# Neurological and Functional Outcomes Associated with SCI Rehabilitation

***Dalton L. Wolfe, Jane T.C. Hsieh, Armin Curt, Robert W. Teasell, and the SCIRE Research Team***

Modern spinal cord injury (SCI) care is purported to involve treatment in specialized centers with an interdisciplinary team of health care professionals providing care as early as possible following injury. Care is delivered throughout the rehabilitation process with appropriate discharge to the community characterized by ongoing outpatient care and follow-up. This article is intended to describe the evidence that exists for aspects of this model of SCI care. Specifically, we examined the evidence for specialized versus general care, early versus late hospital admission, and follow-up care. A second objective of the article is to describe relevant findings of the most common outcomes within the rehabilitation context. We have summarized the outcomes of length of stay, neurological status, and functional status over the rehabilitation stay and examined the interrelationships among these outcomes. **Key words:** *ambulatory care, neurologic examination, rehabilitation, rehabilitation centers, spinal cord injuries, treatment outcome*

The spinal cord injury (SCI) rehabilitation practices of today were influenced greatly by the pioneering efforts of Sir Ludwig Guttman who was instrumental in the creation of specialized spinal units to care for injured soldiers returning to England during and after World War II.[1] Eventual adoption of this more specialized, integrated approach followed in many jurisdictions[2] and was bolstered by reports of reduced mortality that was attributed in part to more effective management of secondary conditions associated with SCI.[3,4]

At present, the trend for modern SCI care is purported to be treatment in specialized, integrated centers with an interdisciplinary team of health care professionals providing care as early as possible after injury and throughout the rehabilitation process, with appropriate discharge to the community characterized by ongoing outpatient care and follow-up.[4,5] This is best facilitated within an organized "system" characterized by seamless transitions as patients proceed from acute care through rehabilitation to outpatient care. Although it is generally accepted

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that this "ideal" more specialized, integrated approach should result in better outcomes, there is very little robust evidence that supports this directly.

Ultimately, it would be extremely valuable to determine the most appropriate model for achieving optimal outcomes in SCI care. One objective of this article is to describe the evidence that exists for specific models of SCI care, in particular as related to SCI rehabilitation. We examined the evidence for specialized versus general care, early versus late hospital admission, and follow-up care. A second objective of the article is to describe relevant findings of the most common outcomes within the rehabilitation context. Therefore, we have summarized the outcomes of length of stay (LOS), neurological status, and functional status over the rehabilitation stay and examined the interrelationships among these outcomes. Specific measures examined include rehabilitation LOS, the FIM™*, and the American Spinal Injury Association (ASIA) Impairment Scale (AIS) (or modified Frankel Scale).

## Method

General methods for the Spinal Cord Injury Rehabilitation Evidence (SCIRE) project as identified by Eng et al. in the first article in this issue[6] and also available online[7] were employed for the present review. In addition to key word searching of electronic databases, electronic browsing was conducted by employing the "Related Articles" tool in PubMed and hand searching was conducted by browsing key review articles and journals. Unlike the majority of topics examined in the SCIRE project, specific interventions were typically not under investigation in the literature addressing rehabilitation outcomes. Accordingly, a quality assessment was not conducted and levels of evidence were not assigned to specific findings in the present review. Equivalent study designs of intervention-based studies would be consistent with the assignment of level 3 or level 4 evidence (i.e., retrospective case-control or series study designs, respectively) for all findings reviewed herein.

## Results: Review of Study Findings

### Models of care

#### *Specialized acute and rehabilitative care (early vs. late admission and specialized vs. general care)*

The question of whether earlier as opposed to later admission to an organized specialist system of SCI care leads to enhanced outcomes is inexorably linked to a similar question of the benefit of specialist versus general SCI care; studies addressing both of these issues are summarized in **Table 1**. In all cases, the authors framed their studies as addressing either the question of delay or the question of the specialist nature of care, yet similar designs were employed for each (i.e., retrospective case-control). For those studies focusing on the timing of admission to a specialized SCI unit, it was either presumed or established that preceding acute care was conducted at a general hospital unit. For the present review, we have indicated this distinction in **Table 1** by noting those studies that focused on the specialist versus general care comparison. Often there was little or no verification of the gen-

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**Table 1.** Studies reviewed with information about early vs. delayed admission and general vs. specialized SCI care

| **Study** | **Study groups/time to admission** | **Outcome measure(s)** | **Study finding(s)** |
|---|---|---|---|
| Tator et al., 1995[5] | • Specialized care (median 5 hr)<br>• General care (13 hr) | Acute care LOS<br>Mortality<br>Neurological status | +<br>+<br>+ |
| DeVivo et al., 1990[9] | • ≤24 hr<br>• > 24 hr | LOS<br>Secondary complications<br>Neurological status | +<br>–<br>~ |
| Dalyan et al., 1998[8] | • ≤24 hr<br>• > 24 hr | Secondary complications (contractures) | + |
| Donovan et al., 1984[4] | • < 48 hr (Australia)<br>• 1–15 days (USMS)<br>• 16–30 days (USMS)<br>• 31–45 (USMS)<br>• 46–60 (USMS)<br>Increased admission time indicative of less specialized care | Secondary complications | + |
| Amin et al., 2005[10] | • ≤ 3 days<br>• > 3 days<br>or<br>• ≤7 days from referral<br>• > 7 days from referral | LOS<br><br><br>LOS | –<br><br><br>+ |
| Oakes et al., 1990[13] | • ≤ 11 days (for tetra)<br>• > 11 days<br>or<br>• ≤ 21 days (for para)<br>• > 21 days | LOS<br>Secondary complications | +<br>+ (tetra only) |
| Aung & El Masry, 1997[11] | • ≤1 wk<br>• < 2 months | LOS<br>Secondary complications | +<br>– |
| Sumida et al., 2001[16] | • ≤ 2 wk<br>• > 2 wk | Rehabilitation LOS<br>Functional status<br>Neurological status | +<br>+<br>+ |
| Heinemann et al., 1989[12] | • Specialized care (mean 27.5 days)<br>• General care (mean 60.8 days) | Rehabilitation LOS<br>Secondary complications (spine instability)<br>Functional status | –<br>+<br>+ (efficiency only) |

