Late Neurologic Recovery After Traumatic Spinal Cord Injury

Steven Kirshblum, MD, Scott Millis, PhD, William McKinley, MD, David Tulsky, PhD

ABSTRACT. Kirshblum S, Millis S, McKinley W, Tulsky D. Late neurologic recovery after traumatic spinal cord injury. Arch Phys Med Rehabil 2004;85:1811-7.

Objective: To present Model Spinal Cord Injury System (MSCIS) data on late neurologic recovery after 1 year after spinal cord injury (SCI).

Design: Longitudinal study of neurologic status as determined by annual evaluations at 1 and 5 years postinjury.

Setting: MSCIS centers contributing data on people with traumatic SCI to the National Spinal Cord Injury Statistical Center database.

Participants: People with traumatic SCI (N=987) admitted to an MSCIS between 1988 and 1997 with 1- and 5-year follow-up examinations.

Interventions: Not applicable.

Main Outcome Measures: American Spinal Injury Association (ASIA) Impairment Scale (AIS) classification, motor index scores (MIS), motor level, and neurologic level of injury (NLI), measured and compared for changes over time.

Results: The majority of subjects (94.4%) who had a neurologically complete injury at 1 year remained complete at 5 years postinjury, with 3.5% improving to AIS grade B, and up to 1.05% each improving to AIS grades C and D. There was a statistically significant change noted for MIS. There were no significant changes for the motor level and NLI over 4 years; however, approximately 20% of subjects improved their motor level and NLI. People with complete and incomplete injuries had similar improvements in motor level, but subjects with an incomplete injury had a greater chance of improvement in NLI and MIS.

Conclusions: There was a small degree of neurologic recovery (between 1 and 5y postinjury) after a traumatic SCI. Late conversion, between 1 and 5 years, from a neurologically complete to an incomplete injury occurred in 5.6% of cases, but in only up to 2.1% was there a conversion from motor complete to motor incomplete status. Limitations of this study included changes in the ASIA classification during the study and in the intra- and interrater reliability typically seen in longitudinal studies of the ASIA standards. Functional changes were not studied. Knowledge of the degree of late recovery may help in analyzing newer interventions to enhance recovery.

Key Words: Neurologic disorders; Recovery of function; Rehabilitation; Spinal cord injuries.

THE ABILITY TO PREDICT the extent of neurologic recovery after a traumatic spinal cord injury (SCI) is extremely important. This knowledge can help determine the effectiveness of various interventions in the acute and chronic period, such as pharmacologic or rehabilitation treatment protocols, and it can help clinicians develop a realistic rehabilitation program.[1] In recent years, our knowledge of the course of neurologic recovery has increased to where it is now possible to predict, within a week of injury, the recovery of arm and leg strength in the early years postinjury.[2,3] The most accurate method used to predict such recovery is to perform a standardized physical examination early after injury, utilizing the *International Standards for Neurologic Classification of Spinal Cord Injury*.[4] This examination makes it possible for clinicians to classify the degree of impairment and it is used by the Model Spinal Cord Injury Systems (MSCIS) database.[5]

During the past half-century, people with SCI have been given hope for long-term survival. With improved acute and chronic medical management, as well as therapeutic and rehabilitation techniques, life expectancy and functional integration into the community have markedly improved. Newer pharmacologic and surgical interventions are being introduced and therefore knowledge of neurologic recovery is important in determining if these newer interventions enhance long-term recovery.

The literature on neurologic recovery after a traumatic SCI has focused on recovery within the first or second year postinjury.[6-27] No previous large-scale study has reported on the extent of long-term recovery. Previous studies found that the major factors in determining recovery in the first year after traumatic SCI include the initial neurologic level of injury (NLI), the initial motor strength, and, most important, whether the injury is neurologically complete or incomplete. Most motor recovery occurs within the first 6 months postinjury, with the greatest rate of change occurring within the first 3 months. Motor strength improvement continues during the second year at a slower pace and to a smaller degree. The etiology of a traumatic SCI only plays a role in determining whether the injury is more likely to be neurologically complete.[28] Radiologic and electrodiagnostic testing early after injury helps confirm the data and prognosis obtained from the clinical evaluation. For details of the extent of recovery at 1 year based on an early examination postinjury, see Kirshblum[1-3] and colleagues.

It has been reported that up to 9%[6,15,27,29] of patients with an initial neurologic complete injury (Frankel or American Spinal Injury Association [ASIA] grade A) progress to a functional incomplete lesion (Frankel grade D or E). Maynard et al[29] found, however, that these subjects may have been improperly diagnosed initially because of a concomitant brain injury that might have interfered with obtaining an accurate initial examination. MSCIS data reported that up to 16% of initially neurologic complete patients improve at least 1 classification grade from initial early examination to 1-year follow-up, but only up

From Kessler Institute for Rehabilitation, West Orange, NJ (Kirshblum); Kessler Medical Rehabilitation Research and Education Corp, West Orange, NJ (Kirshblum, Millis, Tulsky); Department of Physical Medicine and Rehabilitation, University of Medicine and Dentistry of New Jersey, Newark, NJ (Kirshblum, Millis, Tulsky); and Department of Physical Medicine and Rehabilitation, Virginia Commonwealth University, Richmond, VA (McKinley).

Supported by the National Institute on Disability and Rehabilitation Research, Office of Special Education and Rehabilitation Services, US Department of Education (grant no. H133N000022), and the Eastern Paralyzed Veterans Association.

