Early Predictors of Functional Independence 2 Years After Spinal Cord Injury

Linda A. Saboe, BPT, Johanna M. Darrah, PhD, Kerrie S. Pain, PhD, John Guthrie, MD


Objective: To determine: (1) how well factors measured at admission to an acute care facility predict functional independence measure (FIM) scores, use of personal care assistance, and wheelchair ownership 2 years after traumatic spinal cord injury (SCI); (2) the extent that factors measured during inpatient stay add to these predictions; and (3) if FIM scores differ through use of assistance and wheelchair ownership 2 years after SCI.

Design: Prospective, longitudinal.

Setting: Tertiary care acute, rehabilitation hospitals and home settings.

Patients: One hundred sixty SCI admissions.

Main Outcome Measures: FIM, use of personal care assistance (yes/no), and wheelchair ownership (manual/electric/no)

Results: Year 2 FIM scores were highly correlated (.68) to the ASIA admission and discharge light touch, pin prick, and motor scores. Admission neurological status and age accounted for 65% of year 2 FIM score variance. Adding hospital events and the discharge ASIA motor score increased prediction to 76% of the variance. A separate regression model using only year 2 neurological scores and age accounted for 73% of the total FIM variance. Discriminant function analysis indicated 86% correct classification regarding use of personal care assistance and 88% correct classification of wheelchair ownership. Using a separate cross-validation sample, overall classification accuracy for assistance was 80% and wheelchair ownership 67%. FIM scores were significantly lower in assistance users (78 ± 24) than nonusers (120 ± 8) and were significantly different between wheelchair ownership groups: manual (103 ± 21), electric (61 ± 15), and none (125 ± 2).

Conclusions: Late disability can be predicted using early impairment measures. The FIM prediction from variables measured during the early treatment phase was as good as prediction based on concurrent measures.

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Rehabilitation after traumatic spinal cord injury (SCI) is time-consuming and costly and, in spite of an intensive rehabilitation process, functional status can remain severely impaired.1,3 It is unlikely that any other type of trauma leaves such large numbers of its injured, who are otherwise healthy young men, wheelchair dependent. Neurological status is a major predictor of function. Recognition of key motor spinal segments and a positive correlation between motor power and functional ability have allowed specification of functional goals for each neurological level of motor impairment.4,9 There has been, however, considerable diversity in the method and timing of neurological measurement and there are few discussions10 of the relationship of neurological impairment to the widely accepted Functional Independence Measure (FIM).11,12 Furthermore, personal care assistance and wheelchair ownership are major concerns of SCI clients and their families.

Historically, the level (skeletal and/or neurological) of SCI and its completeness has been subject to broad and varied definitions, most of which lack grade homogeneity and bear little tested relation to functional outcome.13-18 Standardized measures developed by the American Spinal Injury Association (ASIA) describe neurological impairment and quantify motor function and sensations of light touch and pin prick.19-20 These scales provide information beyond injury level and completeness. Individuals with higher ASIA neurological scores have higher levels of sensory and/or motor function. Because functional goals are related to motor impairment, these impairment scores, particularly the motor score, would be expected to strongly correlate to concurrent measures of disability. Their ability to predict FIM scores, use of personal care assistance, and wheelchair ownership has not been well documented, however. This is unfortunate because while concurrent measures of impairment and disability are helpful, early identification of eventual personal care and equipment needs would facilitate family and client counseling and discharge planning.

The importance of sensation in predicting functional outcome has also been underemphasized. Many studies on the prediction of disability levels did not include tests of any of the sensations (light touch, pin prick, vibration), some included only one, and most quantified them poorly.4,8,20-26

Neurological status has potential for change. The greatest improvement occurs in the first few hours after injury, and little additional improvement occurs beyond the first year after injury.2,7,11,17,25,28 Previous studies predicted disability and mobility with neurological scores measured at tertiary care admission and/or discharge or, in lieu of prediction, they compared neurological impairments to concurrently measured disability and mobility scores.4,8,20-26 Rarely have late disability and mobility been predicted using a combination of sensory, motor, and impairment scores measured both at admission to, and at discharge from, inpatient tertiary care.