*(continued)*

**Table 1.** Continued

| Study | Study groups/time to admission | Outcome measure(s) | Study finding(s) |
|---|---|---|---|
| Yarkony et al., 1985[17] | • Specialized care (mean 29.9 days)<br>• General care (mean 66.3 days) | Secondary complications (contractures) | + |
| Scivoletto et al., 2005[14] | • ≤ 30 days<br>• 30–59 days<br>• > 60 days | Rehabilitation LOS<br>Functional status<br>Neurological status | ~<br>+<br>– |
| Smith et al., 2002[15] | • Specialized care<br>• General care (time to admission unspecified) | Secondary complications<br>Functional status<br>Social participation<br>Life satisfaction | +<br>+<br>+<br>~ |

*Note:* Underlining indicates study group condition with a positive result. + = beneficial outcome (significant difference); ~ = beneficial outcome (trend only); – = no difference noted for this outcome; LOS = length of stay; USMS = US Model Systems data.

eral nature of the preadmission care or the time of first admission, depending on the primary focus of the study.

In all studies, significant positive benefits were noted for at least one outcome measure associated with earlier admission or specialized versus general care. This was indicated in **Table 1** by the underlined study condition associated with the positive outcome(s) as well as an indication in the rightmost column denoting a significant difference or trend for the outcome measure(s). Several studies focused on these issues during the acute period of care only,[5,8,9] whereas other studies examined initial admission delays ranging from 1 week to 1 month and longer.[4,10–17] With one exception,[12] patients admitted earlier had reduced LOS, regardless of the considerable variation between studies in the definition of what constituted a delay in admission and whether LOS constituted total hospitalization time, time in acute care, or time in rehabilitation.[10,11,13,14,16]

Functional benefits were also demonstrated for individuals admitted earlier to specialist facilities[14,16] or for those receiving specialist versus general care.[15] Most notable were those studies examining this in a rehabilitative context. For example, Scivoletto et al.[14] reported that patients admitted earlier than 1 month postinjury had significantly greater gains and greater efficiency associated with the Barthel Index as well as greater mobility gains and efficiency as measured by the Rivermead Mobility Index, but there were no differences with respect to walking as measured by the Walking Index for SCI. Similarly, Sumida et al.[16] reported increased FIM™ gains and efficiencies for patients admitted earlier than 2 weeks postinjury as compared to those admitted later. These investigators also showed that for a majority of the various patient groups tested (i.e., paraplegia and tetraplegia, early and late), significant associations were seen between a measure of function (i.e., FIM™) and a measure of neurological status (i.e., ASIA motor scores). However, Scivoletto et al.[14] found no effect of early versus late admission on ASIA motor scores. In addition, Smith et al.[15] showed enhanced social participation and a trend for increased life satisfaction for patients receiving care in specialist versus general centers in a survey of 800 individuals living in the United Kingdom.

***Outpatient and follow-up care***

Several authors have noted the importance of providing continued, regular, specialized follow-up care after discharge from rehabilitation.[18–20] Bloemen-Vrencken et al.[21] described various follow-up programs for persons with SCI, noting only five of these being either experimental or quasi-experimental in nature. Of these, three studies were focused on evaluations of telemedicine or nursing education for the prevention of pressure sores or urinary tract infections (UTIs),[22–24] whereas the remaining two had broader goals of general heath and well-being.[25,26] Despite these reports, little direct evidence has been established for the effectiveness of different methods of providing follow-up care.

Of note, Dunn et al.[26] performed an exploratory study of the value of receiving regular, comprehensive outpatient health care follow-up and provided a comparison to patients who were deemed to have no access to these services. Although this investigation was limited by a poor description of the specific services offered to both the experimental and control groups, there were significant differences in the perceived health, independence, and absence of depression in patients seen regularly in outpatient clinics. In addition, this group had significantly less frequent occurrences of specific secondary conditions and also rated the severity of these conditions as less than those having no access to these clinics.[26] Although this trial was prospective in nature and attempted a quasi-experimental controlled methodology, the potential confounds (i.e., gender, completeness, race, age, veteran status) varied greatly between the experimental and control groups.

***More specialized, interdisciplinary acute SCI care is associated with faster transfers to rehabilitation and may result in fewer medical secondary complications, more efficient functional gains, and reductions in overall mortality.***

***Earlier admission to specialized, interdisciplinary SCI care is associated with reduced length of total hospital stay and greater and faster rehabilitation functional gains with fewer medical secondary complications.***

***Routine, comprehensive, specialist follow-up services are associated with improved health.***

***Prospective studies with controlled designs and blinded assessors are needed to strengthen the evidence and provide more direction as to an optimal model of care.***

**Rehabilitation outcomes (LOS, neurological status, and functional status)**

A brief summary of the articles examined for the present review containing findings related to LOS and neurological and functional status is provided in **Table 2**. Articles were only included if they contained an identifiable sample that was deemed representative of an overall heterogeneous population of individuals with traumatic SCI (e.g., unselected sample of a single or multicenter