No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the author(s) is/are associated.

Reprint requests to Steven Kirshblum, MD, Kessler Institute for Rehabilitation, 1199 Pleasant Valley Way, West Orange, NJ 07052, e-mail: *skirshblum@kessler-rehab.com.*

0003-9993/04/8511-8901$30.00/0
doi:10.1016/j.apmr.2004.03.015

Table 1: Current Definitions of Terms Used in Classification of SCI

Key muscle groups: Ten muscle groups that are tested as part of the standardized spinal cord examination.

Root level	Muscle Group	Root Level	Muscle Group
C5	Elbow flexors	L2	Hip flexors
C6	Wrist extensors	L3	Knee extensors
C7	Elbow extensors	L4	Ankle dorsiflexors
C8	Long finger flexors	L5	Long toe extensor
T1	Small finger abductors	S1	Ankle plantar flexors

Motor level: The most caudal key muscle group that is graded 3/5 or greater with the segments cephalad graded normal (5/5) strength.
Motor index score: Calculated by adding the muscle scores of each key muscle group; a total score of 100 is possible.
Sensory level: The most caudal dermatome to have normal sensation for both pinprick/dull and light touch on both sides.
Neurologic level of injury: The most caudal level at which both motor and sensory modalities are intact.
Complete injury: The absence of sensory and motor function in the lowest sacral segments.
Incomplete injury: Preservation of motor and/or sensory function below the neurologic level that includes the lowest sacral segments.
Frankel Scale: The initial scale used by the MSCIS database to classify the degree of incompleteness of an SCI. Replaced in the database by the ASIA Impairment Scale in 1992.
ASIA Impairment Scale: The current scale used to grade the degree of incompleteness of the SCI (table 2).

to 5.8% improve to grade C and 3% to grade D.[27,29,30] Marino et al[27] reported a small difference when using the Frankel and the ASIA Impairment Scale (AIS).

Between 4% and 10% of patients may undergo conversion after 30 days from a neurologically complete to incomplete status, and this late conversion has been reported to occur even years after injury. Motor recovery seems to be slightly improved for those who undergo late conversion, with some usually nonfunctional lower-extremity recovery that may take place.[21,31] People, who "convert" to incomplete status early, within 1 to 3 months after injury, have a better prognosis for motor recovery than patients who remain neurologically complete. Conversion after this time period, however, has not been reported to offer a better prognosis for functional lower-extremity recovery. No previous large-scale study has reported on conversion after 1 year postinjury. McDonald et al,[32] however, described a single case of a patient (C2-level ASIA grade A injury) who 5 years after injury reportedly regained motor function (to ASIA grade C) after undergoing an activity-based therapy program. This case report suggested that late neurologic recovery after 5 years may occur.

Our purpose in this study was to use a longitudinal follow-up of a large database of people with traumatic SCI (MSCIS database) to determine the degree of late neurologic recovery after injury, specifically after the first year postinjury. Our hypothesis was that late neurologic recovery occurs in a very small percentage of cases. The strength of this MSCIS database lies in its longitudinal and multicenter features.[27]

METHODS

Participants

The study sample was composed of patients with traumatic SCI who were admitted to an MSCIS of care between 1988 and 1997. Patients admitted after 1997 were not because we wanted to analyze change at the 5-year follow-up; consequently, we included data collected until December 31, 2002. Only subjects who had some degree of neurologic deficit were included, thereby excluding patients with an initial Frankel or AIS grade E injury. A total of 987 subjects met the inclusion criteria and had almost complete data at 1-year and 5-year follow-ups for the outcome variables used for analysis. The centers were participants in the national MSCIS program funded by the US Department of Education's National Institute on Disability and Rehabilitation Research.

Patient data used in this analysis were collected, per standard MSCIS procedures, at 1 year from injury (considered the baseline) and 5 years postinjury. Neurologic variables included for analysis were the Frankel or AIS grade, motor index scores (MIS), motor level, and NLI. These are based on neurologic examinations performed at each center and reported in the database submission. Subjects were also categorized as tetraplegic and paraplegic (for certain analyses the paraplegia group was further classified into thoracic and upper lumbar paraplegia [T1-L1] and lumbar paraplegia [L2 and below]) to determine whether there were differences in recovery between the 2 groups.

Several changes, made in the database during the years covered by this study, reflect changes made in the ASIA standards and include revisions in 1989, 1992, 1996, and 2000.[33-36] Table 1 lists the most common current definitions of terms used for neurologic classification in SCI. The most significant change occurred in 1992, when the measure of the degree of completeness of injury was changed from the Frankel scale to the AIS.[34] The AIS uses the "sacral sparing" definition of an incomplete injury (table 2).

The motor level definition was changed in 1992 to the lowest key muscle group that has a grade of at least 3, providing the muscles innervated by segments above that level are graded a

Table 2: ASIA Impairment Scale (Revised 2000)

A = Complete: No motor or sensory function is preserved in the sacral segments S4–5.
B = Incomplete: Sensory but not motor function preserved below the neurologic level and includes the sacral segments S4–5.
C = Incomplete: Motor function is preserved below the neurologic level, and more than half of the key muscles below the neurologic level have a muscle grade less than 3.
D = Incomplete: Motor function is preserved below the neurologic level, and at least half of key muscles below the neurologic level have a muscle grade of 3 or more.
E = Normal: Motor and sensory function are normal.