Many SCI clients recover some neurological function before discharge, but rarely is the recovery enough for function to be rated normal on the Frankel scale.2,9,12,27 The amount of recovery that can be translated into functional improvement is related to the SCI level, SCI completeness, and early intervention.4,7,11,12,16,25,26,28 Ninety-four percent of the Model System clients who were admitted 24 hours after injury and had a Frankel complete injury remained complete at discharge.16 In a study of early pharmacologic intervention, Geiser et al28 reported 24% of treated SCI clients improved two or more Frankel...
grades, compared with 6% of the untreated group. The prognosis for functional ability, including ambulation, has further been reported as greater when pin prick is preserved and related to a motor index score or quadriceps strength.

The importance of skeletal level of injury and neurological impairment has perhaps overshadowed the additional influence of other predictors that have been shown to have some influence on functional outcome and mobility. These include age, gender, marital status, education, medical comorbidity, pharmacologic intervention, associated injuries, surgical management of the fracture, medical complications, admission to an intensive care unit (ICU), and interruptions of rehabilitation programs. It is most likely that a combination of variables best predicts FIM, use of assistance, and wheelchair ownership after SCI, and these factors should be considered along with neurological ratings.

The primary purpose of this study was to identify how well factors measured at admission (demographic indicators, associated injuries, and neurological impairment) predict total FIM score, use of personal care assistance, and wheelchair ownership 2 years after traumatic SCI. The secondary purpose was to determine the extent early treatment factors (surgical or nonsurgical spine treatment and early use of steroids), selected hospital events (development of complications, admission to an ICU, and length of interruption of rehabilitation), and discharge neurological scores improve these predictions. Another purpose was to determine if FIM scores differ between clients using personal care assistance and those who do not, and between wheelchair ownership groups (manual, electric, none).

**METHOD**

**Sample**

Subjects were drawn from a prospectively gathered longitudinal data base of 830 spine trauma victims who were consecutively admitted to a major acute tertiary care teaching hospital between 1983 and 1992. One physical therapist gathered information in this data file through patient and family interviews, patient assessments, and review of medical records. All acute care services were provided at a single facility, and rehabilitation assessment and treatment were provided by an interdisciplinary team at one of two tertiary care rehabilitation teaching hospitals. These centers service a population of approximately 1.3 million people. Subjects were included in the analyses if at admission or discharge they were graded A through D with the ASIA impairment scale and if they had complete information on all dependent and all independent variables. A neurological deficit was present in 304 (37%) cases, and 160 (53%) of these cases had complete information on all variables. These 160 cases comprised the model group. Of the remaining cases in the data file, 71 (23%) had some baseline and 2-year information, 51 (17%) were lost to follow-up or had not reached the test time, and 22 (7%) were dead.

**Dependent Variables**

**FIM.** The FIM scoring severity of disability. A seven-point ordinal scale is used to rank 18 items that describe six functional areas. These scores measure burden of care with higher FIM scores representing higher levels of independence. Four of these areas—self care, sphincter control, mobility factors, and locomotion—are measured with 13 items and comprise motor function. Two areas, communication and social cognition, are measured with five items and provide a cognitive function total. A sum of all 18 item ratings provided a total FIM score. All three totals were scored at discharge and at 2 years after SCI.

FIM scoring was done by the first author, who was trained at a UDSMR workshop. During annual in-house reliability testing where 50 or more trained FIM raters were asked to rate three written case studies (54 items), this individual consistently achieved ≥80% agreement on the three written case studies. Intrarater reliability, tested with percent agreement between initial and repeat scores of these same written case studies, resulted in ≥95% agreement.

**Personal care assistance with activities of daily living (ADL).** Personal care assistance with ADL was rated yes or no by the client.

**Wheelchair ownership.** Clients were rated as being manual or electric wheelchair owners or as nonowners of a wheelchair.

**Independent Variables**

Twenty-two independent variables, or possible predictors of year 2 disability, were measured at one of three times: at admission to acute care, during inpatient stay, and at discharge from a tertiary care facility.

**Admission.** Upon admission to acute care, 12 factors were considered. Demographic variables included age, gender, marital status (yes/no), education coded with the 21-grade scale established by Statistics Canada, and medical comorbidity. Medical comorbidity was calculated from the medical history, using a presence/absence checklist that included abdominal, cardiovascular, collagen, metabolic, neurological, psychiatric, renal, and respiratory disease. Associated injuries were measured with the Injury Severity Score (ISS). Admission neurological impairment was measured with skeletal level of bony injury (C1 to L5), ASIA motor score, ASIA light touch and pin prick sensory scores, ASIA impairment scale, and a computed vibration score. Vibration was a total derived from a presence/absence checklist that included bilateral clavicles, humeral condyles, metacarpals, anterior superior iliac spines, patellae, lateral malleoli, and first metatarsals.