**Table 2.** Articles reviewed with information about LOS and/or neurological and functional status

| First author, year | Country | Sample *n*, T/NT | Sample period | Primary outcome measures and definitions |
|---|---|---|---|---|
| Tooth et al., 2003[36] | Australia (single center) | 167, T | 1993–1998 | Rehabilitation LOS (time from bed mobilization to discharge in integrated unit), FIM™. |
| Burke et al., 1985[27] | Australia (single center) | 265, T | 1978–1982 | Frankel scale, LOS (total hospitalization in integrated SCI unit), complication frequency (urinary tract), mortality rate, skill attainment. |
| Chan & Chan, 2005[28] | China (Hong Kong) (single center) | 33, T | 2002 | AIS, FIM. |
| Fawcett et al., 2006[51] | Europe/USA (multicenter) | 217, T | Various | AIS, ASIA motor and sensory scores. |
| Ronen et al., 2004[32] | Israel (single center) | 1,367, T/NT | 1962–2002 | Rehabilitation LOS (first admission after injury and acute care to discharge), SCIM-II. |
| Catz et al., 2002[50] | Israel (single center) | 250, T | 1962–1992 | $T_{adm}$, Frankel grade, and conversion. |
| Scivoletto et al., 2004[64] | Italy (single center) | 284,T/NT | 1997–2001 | AIS, ASIA motor score. |
| Pagliacci et al., 2003[30] | Italy (multicenter) | 684, T | 1997–1999 | LOS (first admission after injury to discharge), neurologic improvement, complication frequency (pressure ulcers). |
| Celani et al., 2001[33] | Italy (multicenter) | 859, T/NT | 1989–1994 | Rehabilitation LOS (first admission after injury to last discharge), complication frequency (pressure ulcers), lesion level, $T_{adm}$. |
| Sumida et al., 2001[16] | Japan (multicenter) | 123, T | 1994–1997 | AIS, ASIA motor score, FIM™. |
| Post et al., 2005[31] | Netherlands (multicenter) | 157, T/NT | 2002–2003 | Functional rehabilitation LOS (time from moment person can sit in wheelchair for 3–4 hours to final discharge), FIM™. |
| Schonherr et al., 1999[35] | Netherlands (single center) | 55, T | 1988–1994 | FIM™, level, complication frequencies. |

**Table 2.** Continued

| **First author, year** | **Country** | **Sample *n*, T/NT** | **Sample period** | **Primary outcome measures and definitions** |
|---|---|---|---|---|
| Muslumanoglu et al., 1997[29] | Turkey (single center) | 52, T/NT | 1992–1995 | AISA (motor and light touch) scores, FIM™. |
| NSCICS, 2005[34] | USA (multicenter) | 23,683, T | 1973–2005 | $T_{adm}$, rehabilitation LOS (as of 1995 separate data available for acute care or rehabilitation days hospitalized, with all short-term discharge days applied to rehabilitation), complication frequency, level, ASIA, FIM™. |
| Ottenbacher et al., 2004[65] | USA (multicenter) | 11,042, T/NT | 1994–2001 | FIM™, mortality rate, discharge and follow-up setting. |
| Bode et al., 2002[42] | USA (multicenter) | 52, T | 1994–1998 | FIM™, rehabilitation LOS (number of weeks in rehabilitation center). |
| Geisler et al., 2001[52] | USA (multicenter) | 760, T | 1992–1998 | AIS, ASIA (motor and light touch) scores. |
| Marino et al., 1999[38] | USA (multicenter) | 3,585, T | 1988–1997 | Frankel, AIS, ASIA motor scores and level. |
| Eastwood et al., 1999[37] | USA (multicenter) | 3,904, T | 1990–1997 | Rehabilitation LOS (not defined in paper but data obtained from US Model Systems – see NSCICS 2005[39]), complication frequency (pressure sores, rehospitalization). |
| Morrison & Stanwyck, 1999[39] | USA (single center) | 127, T | 1991 & 1995 | Rehabilitation LOS (time from admission to discharge in rehabilitation facility), functional skills, complication frequency, employment status. |
| Ditunno et al., 1995[58] | USA (multicenter) | 14,791, T | 1988–1992 | Frankel, AIS, ASIA motor scores and levels, FIM™. |
| DeVivo et al., 1991[43] | USA (multicenter) | 13,763, T | 1973–1990 | Neurologic improvement, FIM™, LOS (total hospital stay from admission to acute care to discharge from rehabilitation for all admitted within 24 hr of injury), complication frequency (rehospitalization), survival rates. |

*(continued)*

**Table 2.** Continued

| First author, year | Country | Sample *n*, T/NT | Sample period | Primary outcome measures and definitions |
|---|---|---|---|---|
| Yarkony et al., 1990[41] | USA (single center) | 1,382, T | 1972–1986 | MBI, rehabilitation LOS (time from admission to discharge in rehabilitation facility). |
| Heinemann et al., 1989[12] | USA (single center) | 338, ? | 1981–1985 | MBI, rehabilitation LOS (time from admission to discharge in rehabilitation facility). |
| Yarkony et al., 1987[40] | USA (single center) | 711, T | 1973–1980 | MBI. |

*Note:* Length of stay (LOS) from this study included data from 25 centers providing rehabilitation-only care (i.e., rehabilitation LOS) and 7 centers providing integrated care (i.e., acute + rehabilitation LOS). AIS = AISA Impairment Scale; ASIA = American Spinal Injury Association; MBI = Modified Barthel Index; *n* = number in sample; NT = nontraumatic SCI; SCI = spinal cord injury; SCIM = Spinal Cord Independence Measure; T = traumatic SCI; $T_{adm}$ = time to admission.

study). Investigations that used matching or stratification procedures were excluded.

The most frequently used primary outcome measurement tools in the 25 articles selected for review (see **Table 1**) include the FIM™ (*n* = 11), LOS (*n* = 11), ASIA scores (*n* = 8), and AIS (*n* = 6). Another commonly used measure was secondary complication frequency (*n* = 7). Modified Barthel Index (MBI) (*n* = 3), Spinal Cord Independence Measure-II (SCIM-II) (*n* = 1), and others were used less frequently. The only data examined from these articles were those pertaining to traumatic SCI.

