity devices.

Seven patients were limited household ambulators. Five wore bilateral AFOs; 1 walked with a combination of one KAFO and one AFO; one walked with bilateral AFOs; and one with one AFO.

The initial ASIA LEMS closely correlated with ambulation status at 1 year. Of the 13 patients with a zero LEMS at 1 month, none achieved community ambulation status at 1 year. Reciprocal gait pattern and community ambulation status were achieved at 1 year by 21% or 3 of 14 patients with a LEMS of 1 to 9 at 1 month; by 63% or 5 of 8 patients with a LEMS between 10 and 19 at 1 month; and by 100% of the 15 patients with a LEMS equal to or greater than 20 points at 1 month. Ambulation status closely correlated with the 1 year LEMS scores, which averaged 9.7 ± 8.2 for nonambulators, 25.6 ± 5.1 for household ambulators, and 36.9 ± 7.6 for community ambulators with a significant difference between the means of the three groups (p < .0001).

Ambulation success depended not only on the LEMS but also on the UEMS. When partitioned according to their ambulation status, patients able to ambulate on a household or community ambulation basis had a higher (p < .0005) mean UEMS than nonambulators, which signifies the importance of upper extremity strength and crutch use in ambulation success (table 5). Overall the UEMS averaged 16.1 ± 9.6 for nonambulators, 22.3 ± 9.6 for household ambulators and 30.3 ± 10.8 for community ambulators.

**Sensory Recovery**

Average sharp/dull and light touch score changes between 1 month and 1 year were 3.0 and 2.9, respectively, for the upper extremity and 3.0 and 5.0 for the lower extremity. The shapes of the annualized rate of recovery curves for sharp/dull and light touch sensation and motor function are similar, the rate of recovery being highest in the first months after injury and subsequently reaching a plateau prior to the second year postinjury. However, the rate for both types of sensation levels off much earlier than the rate for motor recovery at about 3 months after injury (fig 4).
The effective use of upper extremity assistive devices in complete tetraplegia when compared to the ambulation rate patients attained community ambulation status (table 6). The effective use of upper extremity assistive devices in persons with incomplete tetraplegia depends on strong upper extremity assistive devices, thus accounting for the lower community ambulation rate among persons with incomplete tetraplegia when compared to the ambulation rate for patients with paraplegia.

Neurologic recovery following a spinal cord injury involves many physiologic responses. Resolution of cord edema may account for rapid reversal of conduction block and the neurologic recovery often noted immediately following injury. Stretch or contusion of nerve roots may result in neuropraxia rendering viable axons temporarily unable to transmit nerve impulses. More severe nerve root injury may cause axonotmesis, implying loss of axon continuity at the site of injury; the endoneurial tubes, however, remain intact although Wallerian degeneration occurs distal to the injury. In this situation the time needed for functional recovery depends on the time needed for the axons to regenerate from the site of injury to the target muscle. The most severe injury, neurotmesis, implies complete severance of the nerve and destruction to the extent that the axon, endoneurial tube, and connective tissue structures are totally disorganized at the site of injury and regeneration does not customarily occur. In practice, most injuries are of a mixed character. Because recovery of neuropraxia usually occurs before the sixth week postinjury and axonal regeneration would not be expected before 12 months, Ditunno and associates suggested muscle fiber hypertrophy and peripheral sprouting of nerve fibers as major factors in improved strength following complete tetraplegia.

If axonal regeneration of descending corticospinal tracts plays a major role in motor recovery in patients with incomplete tetraplegia, UEMS motor recovery would precede LEMS recovery and was greatest in the first months after injury (figs 3, 4). From these observations, we conclude axonal regeneration of upper motor neurons did not play a major role in neurologic recovery.