NOTE. For an individual to receive a grade of C or D, he/she must be an incomplete injury, that is, have sensory or motor function in the sacral segments S4–5. In addition, the individual must have either (1) voluntary anal sphincter contraction or (2) sparing of motor function more than 3 levels below the motor level.

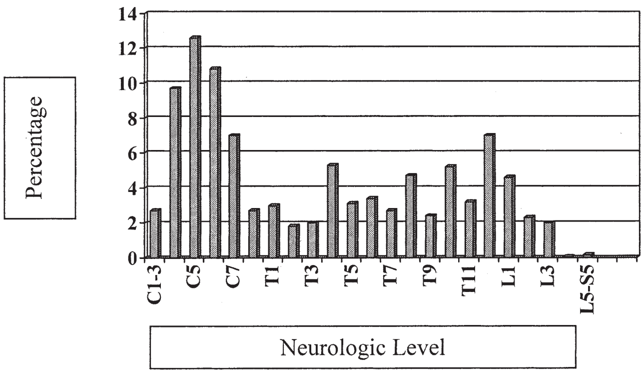

Fig 1. Distribution of NLI at 1 year.

5. A muscle grade 4 was no longer considered to be normal, unless it was the examiner's judgment that certain inhibiting factors, such as pain, positioning of the patient, hypertonicity, or disuse, inhibited full effort.[34] The 1996 standards revised the muscle grading scheme, whereby subjects with these inhibiting factors would be given a muscle grade of 5; they also clarified the distinction between AIS grades C and D.[35] The 2000 revisions assigned a classification of "motor incomplete" (AIS grade C or D) to subjects who have either voluntary anal sphincter contraction or sensory sacral sparing, with sparing of motor function more than 3 levels below the motor level.[36] Previously, since 1992, the person needed only to have motor sparing more than 2 levels below the motor level.

Main Outcome Measures

The data were analyzed to determine the degree of late conversion from a neurologically complete to an incomplete lesion, and to compare the motor level, motor index scoring, and NLI, from 1 year postinjury to the examination at year 5.

The Frankel or AIS score was assigned a value of 1 to 5, corresponding with the classification schema of A through E. The motor level and NLI were coded for analysis by assigning a value from 1 to 29 (C1 being 1, C5 being 5, T1 being 9, etc). The MIS was calculated on a range of 0 to 100; the sum of each of the 20 key muscle groups was graded on a 0 to 5 scale.

Statistical Analysis

Frequency distributions and Spearman ρ correlation coefficients were used to examine the degree of association between AIS ratings at year 1 and year 5. Paired t tests and the Lin concordance correlation coefficients were used to examine change between year 1 and year 5 on the MIS, motor level, and NLI. With regard to the Lin coefficient (ρ), if a patient's MIS stayed exactly the same at year 1 and year 5, the data points would all lie on a line through the origin at 45° on a scatterplot. The Lin coefficient combines measurements of both precision and accuracy to determine whether the observed data deviate from the line of perfect concordance (ie, the line at 45°). The Lin coefficient increases in value as a function of the nearness of the data's reduced major axis to the line of perfect concordance (the accuracy of the data) and of the tightness of the data about its reduced major axis (the precision of the data). The concordance coefficient is composed of the Pearson correlation coefficient, r (a measure of precision), and a bias correction factor, C_b (a measure of accuracy). A limitation of the Pearson r in this context is that its value may be near 1 if there is a systematic change in scores between periods. The Lin coefficient can detect this shift.[37]

RESULTS

The mean age of the 987 subjects at the time of injury ± standard deviation (SD) was 31.0±13.2 years. The NLI at 1 year, for patients available for analysis at 5 years, was most commonly C5, followed by C6, C4, T12, and C7 (fig 1).

ASIA Impairment Scale

Of the 987 patients with AIS data available at 1 and 5 years, the impairment classification at 1 year were: Frankel or AIS grade A, 57.9%; grade B, 11.5%; grade C, 12.3%; and grade D, 18.3%. At 5 years, the AIS classifications were: grade A, 60.4%; grade B, 9.3%; grade C, 11.4%; and grade D, 18.9%. When the sample size was separated into those with tetraplegia and paraplegia, it decreased to 978 subjects, because 9 subjects had incomplete NLI data. The distribution of neurologic classification of this sample was: complete paraplegia, 36.6%; incomplete tetraplegia, 22.5%; complete tetraplegia, 21.4%; and incomplete paraplegia, 19.1%.

The distribution by impairment classification at 1 year for subjects with tetraplegia were: Frankel or AIS grade A, 48.3%; grade B, 16.8%; grade C, 13.4%; and grade D, 21.7%. At 5 years, the impairment classification was: grade A, 51.5%; grade B, 12.7%; grade C, 12.7%; and grade D, 23.1%. The impairment classification for subjects with paraplegia at 1 year with Frankel or AIS grade A was 65.7%; grade B, 7.7%; grade C, 11.4%; and grade D, 15.2%. At 5 years, the impairment classification was grade A, 67.1%; grade B, 6.8%; grade C, 10.5%; and grade D, 15.6%.

The majority of patients (94.4%) with a Frankel or AIS grade A injury at 1 year continued to have a neurologically complete injury (AIS grade A) at 5 years; 3.5% improved to AIS grade B, and 1.05% each to AIS levels C and D (table 3). This relation between status at year 1 and year 5 was strong and statistically significant (ρ=.86, P=.0001).