### *LOS*

*Country-by-country variation of LOS.* Several authors have discussed differences in rehabilitation LOS between countries or across other jurisdictions,[27–32] although there have been no direct comparisons made as the primary focus of a single investigation. Several reports of inpatient rehabilitation LOS from various countries are displayed in **Figure 1** as overall mean values derived from each study.[16,27,28,30,32–36] In some cases, these data points reflect a mean value calculated across several years (and placed at the mid-point of the sample period) or may have been calculated by consolidating data that were originally presented in two or more subgroups.

As has been noted by others[31,32] and as can clearly be seen in **Figure 1**, the data compiled by the US Model Systems (USMS) reflect shorter LOS as compared to reports from all other countries. It should be noted that not all SCI centers in the United States are part of the USMS, although the majority,[12,37–41] but not all,[42] of LOS values reported in the US literature consist of data from Model Systems centers. LOS values from 1973 to 2003 as reported in the most recent USMS Annual Report were used to represent US data and therefore may reflect biases inherent in those centers belonging to this network.[34]

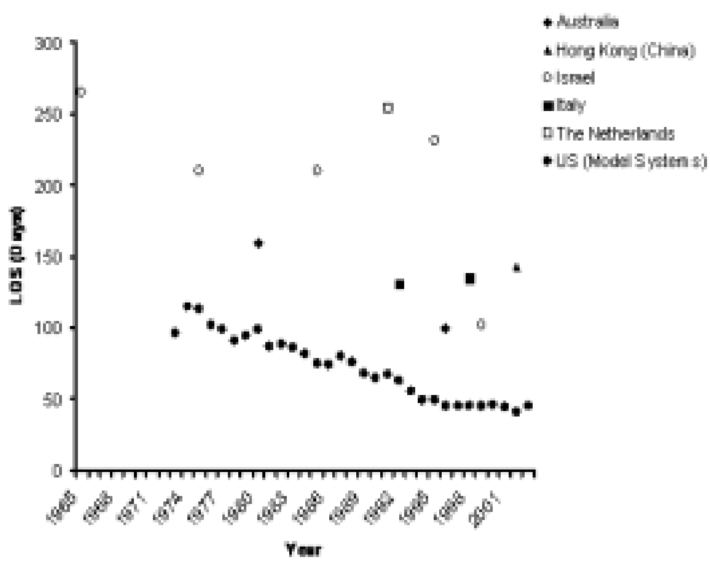


**Figure 1.** Reports of in-patient rehabilitation length of stay (LOS) from various countries.

*Variations of LOS over time.* It is apparent from **Figure 1** that there has been a systematic and ongoing reduction in rehabilitation LOS as is evident in the USMS data. This has continued from the inception of the USMS in 1973 until about 1996, after which the mean LOS values have remained relatively stable (i.e., 45 ± 1 days), to 2003, which was the final year with complete data.[34] Others have examined and identified the trend for progressively shorter LOS over the past several decades in the United States.[37,39,43] Stover noted that reductions in the 1970s and early 1980s were likely due to increased efficiency of rehabilitation teams.[44] More recent reductions in the United States have been attributed to restrictions imposed by third-party payers.[37,39]

Ronen et al. have provided data demonstrating reductions in LOS in Israel and have alluded to reductions in European data.[32] A correlational analysis conducted on the non-US data presented in **Figure 1** provides preliminary support for a trend for reduced LOS in non-US countries over the years (i.e., $r = 0.55$, $p = .062$).

*Relationship of other outcomes and LOS.* Numerous authors have noted significant variations in rehabilitation LOS with similar patterns identified across all studies describing rehabilitation LOS in individuals with varying injuries. In general, the greatest mean rehabilitation LOS values were seen for persons with complete tetraplegia (especially high level), whereas the shortest mean values occurred for those with incomplete paraplegia.[12,27,28,31–33,35–37,39–41,45,46]

More information has been gleaned from investigations with a primary focus on examining various predictive factors associated with LOS. Eastwood et al.[37] examined USMS data ($n$ = 3,904) from 1990 to 1997 using forward stepwise multivariate regression analysis and identified several factors associated with predicting longer LOS. The strongest predictor of LOS was functional status (i.e., longer LOS with lower admission motor FIM™ scores) in addition to the aforementioned effect of longer LOS with less recent admissions. Other significant factors included specific methods of bladder management, tetraplegia, race, education, marital status, discharge disposition, and age.

Other investigators have also demonstrated a strong association between LOS and functional status.[36,42,47] Ronen et al.[32] identified a tendency for longer LOS in individuals with lower initial SCIM-II scores, especially when LOS was short (i.e., <70 days). Similar observations were made by Tooth et al.,[36] who noted a relationship between function and LOS, although this was less clear in patients with lower functional status and longer LOS, indicating the difficulty in applying a single factor to predict LOS. Overall, it seems apparent that in persons with less function and more severe neurological impairment there may be other potential factors that interact to impact LOS to a greater extent. Of note, Post et al.[31] demonstrated that the presence of secondary complications (especially pressure sores) was associated with increased LOS.

Eastwood et al.[37] also noted a concomitant rise in the rehospitalization rate associated with the development of various secondary complications as well as a rise in the proportion of individuals discharged to skilled nursing facilities (as opposed to home) during the same period in which rehabilitation LOS was gradually getting shorter. Similar observations were noted by Cardenas et al.[48] and Morrison and Stanwyck.[39]

***Rehabilitation LOS in the United States has become progressively shorter than that reported from any other country.***

***There is preliminary evidence for a general trend of reduced LOS across countries.***

***Patients with higher injury levels, more severe injuries, and lower function have longer rehabilitation LOS.***

***Excessively short rehabilitation LOS has been linked to negative consequences including increased incidence of secondary complications and rehospitalization.***

### *Neurological status*

*Proportion of AIS/Frankel categories at rehabilitation admission and discharge.* Neurological status as assessed by the International Standards of Neurological Classification (ASIA)[49] is comprised of a physical examination of standard myotomes and dermatomes to determine motor and sensory scores, respectively, which also permits designation of motor and sensory neurological levels and classification by the AIS. Data from several investigators reflecting the proportions of patients that comprise each AIS (or Frankel) level at admission and discharge to rehabilitation are summarized in **Table 3**.