Admission neurological scoring was by necessity a compilation of information from paramedic logs, chart reviews, patient interviews, and physician contact. At admission to acute care, the emergency room (ER) physician’s assessment included a neurological examination. Within hours of this initial triage the SCI individual was assessed by an orthopedic and/or neurological surgeon, and neurological status was evaluated and documented. As soon as possible, but within 96 hours of admission, ER and admission hospital records and transfer and paramedic notes were reviewed by an experienced physical therapist (the first author). She then interviewed and tested the SCI person. Neurological testing was done in the order of light touch, pin prick, vibration, and motor function. Sensory testing was done distal to proximal in each dermatome on both sides of the body. Light touch and pin prick were scored as absent, impaired, normal, or not testable. Vibration was scored as present, absent, or not testable. Motor scores were recorded with MRC’s 5-point scale or as not testable. Findings were then checked across multiple data and resource persons. When any admission neurological score was in question, hospital personnel or referring physicians, paramedics, or nursing personnel were contacted to discuss the involved individuals. In all cases followed up in this manner, all parties agreed on presence or absence of a deficit.

**During inpatient tertiary care hospital stay.** Five treatment factors were considered. These included surgical or nonsurgical spine treatment, early use of steroids, development of complications (a total derived from a presence/absence checklist of complications including abdominal, bladder, chest, and deep vein thrombosis), total days stay in an ICU, and total days of interruption of rehabilitation (days spent away from a rehabilitation facility for medical treatment).
At discharge from the rehabilitation facility and 2 years after SCI, neurological impairment was rated with ASIA motor, light touch, and pinprick scores, and a computed vibration score. This testing was done by the physical therapist who did the physical testing. As a quality control measure, the test results were randomly compared with those of an orthopedic or neurological surgeon.

Analyses

**FIM.** A multiple linear regression analysis was used to identify the combination of factors measured during stay in tertiary care hospitals that best predicts FIM scores 2 years after SCI. All 22 previously described predictors were entered in a stepwise fashion (with deletion). The entry of these independent variables, however, was controlled by grouping them into three blocks: acute care admission, during inpatient stay, and discharge. This allowed the final model to reflect the sequential nature of the measures and identify the extent to which information gathered after admission added to predictions of year 2 FIM.

To compare the strength of these early predictions of the FIM scores relative to concurrently measured neurological impairment, a separate multiple linear regression analysis was run. ASIA motor, light touch, and pinprick scores, the ASIA impairment scale, and a computed vibration score all measured at 2 years after SCI and age at injury were entered in a stepwise fashion (with deletion).

Correlation coefficients were calculated to determine the pattern of intercorrelations between factors that were left in the equation and those that were dropped. For all analyses an alpha level of .05 was set for significance.

**Assistance with ADL and wheelchair ownership.** Discriminant function analyses (DFAs) were used to identify the independent variables that best classified individuals for assistance with ADL and wheelchair ownership 2 years after SCI. To capture the natural sequence of the available information, three separate DFAs were run for each of the two dependent variables. The first DFA introduced the 12 admission variables, the second included the 12 admission variables plus the 5 variables measured during inpatient stay, and the final DFA contained all 22 independent variables. Each DFA entered variables in a stepwise fashion. Prior probabilities of group membership were set from the number of cases in each category.

To evaluate the ability of each function to correctly classify use of personal care assistance and wheelchair ownership, actual group memberships were compared with those predicted by the DFA. To further test classification accuracy the discriminant functions derived from each of the six DFAs were applied to a separate cross-validation sample. These samples were drawn from the 71 previously described cases remaining in the data file. Cases having complete information for a discriminant function were chosen and classified by the computer-program.

Comparisons of FIM scores by use of personal care assistance (yes/no) and wheelchair ownership (manual/electric/none) were made with t tests and analysis of variance (ANOVA) with a post hoc Scheffé (p ≤ .05).