The data were further analyzed for subjects who experienced conversion after 1 year from a neurologically complete injury (Frankel or AIS grade A) to motor incomplete status (AIS grade C or D) at 5 years (n=12). Of the 6 subjects documented at 5 years as AIS grade D, 3 (all 6 were paraplegic) were most likely improperly coded because their MIS and other data showed no improvement. In the intervening years, specifically when available at years 2 to 4, there were no changes in their AIS classification. However, these cases were not excluded from the analysis because it was not possible to determine absolutely that they were miscoded as a motor incomplete status, perhaps AIS grade C. Moreover, it was an extremely small number of subjects. For the remaining 9 cases (8 men, 1 woman) who showed improvement in motor incomplete status, mean initial age ± SD was 32.8±19.3 years (range, 18–77y) (table 4). In some cases, yearly examinations were also available for review and the examination year that the subjects "converted" is listed in the table.

Table 3: ASIA Impairment Classification at 1 and 5 Years

	Year 5				
Count	A	B	C	D	Total
Year 1					
A	539	20	6	6	571
B	36	55	18	5	114
C	14	11	70	26	121
D	7	6	18	150	181
Total	596	92	112	187	987

Table 4: Confirmed Conversion From Complete Injury (Frankel or AIS grade A) at 1 Year to Motor Incomplete Status (AIS grade C or D) at 5 Years

Subject	Age (y)	Gender	AIS at 5y (grade)	MIS at 1y	MIS at 5y	NLI at 1y	Year of Change
1	30	Male	C	50	—	T11	1–2
2	77	Female	C	17	32	C5	4–5
3	30	Male	C	20	29	C6	2–5
4	20	Male	C	75	75	L3	3–4
5	49	Male	D	18	47	C5	1–3
6	19	Male	D	14	—	C4	1–2
7	18	Male	D	—	80	T1	3–5
8	30	Male	C	59	68	T12	2–3
9	22	Male	C	5	15	C5	3–4

NOTE. Motor scores were not added to the database until 1993.

Of subjects with a motor incomplete injury (Frankel or AIS grade C or D) at 1 year postinjury, 87.4% remained grade C or D, with 7% being classified as AIS grade A, and 5.6% as grade B at 5-year follow-up (table 3).

Of the subjects with complete tetraplegia (Frankel or AIS grade A lesion), 91% remained complete at 5 years; 6.6% improved to grade B, 1.4% improved to grade C, and 1% improved to grade D. Again, the relation between status at year 1 and year 5 was strong (ρ=.85, P=.0001). For subjects with paraplegia, 96% with grade A injury remained complete, with 1.6%, 0.8%, and 1.1% improving to grades B, C, and D at 5 years, respectively (ρ=.88, P=.0001). There was a statistically significant difference in the correlations (z=.2061, P=.04), which suggests that there is a stronger relation between status at year 1 and year 5 in paraplegia; however, this difference may not be clinically meaningful (table 5). As noted, 3 paraplegic subjects coded in the database as AIS grade D at 5 years were improperly coded.

Motor Level

The motor level was examined separately for left and right sides. Analysis on 117 patients with complete data available at 1 and 5 years postinjury revealed that there was minimal change over time: the average difference was -0.56 ± 3.93 points on the left and -0.70 ± 4.95 on the right. These differences were not statistically significant (t_{116}=1.53, P=.13; t_{116}=1.53, P=.13, respectively). There was also substantial concordance in patients' motor levels scores at year 1 and year 5 for the left (Lin ρ=.83, P=.0001) and for the right (Lin ρ=.73, P=.0001). In short, patients' motor level scores tended to remain stable over time (fig 2).

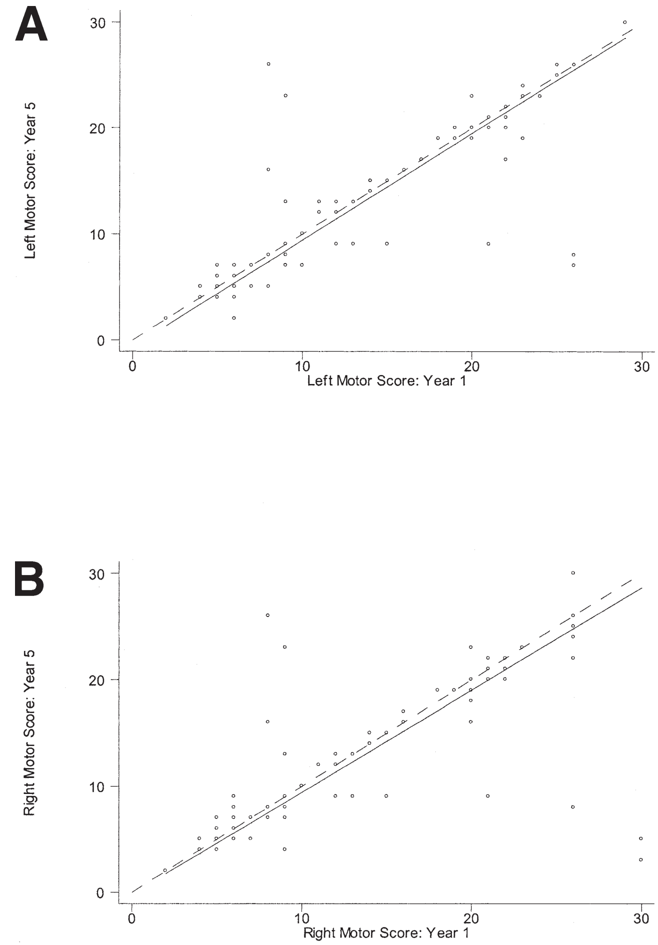

Fig 2. Motor level change at 1 and 5 years for (A) left and (B) right. NOTE. Data must overlay dashed line for perfect concordance.