Even though these reports reflect quite different geographic locations (i.e., Australia,[27] Israel,[50] Italy,[30] Japan,[16] United States[38]) with the potential for differences in injury characteristics related to inherent regional etiological or health system patterns (e.g., time to admission [$T_{adm}$], LOS), their similarities are striking. Catz et al.[50] provides more disparate results. AIS A patients comprise 40%–50% of individuals admitted to SCI rehabilitation centers and a similar, but slightly reduced, percentage of those are assessed AIS A at discharge. AIS B and AIS C patients comprise ~5%–15% and ~10%–

**Table 3.** Percentage of patients at each AIS (or Frankel) category at admission and discharge

| AIS / Frankel | Admission | | | | | Discharge | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1985[27]** | **1999[38]** | **2001[16]** | **2002[50]** | **2003[30]** | **1985[27]** | **1999[38]** | **2001[16]** | **2002[50]** | **2003[30]** |
| *N* | 352 | 3,585 | 123 | 250 | 684 | | | | | |
| A (%) | 48.5 | 48.4 | 41.5 | 29.6 | 51.4 | 39.7 | 43.8 | 38.5 | 26.8 | 49.0 |
| B (%) | 14.9 | 14.0 | 6.5 | 16.8 | 10.7 | 11.8 | 9.9 | 4.1 | 12.8 | 5.3 |
| C (%) | 9.5 | 17.9 | 28.5 | 40.0 | 22.1 | 7.6 | 12.2 | 13.1 | 23.2 | 11.9 |
| D (%) | 23.3 | 19.7 | 23.6 | 13.6 | 14.0 | 27.1 | 33.8 | 36.1 | 26.0 | 28.7 |
| E (%) | 3.8 | 0.0 | 0.0 | 0.0 | 1.8 | 13.7 | 0.3 | 8.2 | 11.2 | 5.1 |

*Note:* AIS = American Spinal Injury Association Impairment Scale.

30%, respectively, with similar moderate reductions in these percentages manifest at discharge. Conversely, persons assessed as AIS D comprise ~15%–25% of those admitted, which increases to ~25%–35% by discharge.

*AIS/Frankel conversion rates.* Patterns of AIS conversion during initial inpatient rehabilitation have been provided in these same investigations[16,27,30,38,50]; these are presented in **Figures 2–5** from patients admitted as AIS A (**Figure 2**), AIS B (**Figure 3**), AIS C (**Figure 4**), and AIS D (**Figure 5**). Again, there is much uniformity across the various datasets, with Catz et al.[50] providing more disparate results. These differences might be due to the authors' acknowledged limitation associated with the retroactive assignment of Frankel grades from clinical notes. This was made necessary as quantitative measurement of neurologic deficit was introduced into the authors' practice only in the last decade of the study when there were also several updates to the AIS classification system.

As seen in **Figures 2** and **3**, the majority of patients assessed complete at admission remained AIS A at discharge, whereas a much greater proportion of individuals originally assessed AIS B recovered significant motor function during rehabilitation so as to be assessed AIS C or D. Similarly, among those originally assessed AIS C, more than 50% recovered significant motor neurological function to be assessed AIS D and a small percentage (i.e., <10%) recovered to AIS E. Conversely, the majority of patients initially assessed AIS D did not recover significant neurological function to convert to AIS E, which has been noted as evidence of a potential ceiling effect for the utility of the AIS as a tool in clinical trials.[51]

In the majority of reports, approximately15%–30% of patients did convert to AIS E. This was not the case with the large-scale reporting of the USMS data ($n = 3{,}585$), as only 1.2% of AIS D individuals (n = 399) were assessed AIS E at discharge.[38] This was likely due to the shorter LOS associated with the US data. By 1 year postinjury, Marino et al.[38] reported a conversion rate of 10.2% from D to E in the same group of patients.

It is less well established exactly when these conversions occur. Fawcett et al.[51] presented unpublished data from the European Multicenter Study in SCI and noted that

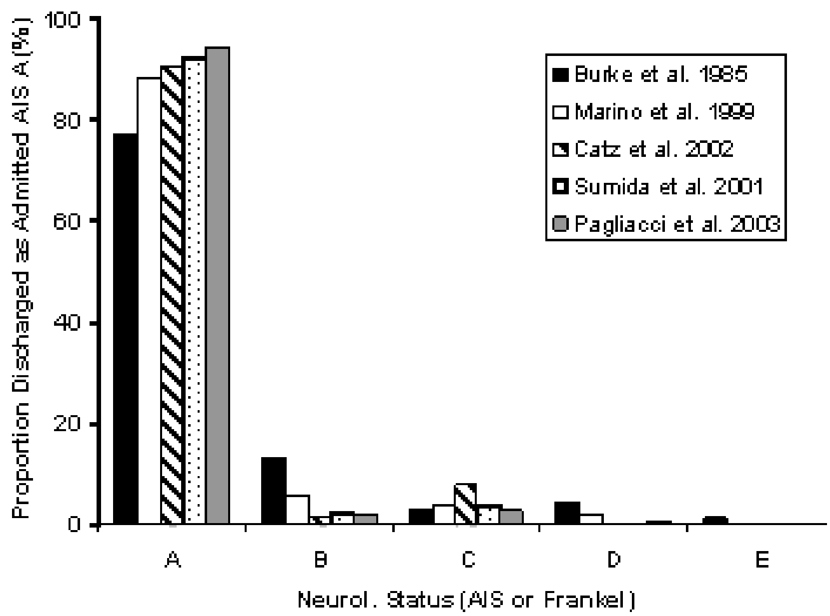


**Figure 2.** Proportion of patients discharged at each AIS level for those assessed AIS A at admission. AIS = American Spinal Injury Association Impairment Scale.