**RESULTS**

The 160 cases in the model group had a mean age at injury of 30 ± 13 years, 78% were male, and 42% were married. Forty-nine percent had less than a high school education. Mean medical comorbidity was .49 ± .73 and ISS was 24 ± 10. Sixty-nine percent of this series had spine surgery. The complication score was 1 ± 1 and 77 (48%) of the series spent 17 ± 27 days in an ICU. Fifteen (9%) had an interruption in their rehabilitation program (20 ± 29 days). Total length of tertiary care hospital stay was 144 ± 111 days.

Admission, discharge, and year 2 neurological ratings are summarized in table 1. Twenty-three percent improved one or more impairment scale ratings between admission and discharge and 6% improved a rating from discharge to year 2.

At 2 years after SCI the mean total FIM score (105 ± 25) was statistically significantly higher than at discharge (102 ± 26). Separate FIM totals were calculated for motor and cognitive items. Year 2 totals were significantly greater than discharge totals for total FIM motor function (68 ± 25 and 71 ± 25) and total FIM cognitive function (34 ± 2 and 35 ± 2). Between discharge and year 2, 79 clients (49%) improved their FIM motor scores, 54 (34%) did not change, and 27(17%) showed a decrease. In contrast, FIM cognitive scores remained the same in 135 (84%), improved in 24 (15%), and decreased in only one client. At year 2, 156 (98%) of the series had the maximum total FIM cognitive score of 35. Thus, adding year 2 cognitive FIM total to the FIM motor total was the same as adding a constant. Because FIM totals in the clinical environment typically include all 18 items the total FIM score was used in the regression analyses. The results would be essentially equivalent if only the FIM motor total were used.

**FIM**

Two years after SCI the FIM scores were most highly correlated (r = .73) with ASIA admission and discharge light touch and pinprick sensory scores and ASIA discharge motor score. However, ASIA sensory and motor scores and impairment scale and the computed vibration score were all highly correlated to each other within and between measurement times (table 2).

In predicting year 2 FIM scores, admission ASIA light touch score alone accounted for 56% of the variance. Addition of other admission scores accounted for 65% of the total variance. Adding hospital events and discharge measures of neurological status, increased prediction to 76% of the variance (table 3).

When we examined concurrent relationships using multiple regression, the ASIA year 2 motor score accounted for 64% of the variance of the total year 2 FIM score. An additional 5% was added with the addition of the ASIA year 2 impairment scale and light touch score. When injury age was added, year 2 impairment measures accounted for 73% of the year 2 FIM total variance (table 4).

<table>
<thead>
<tr>
<th>Level of bony injury</th>
<th>Admission</th>
<th>Discharge</th>
<th>Year 2</th>
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<tbody>
<tr>
<td>Cervical (C1-C7)</td>
<td>72 (45)</td>
<td>71 (43)</td>
<td>68 (36)</td>
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<tr>
<td>Thoracic (T1-T10)</td>
<td>32 (20)</td>
<td>31 (19)</td>
<td>30 (17)</td>
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<tr>
<td>Thoracolumbar (T11-L2)</td>
<td>40 (31)</td>
<td>39 (30)</td>
<td>38 (29)</td>
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<tr>
<td>Lumbar (L3-L5)</td>
<td>7 (4)</td>
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<table>
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<th>Neurological score</th>
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<th>Discharge</th>
<th>Year 2</th>
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<tr>
<td>ASIA Motor</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
<td>Mean (SD)</td>
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<tr>
<td>Complete</td>
<td>79 (9)</td>
<td>74 (9)</td>
<td>70 (8)</td>
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<tr>
<td>S4-S5 Sensory</td>
<td>9 (7)</td>
<td>8 (7)</td>
<td>7 (6)</td>
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<tr>
<td>Motor &lt;3</td>
<td>1 (2)</td>
<td>1 (3)</td>
<td>0 (2)</td>
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<tr>
<td>Motor &gt;3</td>
<td>8 (6)</td>
<td>5 (6)</td>
<td>3 (5)</td>
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<tr>
<td>Normal</td>
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<td>10 (4)</td>
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<table>
<thead>
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<th>ASIA impairment scale</th>
<th>Admission</th>
<th>Discharge</th>
<th>Year 2</th>
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<td>36 (1)</td>
<td>36 (1)</td>
<td>36 (1)</td>
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<td>B. Motor &lt;3</td>
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<tr>
<td>C. Motor &gt;3</td>
<td>36 (1)</td>
<td>36 (1)</td>
<td>36 (1)</td>
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<tr>
<td>E. Normal</td>
<td>36 (1)</td>
<td>36 (1)</td>
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Table 2: Correlation Coefficients of Bony Injury, Neurological Ratings, and Year 2 FIM Score