Table 5: ASIA Impairment Classification for People With Tetraplegia and Paraplegia

Tetraplegia: Year 1 and Year 5 AIS					
	Year 5				
Count	A	B	C	D	Total
Year 1					
A	190	14	3	2	209
B	24	32	13	3	72
C	7	6	31	14	58
D	2	3	8	81	94
Total	223	55	55	100	433

Paraplegia: Year 1 and Year 5 AIS					
	Year 5				
Count	A	B	C	D	Total
Year 1					
A	345	6	3	4	358
B	12	23	5	2	42
C	6	5	39	12	62
D	3	3	10	67	83
Total	366	37	57	85	545

Analysis of motor level change from 1 to 5 years found that 50.4% of patients had no change in level, 20.5% improved 1 or more motor levels, and 30% lost 1 or more levels. Sixteen of 76 subjects (21%) with a neurologically complete injury at 1 year improved motor level at 5 years; 12 (15.8%) improved 1 level and 4 (5.3%) improved 3 or more levels. Subjects with a neurologically complete injury were further classified by level of injury including tetraplegia, thoracic and upper lumbar paraplegic (T1-L1), and lumbar paraplegia (L2 and below). Among the 20 subjects with complete tetraplegia, 60% had no change, 25% had improvement in their motor level (3 subjects improved 1 level, 2 subjects improved >3 levels), and 15% had worse motor levels (2 subjects by 1 level, 1 subject by 2 levels). For subjects with complete thoracic and upper lumbar paraplegia (n=52), 56% (n=29) showed no change, 21% (n=11) had improved in their motor levels (9 subjects improved 1 level, 2

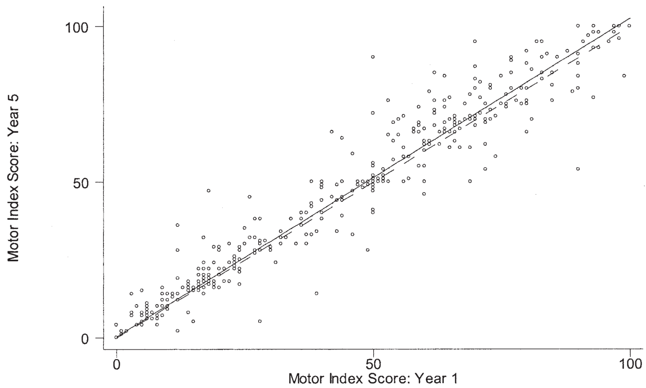

Fig 3. MIS at 1 and 5 years. NOTE. Data must overlay dashed line for perfect concordance.

subjects ≥3 levels), and 23% (n=12) had worse motor levels. There were only 4 subjects with low paraplegia available for analysis; 2 had no change and 2 had a slightly more rostral motor level reported at 5-year follow-up. For subjects with an incomplete injury, 8 of 41 (19.5%) had motor level improvement; 2 improved 1 level (4.85%); 2 improved 2 levels (4.85%); and 4 (9.8%) improved 3 or more levels.

Motor Index Scoring

Analysis was performed on 559 subjects with complete MIS available at 1 and 5 years. The mean MIS at 1 year was 45.23±22.8; at 5 years, it was 46.61±23.35. This mean difference (1.38±6.22) was statistically significant because of the large sample size. As with motor level, there was substantial concordance in MIS at year 1 and year 5 (Lin ρ=.96, P=.0001). The concordance coefficient is very close to 1.0; the scatterplot (fig 3) reveals that the data tend to hug the line of perfect concordance.

Analyzing MIS changes from 1 to 5 years, 246 of 559 (44%) of subjects showed no change, 218 (39%) subjects improved, and 95 (17%) had a decrease. When separated into neurologic complete versus incomplete lesions, 93 of 342 (27.2%) subjects with a complete injury showed improvement in MIS; 70 (20.4%) improved by 1 to 5 points, 18 (5.3%) improved by 6 to 10 points, and 5 (1.5%) improved by 10 or more points. Subjects with a neurologically complete injury were further classified as tetraplegic or paraplegic. For subjects with complete tetraplegia, 57% had no change, 28% showed improvement, and 15% showed a decline in MIS at 5 years. For subjects with complete paraplegia, 83% had no change, 11% had improvement, and 7% showed a decline at 5 years. For subjects with an incomplete injury, 125 of 215 (58.1%) subjects showed improvement in MIS; 65 (30.2%) improved by 1 to 5 points, 29 (13.5%) improved by 6 to 10 points, and 31 (14.4%) improved by 10 or more points.

Neurologic Level of Injury

Neurologic level was correlated separately for left and right sides. Analysis of 979 subjects was possible. Mean NLI at 1 year was 11.47±6.51 for the left side and 11.43±6.60 for the right. At 5 years, an almost identical pattern was observed: left, 11.50±6.55; and right, 11.39±6.55. None of the differences reached statistical significance. Concordance between year 1 and year 5 on NLI was very high, with correlations of .91 and .92 for the left and right sides, respectively (fig 4).