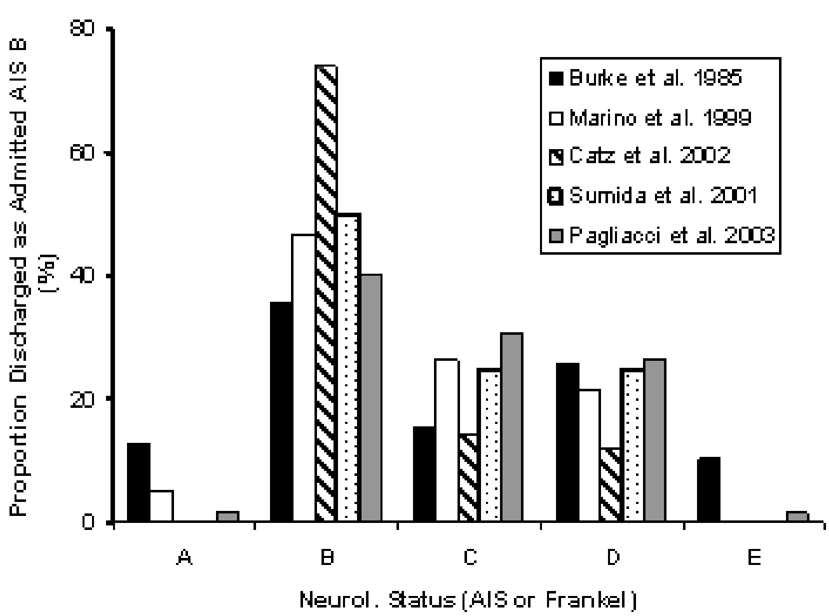


**Figure 3.** Proportion of patients discharged at each AIS level for those assessed AIS B at admission. AIS = American Spinal Injury Association Impairment Scale.

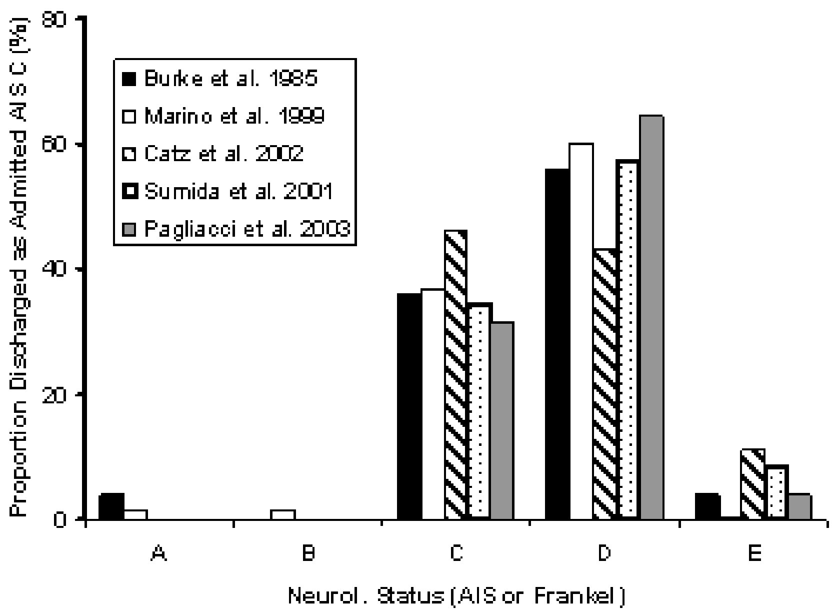


**Figure 4.** Proportion of patients discharged at each AIS level for those assessed AIS C at admission. AIS = American Spinal Injury Association Impairment Scale.

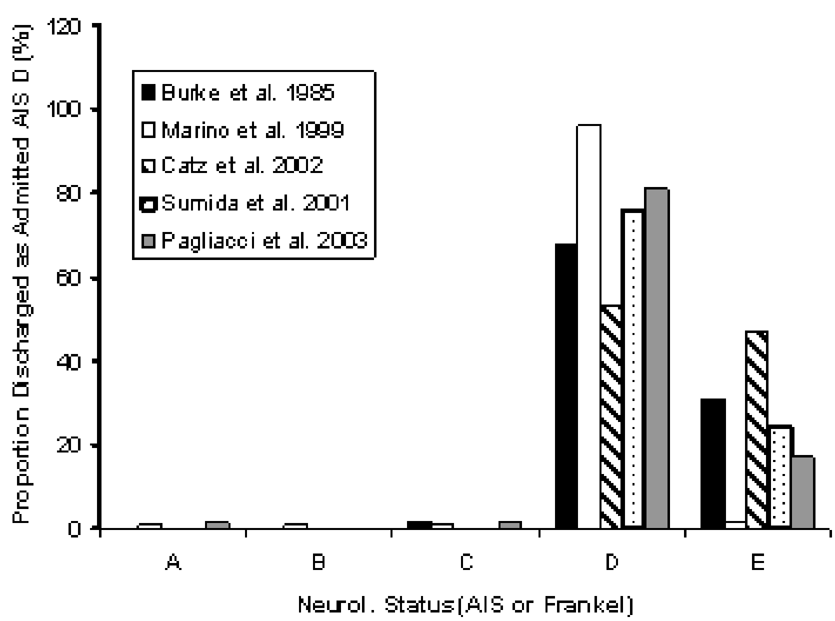


**Figure 5.** Proportion of patients discharged at each AIS level for those assessed AIS D at admission. AIS = American Spinal Injury Association Impairment Scale.

approximately 80% of AIS conversions ($n$ = 67) occurred in the first 3 months following injury. These findings are similar to those seen in a reanalysis of the Sygen study data[52] and also in reports by Bracken et al.[53] and Waters et al.[54,55] where over half of the expected recovery occurred in the first 2 months and continued but slowed noticeably after 3–6 months.