<table>
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<th>Measurement Time</th>
<th>Bony Injury</th>
<th>Admission</th>
<th>Discharge</th>
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<tr>
<td>Year 2 FIM score</td>
<td>.53</td>
<td>.68</td>
<td>.76</td>
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<tr>
<td>Admission Bony injury</td>
<td>.68</td>
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<td>.75</td>
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<tr>
<td>ASIA Motor</td>
<td>.96</td>
<td>.97</td>
<td>.74</td>
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<tr>
<td>ASIA Light Touch</td>
<td>.86</td>
<td>.91</td>
<td>.74</td>
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<tr>
<td>ASIA Pin Prick</td>
<td>.69</td>
<td>.67</td>
<td>.23</td>
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<tr>
<td>Computed Vibration</td>
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<td>ASIA Impairment</td>
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<td>.57</td>
<td>.67</td>
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<tr>
<td>Year 2 FIM score</td>
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<td>.76</td>
<td>.64</td>
</tr>
<tr>
<td>Admission Bony injury</td>
<td>.59</td>
<td>.61</td>
<td>.70</td>
</tr>
<tr>
<td>ASIA Motor</td>
<td>.92</td>
<td>.89</td>
<td>.92</td>
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<tr>
<td>ASIA Light Touch</td>
<td>.75</td>
<td>.74</td>
<td>.74</td>
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<tr>
<td>ASIA Pin Prick</td>
<td>.74</td>
<td>.74</td>
<td>.74</td>
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<td>.78</td>
<td>.74</td>
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<td>ASIA Motor</td>
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<td>Computed Vibration</td>
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</tr>
<tr>
<td>ASIA Impairment</td>
<td>.75</td>
<td>.75</td>
<td>.85</td>
</tr>
</tbody>
</table>

Person Care Assistance With ADL

Overall, 86% of the cases in the model group were correctly classified on the basis of the ASIA admission light touch score and age. This same function correctly classified 80% of the cross validation sample. Adding hospital events did not improve classification accuracy. When discharge variables were added, 94% of the model group's nonusers of personal care assistance were correctly classified. Overall correct classification was 88%. While age still featured as a predictor variable, admission ASIA light touch was replaced by the admission ASIA motor and pin prick scores. There were insufficient cases to apply the third function to the cross validation sample. Table 5 provides results of the three DFAs including the function variables used to classify use of personal care assistance.

Wheelchair Ownership

Using only admission measures of the ASIA motor score and impairment scale and a computed vibration score, 88% of the model group and 67% of cross-validation cases were correctly classified into a wheelchair ownership group. Adding variables measured during hospital stay did not change this discriminant function or its results. Greatest classification accuracy was for nonownership of a wheelchair (95%), followed by ownership of a manual wheelchair (90%). Addition of ASIA discharge motor scores improved correct classification of electric wheelchair ownership from 62% to 90% and left overall correct classification unchanged. Table 6 provides results of the three DFAs including the function variables used to classify wheelchair ownership.

FIM Scores, Personal Care Assistance, and Wheelchair Ownership

Two years after SCI, 35% of the model group used personal care assistance. These individuals had significantly lower FIM scores (78 ± 24) than nonusers of personal care assistance (120 ± 8). The 95% FIM score confidence interval around the mean for users of personal care assistance was 71 to 84 and for nonusers of assistance 119 to 122.

Two thirds of the model group owned a wheelchair 2 years after SCI (53% owned a manual chair and 13% owned an electric wheelchair). Each of the wheelchair ownership groups had significantly different FIM scores. Those owning electric wheelchairs had the lowest FIM scores (61 ± 15); nonowners scored highest (125 ± 2) and manual wheelchair owners were more centrally placed (104 ± 21). The FIM score 95% confidence intervals around the mean were: nonowners, 124 to 125; manual wheelchair owners, 99 to 108; and electric wheelchair owners, 54 to 68.