Analyzing NLI changes from 1 to 5 years, 56% of subjects showed no change, with 19.4% of subjects improving (ie, a more caudal NLI) and 24.6% of patients showing a more cephalad NLI. When separated into neurologic complete versus incomplete lesions, 96 of 567 (16.9%) subjects with a complete injury showed improvement in NLI; 67 (11.8%) improved by 1 level, 15 (2.6%) improved by 2 levels, and 14 (2.5%) improved 3 or more levels. Subjects with a neurologically complete injury were further classified by level of injury: tetraplegia, thoracic and upper lumbar paraplegia, and lumbar paraplegia. For subjects with complete tetraplegia (n=214), 58% (n=125) had no change, 19% (n=40) showed improvement, and 23% (n=49) had a more rostral NLI at 5 years. For subjects with complete thoracic and high lumbar level paraplegia, 57% (n=198) had no change, 16% (n=56) showed improvement, and 27% (n=92) had a more rostral NLI at 5 years. There were only 7 patients available for analysis for low paraplegia—4 that had no change and 3 had a more rostral NLI at 5 years. For subjects with an incomplete injury, 94 of 412 (22.8%) showed improvement in NLI; 40 (9.7%) improved by 1 level, 29 (7%) improved by 2 levels, and 25 (6.1%) improved by 3 or more levels.

DISCUSSION

The mean age of our sample as well as the overall distribution of subjects by level of injury and degree of impairment were similar to that reported in other MSCIS data.[27,30] The categories of neurologic impairment differed slightly from

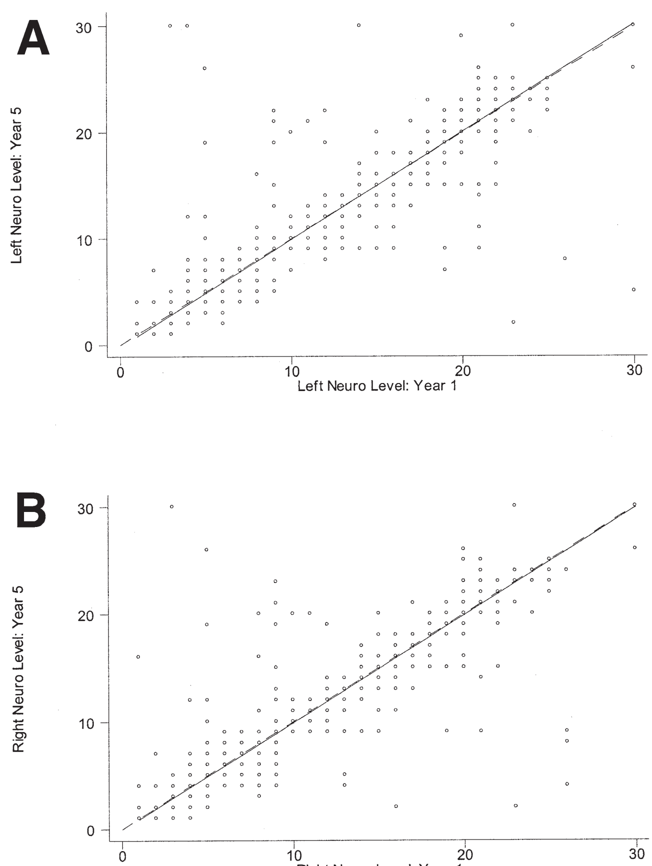

Fig 4. NLI at 1 and 5 years for (A) left and (B) right. NOTE. Data must overlay dashed line for perfect concordance.

previous reports, with a slightly greater proportion of subjects having complete injuries.[27,30]

Although there was consistency over the time after injury in the parameters studied, there was some degree of neurologic recovery from the first- to fifth-year examinations in the AIS scores, motor level, MIS, and NLI. Our data indicate that late conversion from complete to incomplete status after 1 year occurs in up to 5.6% of cases, with a greater potential for conversion in subjects with tetraplegia relative to paraplegia. Only up to 2.1% of cases improved from a neurologically complete injury at the 1-year examination to a motor incomplete injury (AIS grade C or D) at the 5 year examination, with only approximately 1% improving to AIS grade D status (functional lower-extremity movement). On further review of the data, however, this conversion to motor incomplete status after 1 year, especially to ASIA grade D, is lower, because of probable classification errors. Patients with AIS grade D lesions are less likely to receive follow-up evaluation than are patients with AIS grades A, B and C, and therefore recovery may be underestimated to some degree in the database.[38] For subjects with a sensory incomplete injury at 1 year (Frankel or AIS grade B), 20.2% improved to motor incomplete status (15.8% and 4.4% to AIS grades C and D, respectively) at 5 years.

Approximately 20% of subjects improved their motor level as well as their NLI from year 1 to year 5 postinjury. People with a complete and an incomplete injury had similar improvement in motor levels, but subjects with an incomplete injury had a greater chance of NLI improvement at 5 years relative to those with a neurologic complete injury (22.8% vs 16.9%). Almost 40% of subjects showed improvement in MIS, with subjects with an incomplete injury having a much greater chance of improvement relative to those with a neurologically complete injury (58.1% vs 27.2%). Subjects with a neurologically complete lesion were further classified into tetraplegia and paraplegia groups to determine if there was any difference in changes of levels (motor, NLI) or MIS between these groups. For the levels T2-L1, the sensory level determines the motor, and therefore the NLI, because there are no key muscle groups tested at these levels.[4] Recovering the motor level or NLI from C6 to C7, for example, is a more clinically relevant finding (because it may also correspond to functional improvement) than improving from T6 to T7. No significant differences were found for motor level or NLI. There was, however, an increase in MIS in patients with tetraplegia, as would be expected. This is because in subjects with paraplegia, for the levels T2-L1, as the motor level improves with the sensory level, there are no key muscles tested to increase the overall MIS. There were too few patients to permit an analysis of those with complete lumbar paraplegia below the L2 level of injury.