In addition, Kirshblum et al.[56] identified that a small proportion of individuals recovered neurological function after several years. They found that 5.6% of individuals assessed AIS A at 1 year postinjury converted to AIS B, C, or D by 5 years postinjury.[56]

***Functional status***

The Consortium for Spinal Cord Medicine's *Clinical Practice Guidelines*[57] provide a comprehensive review itemizing expected functional achievements for individuals at every level of SCI. Many individuals make significant functional gains during rehabilitation. Most often functional status has been assessed at admission and discharge from rehabilitation using the FIM™,[28,29,36,43,46,58] although other instruments have been used such as the MBI[40,41] or customized approaches assessing goal attainment with various functional tasks.[27,35,45] More recently, the SCIM and subsequent versions (SCIM-II, SCIM-III)[32,59,60] and the Needs Assessment Checklist (NAC)[47,61] have been advocated for use as SCI-specific measures. The FIM™ represents the most common outcome measurement tool in SCI rehabilitation and serves numerous purposes such as a basis for reimbursement[36] and as an outcome to assess intervention effectiveness or system change.

Typically, functional gains are greater during rehabilitation for patients with incomplete injuries as compared to complete injuries and for patients with paraplegia as compared to tetraplegia.[28,29,31,36,43,58] For example, DeVivo et al.[43] reported similar average FIM™ gains for patients with incomplete and complete paraplegia and incomplete tetraplegia (i.e., 37, 36, and 34, respectively) but much reduced gains for patients with complete tetraplegia (i.e., 15), as has been reported by numerous investigators.[29,31,36,43] These differences are even more striking when one examines FIM™ gain at specific levels and severity of injury (e.g., Hall et al.[46] described level-by-level differences in individuals assessed as AIS A, B, or C). Increases seen in the FIM™ during SCI rehabilitation are reflected mostly by motor FIM™ changes with little change in cognitive FIM™ scores due to a ceiling effect.[28,46]

***Most individuals make significant functional gains during inpatient rehabilitation, less so in complete tetraplegia.***

***A significant proportion of people improve 1 or more AIS grade(s) in the first few months postinjury, particularly those initially assessed AIS B and C.***

## Discussion

The evidence examined in the present review provides limited support for earlier admission to multidisciplinary, specialized SCI units and subsequent routine specialized follow-up services for achieving optimal outcomes. The provision of care and rehabilitation interventions are served upon a backdrop of a natural course of recovery that varies between individuals. Ideally, the rehabilitation process is intended to maximize functional potential and facilitate full community participation. Therefore, we have presented findings associated with the most common rehabilitation outcomes: LOS, a measure of health service delivery; FIM™, a measure of functional status; and AIS, a measure of neurological status. This review was conducted to provide further insight into the time course of expected outcomes and recovery and also to examine some of the shortcomings inherent in the literature examining these outcomes. Presentation of the findings related to measures of participation or health-related quality of life was beyond the scope of this article.

Despite the indication of support for early, specialized services, there are significant issues that serve to constrain the strength of evidence in this area. First and foremost was the retrospective nature of most studies. It was difficult to ascertain how comparable the "early" versus "later" groups truly were with respect to potential confounding variables. In particular, there was a paucity of information on the preadmission level of care and medical status, especially for the delayed admission groups, and the details of the specific differences that might be manifest in "specialized" versus "general care." There was considerable variation between studies that may have been related to regional health system differences, including whether studies were conducted in a system of integrated or distinct acute/rehabilitation service delivery models, at what point along the care continuum they were conducted, and how LOS may have been defined. In addition, it was difficult to discern the potential role that medical status may have played in admission delays. The retrospective nature of these studies makes it difficult to determine whether individuals with poorer medical status comprised a greater proportion of the delayed admission groups. Finally, issues that serve to limit the ability to design and conduct future trials in this area include the relatively low incidence of SCI requiring many centers to mount a reasonably powered trial, difficulty in obtaining adequate controls, and the inherent difficulty in ascribing potential outcomes to such a multifaceted process as rehabilitation. More carefully controlled prospective studies, preferably with blinded assessors, would be difficult to implement, but they are required to strengthen the evidence in this area.

These concerns were amplified by a closer examination of specific findings of rehabilitation measures. For example, it is obvious from the country-to-country variation in rehabilitation LOS that there are widely divergent approaches to health care service delivery. These differences may be partially responsible for the variety of definitions for LOS noted between studies, although individual investigators also bear some responsibility for a lack of clarity. It is suggested that investigators need to better describe LOS in relation to time of injury or onset and also describe the care received prior to admission (e.g., acute care LOS, acute care $T_{adm}$) as well as make explicit reference of how LOS was calculated.

These regional variations can impact the specific findings obtained from a particular study and therefore must be considered when assessing study relevance and generalizability. For example, Eastwood et al.[37] noted that functional status was a strong predictor of LOS as determined with USMS data. However, in a Japanese study, admission varied from 2 weeks to more than 6 months postinjury and, therefore, functional status was not a good predictor of LOS.[16] Even despite a higher FIM™ score at admission, the LOS was longer for patients who were delayed in rehabilitation admission.