DISCUSSION

This study found that factors measured at admission to an acute care facility can predict, with a high level of accuracy, total FIM scores, use of personal care assistance, and wheelchair ownership 2 years after traumatic SCI. These predictions are marginally improved with the addition of early treatment factors, selected hospital events, and discharge neurological scores. Early predictions of year 2 FIM are as strong as the relation between concurrently measured neurological impairment and injury age. Thus, clinicians, with the assistance of computer programs, can use admission information to advise and counsel...
clients and their families regarding their probable burden of care, use of personal care assistance, and wheelchair ownership two years after SCI.

This study used several different neurological indicators. ASIA sensory or motor ratings or the impairment scale and/or the computed vibration score entered into one or more of the models. Each of these ratings was highly correlated across the two measurement times (.85 to .96), i.e., individuals admitted with a relatively high or low neurological rating were also discharged with a relatively high or low neurological rating. Rehabilitation specialists do not typically see SCI individuals at admission to acute care, but the very high correlations between admission and discharge ratings suggest that neurological scores measured at any time between admission to and discharge from tertiary care would, in most cases, be equally effective at predicting disability and mobility 2 years after SCI. Knowing this, rehabilitation practitioners can confidently provide counseling as to the burden of care and probability of wheelchair ownership. This finding is what many experienced clinicians have long presumed to be true and it would be interesting to compare their predictions to those generated by the numerical analysis. It is possible that experienced clinicians' predictions would be even more accurate than those described in this article. In the interim these formulae and a computer program provide inexperienced and experienced clinicians the opportunity to reach the same prediction.

Fifty-six percent of the year 2 FIM score variance was accounted for with the ASIA admission light touch score. Age was the next factor to enter the prediction model and in accounts on the negative effect of increased age on function.33,32,39 Among SCI persons,7,39,40 the additional 7% was accounted for by the admission computed vibration score and the ASIA impairment scale and motor score. This is not surprising because vibration and motor scores, when combined with light touch, provide a measure of anatomic integrity of the spinal cord: light touch the anterior and lateral spinothalamic tracts, vibration the posterior columns, and motor function the lateral corticospinal tracts and central grey matter. Even in the presence of detailed ASIA motor, pinprick, and light touch scores, however, completeness of injury, as measured with the ASIA impairment scale, accounted for an additional 2% of FIM variance. This underlines the importance of potential for recovery known to be associated with incomplete SCI and reinforces the importance of detailed early neurological examination and inclusion of completeness of injury when making early predictions of late FIM scores.

Hospital events accounted for an additional 7% of FIM score variance. Although longer stays in an ICU and development of complications were negative FIM score predictors, spine surgery and early use of steroids added positively to the prediction model. Presumably this was secondary to their known association with improved motor and sensory function.

Mean values of ASIA motor, light touch, and pin prick scores and the computed vibration score increased between admission and discharge. Of the discharge variables, however, only the motor score was selected by the regression model and it added 4% to the variance. The final regression model, which included a combination of admission, during-stay, and discharge variables, accounted for 76% of the year 2 FIM score variance.

FIM scores were significantly and distinctly lower among personal care assistance users than among nonusers. This strengthens claims that FIM scores reflect burden of care among SCI clients. Even for those who did have personal care assistance, the burden of care, reflected by the FIM scores, was quite variable. This was indicated by the FIM scores' large standard deviation and 95% confidence interval around the mean. Perhaps future studies should focus on FIM scores relative to actual amounts of personal care assistance used. Some subgroups may be more accurately predicted. Unquestionably, a simple yes or no to use of personal care assistance is very accurately predicted with admission only information.

In as much as FIM total scores did improve from discharge to year 2, some lessening of disability might be expected. In view of the excellent predictability of wheelchair ownership and use of personal care assistance and the accompanying confidence intervals around the means of these items, large functional gains after discharge cannot be anticipated. It remains to be determined how much the significant but small FIM score gain actually decreased the burden of care.