There were a significant number of subjects in the database with a decrease in MIS (17.4%), a more cephalad motor level (30%), and NLI (24.6%). In addition, 12.6% of subjects showed some degree of neurologic worsening, based on the AIS grade, from the first- to fifth-year examinations. These may be attributable to a number of factors, including the 1992 changes in the standards from the Frankel to the AIS, because the Frankel classification (pre-1992) had a higher rate of conversion from incomplete to complete status.[34] Other possible factors include changes in the standards as they relate to the clarification of muscle grades and the definition of the motor level, clarification in the definition of AIS grade C versus grade D, data entry errors into the database, and the development of a syrinx that can lead to true neurologic deterioration. Last, there is a limitation to the data that are submitted to the national database from the individual MSCIS centers, because the interrater reliability of the standards is not as high as would be expected.[39,40] This may be due to the time gap between examinations and the lack of consistency in having the same person and discipline perform the evaluations.

In this study, we did not separate patients based on etiology of injury. It has been reported that people with violence-related SCI are more likely to have an initial neurologically complete injury than are those with nonviolent injuries, and, if neurologically complete at the 72-hour examination, may be more likely to remain complete at 1 year.[27] This finding may be due to an increased chance of more severe damage to the spinal cord from a violent cause (gunshot or stab wound). However, Waters et al,[28] in a study of patients examined at 30 days postinjury (rather than at 72h), did not find any difference in recovery between subjects with penetrating and nonpenetrating injuries. Because the baseline examination we used was at 1 year postinjury, we did not believe that separating these groups was necessary.

Changes in the definitions of the motor level and in what constitutes a neurologically complete injury during this study may have had some impact on the data analysis. Overall, however, we believe that these changes may have had only a small impact on the motor level and motor index scoring from years 1 to 5 postinjury. Although the definition of a complete injury revised from the 1992 guidelines may have affected those patients changing from incomplete to complete status at the 5-year follow-up, in the intervening years of data collection, it would not have affected changes from the complete to incomplete status. This is because, despite the change to using sacral sparing definition of a complete injury, patients with a neurologically complete injury before the definition was changed remained classified with a complete injury after the change.[31]

This study only analyzed degree of neurologic recovery and did not examine any functional changes in the groups studied. Recovery data after the 5-year period were not studied because the sample with complete data is thought to be small. Even though neurologic conversion from neurologically complete to incomplete status and recovery occurs from 1 to 5 years postinjury, it is not common. Nevertheless, further longitudinal study would help to determine whether pharmacologic or rehabilitation interventions can affect neurologic recovery.

CONCLUSIONS

There is a small degree of neurologic recovery (between 1 and 5y postinjury) after a traumatic SCI. Late conversion from a complete to an incomplete injury occurred in 5.6% of cases, but in only up to 2.1% of cases to motor incomplete status. Functional changes were not studied. Knowledge of the degree of late neurologic recovery may be useful in future studies of surgical or pharmacologic interventions designed to enhance recovery.

References

1. Kirshblum S, O'Connor K. Predicting neurologic recovery in traumatic cervical spinal cord injury. Arch Phys Med Rehabil 1998;79:1456-66.
2. Kirshblum S, O'Connor K. Levels of injury and outcome in traumatic spinal cord injury. Phys Med Rehabil Clin North Am 2000;11:1-27.
3. Ditunno J, Flanders A, Kirshblum SC, Graziani V, Tessler A. Predicting outcome in traumatic spinal cord injury. In: Kirshblum SC, Campagnolo D, DeLisa JE, editors. Spinal cord medicine. Philadelphia: Lippincott Williams & Wilkins; 2002. p 108-22.
4. American Spinal Injury Association/International Medical Society of Paraplegia. International standards for neurologic and functional classification of spinal cord injury, revised 2000. Chicago: AISA; 2002.