Without clarity of LOS, the relationship to other outcomes is less meaningful. FIM™ and AIS are often assessed at rehabilitation admission and discharge, but these should also be related to time postinjury, providing a link to the natural course of recovery. For example, Hall et al.[46(p1472)] indicated in their article on assessing the utility of the FIM™ in SCI that data were included for patients admitted to "*inpatient rehabilitation* [emphasis added] within 60 days after injury (mean days = 8, *SD* = 13 days; median = 1 day)." The median of 1 day indicates that 50% or more patients were admitted within 1 day of injury to inpatient rehabilitation and suggests that admission FIM™ scores were collected close to this time. This contrasts markedly with the situation described by Post et al.[31] who also examined FIM™ scores yet identified admission to rehabilitation as occurring after a mean of 48.6 days (median 31 days) for the acute hospital stay. Furthermore, rehabilitation was further subdivided into "acute" and "functional" phases and the admission FIM™ was not conducted until after the "acute" rehabilitation phase had ended (i.e., marked by the time for the patient to become "mobilized" in the wheelchair), which resulted in an additional mean of 48.8 days (median 35 days). Clearly, admission FIM™ values would be collected in this system after many discharges would have already taken place in the USMS framework described by Hall et al.[46]

There are additional factors that may serve to confound these measures that are also related to the time they are taken. For example, early assessments of AIS may be confounded by spinal shock whereas these assessments may be more reliable by 1 month postinjury; this could impact conversion rates if there are systematic differences in the time of data collection.[62] There is little information to indicate the degree to which measurement error (e.g., incorrect assignment of AIS) may play a role in the observed differences in conversion rates. It is possible that some of the individuals noted by Kirshblum et al.[56] who recovered neurological function after several years may have been incorrectly assigned an AIS grade in the original assessment.

Despite the wide variation in the timing of rehabilitation between countries, general patterns of neurological and functional status are strikingly similar. Part of this observation may be attributed to the specific features of the outcome measurement tools themselves. The AIS should primarily be used as a tool to classify patients; it may have use in rehabilitation or as a stratification tool in clinical trials. It is relatively insensitive to more subtle changes in neurological function and has an inherent ceiling effect with patients classified as AIS D. More responsive measures are the ASIA motor and sensory scores. The reader is referred to a recent article by Fawcett et al.[51] for a discussion of the natural course of recovery seen with these measures.

The FIM™ is also recognized as possessing limitations, with floor and ceiling effects evident in some subscales for persons with lower level or less severe injuries and reduced responsiveness especially in persons with high-level tetraplegia.[46] The FIM™ cognitive subscale is also subject to a ceiling effect for the majority of patients.

Comparisons across jurisdictions, as conducted in the present review, have numerous limitations. First, there is often inconsistent and/or missing information (e.g., $T_{adm}$ most frequently missing, and LOS with varying definitions) among the various reports. Second, definitions or perspectives regarding various rehabilitation processes may vary between regions, and the use of specific terms may imply different information to different people such as noted earlier in the different perspective of inpatient rehabilitation and methods for determining LOS between Hall et al.[46] and Post et al.[31] Third, there is some evidence from data collected in individuals following stroke that there are major limitations in pooling or comparing raw FIM™ data across countries.[63] This may be due to differences in training methodologies between countries, and specific mathematical adjustments were noted that would make group comparisons possible. In practice, as was noted in the present review, there are likely to be systematic differences in rehabilitation processes (i.e., as manifest by large differences in $T_{adm}$ and LOS). These were not routinely reported, which made country-by-country comparisons less meaningful.

Given these concerns, it is important that cross-jurisdictional comparisons are made with an explicit understanding of the nature of the care delivery system across the entire care continuum. For example, the observation that reduced rehabilitation LOS in USMS centers may have reached a point of negative consequences through increased incidence of secondary complications, increased rates of rehospitalization, or less than optimal functional outcomes[37,39,48] should be considered alongside other aspects of the care system that may impact this area. For example, enhancing the scope of outpatient and follow-up services, given the evidence for these programs in enhancing postdischarge health, might be considered as another mechanism for addressing these consequences. Of note, unpublished USMS data collected during a similar timeframe as two of these investigations (i.e., 1995–1999) demonstrated an increasing utilization of outpatient services over this time period. Emerging literature regarding postdischarge follow-up practices using telehealth initiatives are of interest in this regard, especially in improving pressure ulcer management that may in turn affect employment rates.[23] Phillips et al.[24] reported similar 1-year postdischarge improvements in health-related outcomes for newly injured SCI patients by using in-home telephone or video-based interventions versus standard follow-up care, but they have yet to determine the differential advantages of the two intervention methods and their associated program cost-savings. Regardless, all authors investigating the issue of the potential impact of reducing LOS acknowledged limitations within their studies and cited the need for further study, especially the investigation of health service delivery factors that also address long-term issues across the care continuum including personal, vocational, and family impact.[37,39,48]

Although some findings may have universal significance across regions, it is clear that evidence must be evaluated as to its relevance to the specific health system under consideration. Despite this limitation, the findings noted previously have some utility and raise some issues for further study. Specifically, in the context of present models of rehabilitation practice, the determination of optimal LOS for ensuring maximal function yet minimizing the negative consequences requires further study. Additional information regarding the natural history of neurological and functional recovery would aid the clinician and would also further inform clinical trial development. It also seems apparent that details in addition to LOS or $T_{adm}$ are needed to characterize the extent and nature of rehabilitation that is applied to individual acute SCI patients. More investigation into the specific features and components of the rehabilitation process (e.g., staffing issues, specific practices, structural elements, cost-benefit analyses) that may lead to optimal outcomes are urgently required. In addition, innovations to the practice of rehabilitation are certainly warranted, and these might best be guided by considering the various initiatives being conducted around the world in examining other models of care (e.g., Christopher Reeve NeuroRecovery Network, European Multicenter Study in SCI, enhancing postdischarge care, telehealth initiatives).

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