A focal spinal cord conduction block is consistent with the rapid early neurologic recovery in both the upper and lower extremities. This hypothesis assumes some axons in ascending and descending upper and lower motor neuron tracts remain viable at the site of injury but become focally nonconductive. An upper motor neuron conduction block is analogous to recovery of neuropraxia following a peripheral nerve injury except that it involves upper motor neurons instead of lower motor neurons. Later reversal of focal nonconductivity at the site of cord injury would account for the simultaneous return of upper and lower extremity motor and sensory function following incomplete tetraplegia. This hypothesis would also explain why the pattern of LEMS recovery for incomplete tetraplegics follows the same course as for incomplete paraplegics with upper motor neuron injury above T12 (fig 5).

Bunge and colleagues performed detailed histopathologic analyses of spinal cords following traumatic spinal cord injury. Using silver-staining methods, they identified surviving demyelinated axons in the lateral columns of the white matter that could be differentiated from axons that were demyelinated and undergoing Wallerian degeneration secondary to axonal necrosis. Because demyelinated axons are unable to conduct, Bunge postulated that remyelination of focally demyelinated viable axons could account for recovery of conductivity and function. Other physiologic mechanisms could also contribute to reversal of focal nonconductivity.

Terminal axonal sprouting and hypertrophy of partially innervated muscle may also account for parallel UEMS and LEMS motor recovery following incomplete tetraplegia. However, a comparison of UEMS recovery in complete and incomplete tetraplegics leads to the conclusion that reversal of focal nonconductivity plays at least as important a role for the following reasons. UEMS recovery for incomplete tetraplegics was approximately twice as great as for previously reported complete tetraplegics even though the 1-year follow-up ambulation status (table 6).

### Table 6: 1 Year Follow-Up Ambulation Status

<table>
<thead>
<tr>
<th>Lower Extremity ASIA Motor Score (initial)</th>
<th>Community Ambulation Status (1 year)</th>
<th>Complete Paraplegia</th>
<th>Incomplete Paraplegia</th>
<th>Incomplete Tetraplegia</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&lt;1%</td>
<td>33%</td>
<td>0%</td>
<td></td>
</tr>
<tr>
<td>1-9</td>
<td>45%</td>
<td>70%</td>
<td>21%</td>
<td></td>
</tr>
<tr>
<td>10-19</td>
<td>100%</td>
<td>63%</td>
<td>n = 3/14</td>
<td></td>
</tr>
<tr>
<td>≥20</td>
<td>100%</td>
<td>100%</td>
<td>n = 5/5</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>5%</td>
<td>76%</td>
<td>46%</td>
<td></td>
</tr>
</tbody>
</table>

Data for complete and incomplete paraplegics from Waters and coworkers.2,4

![Mean ASIA Motor Score](image_url)
month UEMS was higher in the latter group (fig 6). Furthermore, among patients with complete tetraplegia, most motor and sensory recovery only occurred within the zone of injury immediately below the neurologic level of injury. Finally, if reversal of focal nonconductivity played a significant role in UEMS recovery in complete tetraplegics, it is logical to conclude that it would play a similar role in LEMS recovery. It did not, however, because only 10% of the patients with complete tetraplegia at 1 month regained any lower extremity function, and in this subset, the average LEMS at 1 year was only 2.5 points.

Lastly, it is a common practice to group data on motor recovery by combining results of patients who are motor and sensory complete (Frankel A) with patients who are motor complete but sensory incomplete (Frankel B). However, Frankel B tetraplegic patients had greater UEMS recovery than the Frankel A tetraplegic patients reported upon previously. Also, although LEMS recovery was the same in Frankel A and B tetraplegics patients who lacked bilateral sacral pin sensation (S4, S5), Frankel B patients with bilateral pin sensation had greater LEMS recovery than Frankel A patients. Our findings support the findings of Crozier and colleagues who reported that patients with preserved sacral pin sensation had a significantly better prognosis for LE motor recovery and subsequent ambulation that those lacking sacral pin sensation. We conclude Frankel B patients should not be grouped with Frankel A patients when assessing or anticipating motor recovery.

References