5. Stover S, DeLisa JA, Whiteneck GG. Spinal cord injury: clinical outcomes from the model systems. Gaithersburg: Aspen; 1995.
6. Bedbrook GM, Sakae T. A review of cervical spine injuries with neurologic dysfunction. Paraplegia 1982;20:321-33.
7. Crozier KS, Cheng LL, Graziani V, Zern G, Herbison G, Ditunno JF. Spinal cord injury: prognosis for ambulation based on recovery of quadriceps function. Paraplegia 1992;30:762-7.
8. Crozier KS, Graziani V, Ditunno JF, Herbison GJ. Spinal cord injury: prognosis for ambulation based on sensory examination in patients who are initially motor complete. Arch Phys Med Rehabil 1991;72:119-21.
9. Ditunno JF, Cohen ME, Belikoff MM, Herbison GJ. Recovery of upper extremity muscles following cervical spinal cord injury [abstract]. J Spinal Cord Med 1997;20:144.
10. Ditunno JF, Sipski ML, Psouniak EA, Chen YT, Stass WE, Herbison GJ. Wrist extensor recovery in traumatic quadriplegia. Arch Phys Med Rehabil 1987;68:287-90.
11. Ditunno JF, Stover SL, Freed MM, Ahn JH. Motor recovery of the upper extremities in traumatic quadriplegia: a multicenter study. Arch Phys Med Rehabil 1992;73:431-6.
12. Ditunno JF, Cohen ME, Hauck W. Early prediction of upper extremity motor recovery in tetraplegia: results of a 10 year multicenter study [abstract]. J Spinal Cord Med 1998;21:162.
13. Folman Y, Masri WE. Spinal cord injury: prognostic indicators. Injury 1989;20:92-3.
14. Foo D. Spinal cord injury in forty-four patients with cervical spondylosis. Paraplegia 1986;24:301-6.
15. Frankel HL, Hancock DO, Hyslop G, et al. The value of postural reduction in initial management of closed injuries of the spine with paraplegia and tetraplegia. I. Paraplegia 1969;7:179-92.
16. Katoh S, El Masry WS. Motor recovery of patients presenting with motor paralysis and sensory sparing following cervical spinal cord injuries. Paraplegia 1995;33:506-9.
17. Mange KC, Ditunno JF, Herbison GJ, Jaweed MM. Recovery of strength at the zone of injury in motor complete and motor incomplete cervical spinal cord injured patients. Arch Phys Med Rehabil 1990;71:562-5.
18. Mange KC, Marino RJ, Gregory PC, Herbison GJ, Ditunno JF. The course of motor recovery at the zone of injury in complete spinal cord injury. Arch Phys Med Rehabil 1992;73:437-41.
19. Stauffer ES. Neurologic recovery following injuries to the cervical spinal cord and nerve roots. Spine 1984;9:532-4.
20. Tominaga L. Periodic neurologic-functional assessment for cervical cord injury. Paraplegia 1989;27:227-36.
21. Waters RL, Adkins RH, Yakura JS, Sie I. Motor and sensory recovery following complete tetraplegia. Arch Phys Med Rehabil 1993;74:242-7.
22. Waters RL, Adkins RH, Yakura JS, Sie I. Motor and sensory recovery following incomplete tetraplegia. Arch Phys Med Rehabil 1994;75:306-11.
23. Waters RL, Yakura JS, Adkins RH, Sie I. Recovery following complete paraplegia. Arch Phys Med Rehabil 1992;73:784-9.
24. Waters RL, Adkins RH, Yakura JS, Sie I. Motor and sensory recovery following incomplete paraplegia. Arch Phys Med Rehabil 1994;75:67-72.
25. Wu L, Marino RJ, Herbison GJ, Ditunno JF Jr. Recovery of zero-grade muscles in the zone of partial preservation in motor complete quadriplegia. Arch Phys Med Rehabil 1992;73:40-3.
26. Young JS, Dexter SR. Neurologic recovery distal to the zone of injury in 172 cases of closed, traumatic spinal cord injury. Paraplegia 1978;16:39-49.
27. Marino RJ, Ditunno JF, Donovan WF, Maynard F. Neurologic recovery after traumatic spinal cord injury: data from the model spinal cord injury systems. Arch Phys Med Rehabil 1999;80:1391-6.
28. Waters RL, Sie I, Adkins RH, Yakura JS. Injury pattern effect on motor recovery after traumatic spinal cord injury. Arch Phys Med Rehabil 1995;76:440-3.
29. Maynard FM, Glen GR, Fountain S, Wilmot C, Hamilton R. Neurologic prognosis after traumatic quadriplegia. J Neurosurg 1979;50:611-6.
30. Ditunno JF, Cohen MS, Formal C, Whiteneck GG. Functional outcomes. In: Stover SL, DeLisa JA, Whiteneck GG, editors. Spinal cord injury: clinical outcomes from the model systems. Gaithersburg: Aspen; 1995. p 170-84.
31. Waters RL, Adkins RH, Yakura JS. Definition of complete spinal cord injury. Paraplegia 1991;29:573-81.
32. McDonald JW, Becker D, Sadowsky CL, Jane JA Sr, Conturo TE, Schultz LM. Late recovery following spinal cord injury: case report and review of the literature [published erratum in: J Neurosurg 2002;97(3 Suppl):405-6]. J Neurosurg 2002;97(2 Suppl):252-65. Comment in: J Neurosurg 2003;98(2 Suppl):227-8; author reply 228.
33. American Spinal Cord Injury Association. Standards for neurologic classification of spinal cord injury. Chicago: ASIA; 1989.
34. American Spinal Injury Association/International Medical Society of Paraplegia (ASIA/IMSOP). International standards for neurologic and functional classification of spinal cord injury (revised). Chicago: ASIA; 1992.
35. American Spinal Injury Association/International Medical Society of Paraplegia. International standards for neurologic and functional classification of spinal cord injury. Chicago: ASIA; 1996.
36. American Spinal Injury Association/International Medical Society of Paraplegia. International standards for neurologic and functional classification of spinal cord injury. Chicago: ASIA; 2000.
37. Lin L. A concordance correlation coefficient to evaluate reproducibility. Biometrics 1989;45:255-68.
38. Richards JS, Go BK, Rutt RD, Lazarus PB. The national spinal cord injury collaboration database. In: Stover SL, DeLisa JA, Whiteneck GG, editors. Spinal cord injury: clinical outcomes from the model systems. Gaithersburg: Aspen; 1995. p 10-20.
39. Donovan WH, Brown DJ, Ditunno JF Jr, Dollfus P, Frankel HL. Neurologic issues. Spinal Cord 1997;35:275-81.
40. Cohen ME, Ditunno JF Jr, Donovan WH, Maynard FM Jr. A test of the 1992 International Standards for Neurologic and Functional Classification of Spinal Cord Injury. Spinal Cord 1998;36:554-60.