The incidence of concomitant traumatic brain injury among SCI clients is reported to be between 10% and 60%.41 In this series all but four had full scores for cognition at year 2 and one of these had suffered a postdischarge traumatic brain injury with a marked decrease in cognitive function. The high FIM cognition scores in this series most likely reflect the reported inadequacy of the FIM in measuring cognitive dysfunction among SCI persons.41

A discriminant function of admission ASIA light touch and age correctly classified use of personal care assistance in 86%
of the model cases and in 80% of the cross-validation sample. These are the same variables that accounted for 38% of the FIM score variance, and these findings reinforce the ability of admission neurological impairment to predict disability and use of personal care assistance 2 years after SCI. This claim is supported by the failure of additional information used in the second and third discriminant functions to improve classification accuracy. Adding hospital events of complications and spine surgery did not improve classification accuracy at all. Waiting until discharge, which was on average 144 days after injury, resulted in a discriminant function of ASIA admission motor and pin prick scores, age, and ASIA discharge motor score and impairment scale. Classification of clients with this discriminant function was only marginally more accurate and required more information be gathered over a longer period of time. Moreover, the final discriminant function could not be tested because the cross-validation sample cases lacked all of the function variables.

Walking is a major concern of SCI clients and their families. This study avoided the problems associated with the many broad definitions of walking by restricting itself to examination of wheelchair ownership. It must be noted that while some of these wheelchair owners did walk, all who owned a wheelchair used it on at least some occasions. Results of the DFAs might have been different if walking rather than nonownership of a wheelchair were being predicted. When counselling clients with these discriminant functions, clinicians must stress that their predictions are limited to probability of wheelchair ownership and that wheelchair ownership does not preclude walking for all individuals.

A function of the ASIA admission motor score, impairment scale, and a computed vibration score correctly classified 90% of the manual wheelchair owners and 95% of nonowners. Nobody in this group who had been predicted to own an electric wheelchair became a nonowner of a wheelchair 2 years after their SCI. Had the discriminant function analysis been run for ownership of a wheelchair (yes/no), the model would have had an even higher overall correct classification rate. This, combined with an overall classification accuracy rate of 61% among a cross-validation sample, reinforces the utility of admission factors in predictions of late wheelchair ownership.

Information measured during inpatient stay did not change the function or its accuracy. The final discriminant function added the ASIA discharge motor score, and although it did not improve overall classification accuracy of manual wheelchair owners or of nonowners, correct classification of electric wheelchair ownership was improved from 62% to 90%. The discharge motor score played a role in predictions of FIM scores and electric wheelchair ownership. Perhaps this emphasizes the importance, or the strength, of the relationships among motor function, functional independence, and mobility. Electric wheelchair owners had the lowest year 2 FIM scores, and these were associated with lower admission and discharge ASIA motor scores. Lower FIM scores were also associated with users of personal care assistance. Conversely, nonowners of wheelchairs had higher ASIA motor scores and higher FIM scores and were typically nonusers of personal care assistance.

Identifying admission motor scores for predictions of wheelchair ownership and admission light touch scores for predictions of FIM scores and use of personal care assistance does not suggest that sensory and motor function have independent effects. All of the neurological measures were highly correlated. Light touch correlated more highly than the other neurological scores with FIM scores and use of personal care assistance. Therefore, it entered the equations first. Other neurological ratings with high correlations could not explain any further variance and so did not enter the regression model. Pin prick has a known ability to predict function23-25 and it has a close anatomic relationship to the motor tracts. Because of its high correlation to light touch (.97) and motor function (.89), it could not explain any further FIM score variance or use of personal care assistance and, therefore, it did not enter these equations. Lacking a light touch score, pin prick or motor scores measured at admission could be equally effective predictors. We advise using caution when interpreting results of any single measure entered in the formulae.

Vibration, which is a sensation not included in the ASIA neurological standards, featured in both the FIM regression and the wheelchair ownership DFA. Testing vibration sensation is comparatively easy, is not time-consuming to administer, and is not uncomfortable for the client. This might indicate that it should be used in future SCI research studies. Vibration testing, however, does not localize the SCI level of injury, nor does it provide information on sacral sparing. Because of the high correlations among neurological impairment measures, many of the ASIA neurological scores would be almost as effective in contributing to late predictions.

**CONCLUSION**

FIM scores, use of personal care assistance, and wheelchair ownership 2 years after traumatic SCI can be accurately predicted using admission ASIA sensory and/or motor scores and age. Adding hospital events and discharge ASIA motor scores improves prediction of FIM scores but adds little to correct classification of personal care assistance and wheelchair ownership. The strength of FIM prediction is as strong as that using concurrent measures of neurological impairment. FIM scores are distinct between users and nonusers of personal care assistance and between wheelchair ownership groups (manual/electric/no). These results affirm that functional outcome or disability can be predicted very early after SCI.
References


31. White Predictors of Late FIM Scores, Saboe