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Article

Predicting No and Low Responders and Outliers in Patients with Spinal Cord Injury

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Abstract

Background Patients with spinal cord injury (SCI) typically have longer lengths of stay (LOS) compared to other rehabilitation patients and show variable therapeutic responses. Identifying reliable predictors of functional outcomes is essential. This study aimed to find prognostic factors to detect patients with high/low functional response, prolonged LOS, and those discharged home. **Methods** We retrospectively reviewed charts of SCI patients admitted to our center since 1997, recording neurological status (International Standards for Neurological Classification of SCI), Spinal Cord Independence Measure (SCIM), and Walking Index for SCI (WISCI). Rehabilitation results were measured by treatment effectiveness, reflecting the proportion of potential improvement achieved. Patients with SCIM and WISCI effectiveness above the mean plus one standard deviation (SD) were considered outliers, as were those with LOS exceeding mean plus one SD. Forward stepwise multiple regression identified variables linked to high effectiveness, LOS, and discharge destination. **Results** A total of 1059 patients were included (739 males, mean age 50.8±18; 587 with non-traumatic etiology). There were 132 LOS outliers, 163 high SCIM responders, and 144 high WISCI responders; 913 were discharged home. Regression analysis found age, lesion level, and complications at admission and during rehabilitation predicted SCIM outliers; AIS grade, age, and rehabilitation complications predicted WISCI outliers; rehabilitation complications, discharge SCIM, bladder management independence, and lesion etiology were linked to longer LOS; discharge SCIM, fecal incontinence, and gender influenced home discharge. **Conclusions** Our data provide a basis for further research into the problem of SCI prognosis. Subgroups of subjects with poor or excellent rehabilitation prognosis could be recognized at the beginning of treatment based on clinical factors.

Keywords: spinal cord injury; outliers; outcomes; length of stay; discharge destination

1. Introduction

Spinal cord injuries (SCI) and lesions have a relatively lower incidence compared to other disabling conditions, such as stroke. The estimated incidence of traumatic SCI ranges from 3.3 to 195.4 cases per million people annually, depending on the country; however, obtaining reliable data can be challenging in certain regions [1]. Data on non-traumatic SCI are even more limited and often of low quality. Due to methodological challenges—such as varying inclusion/exclusion criteria, incomplete diagnoses, and underreporting—the reported incidence of non-traumatic SCI varies widely, from 11.4 new cases per million in Spain to 68 per million in Canada [2].

Despite their relative rarity, SCIs are typically associated with substantial economic burdens during and following inpatient rehabilitation [3]. Given that SCI affects multiple functional domains, rehabilitation must be multidisciplinary, involving motor therapy, occupational therapy, respiratory

training, urological rehabilitation, and, when necessary, speech and swallowing therapies. The cost of inpatient rehabilitation varies, averaging approximately \$106,890 in Canada and \$190,620 in the USA, but can reach as high as \$433,044 depending on lesion level and severity, associated injuries, and the occurrence of complications during the rehabilitation stay [3].

Although inpatient SCI rehabilitation is costly and time-intensive, it has been shown to improve functional outcomes and enhance quality of life [4]. Nonetheless, SCI patients generally have longer lengths of stay (LOS) compared to other rehabilitation populations [5] and exhibit heterogeneous therapeutic responses, with a large intermediate group demonstrating neither very favorable nor very poor prognoses, alongside distinct subgroups with excellent or poor outcomes [6]. This variability underscores the need for reliable predictors of functional outcomes. Accurate outcome prediction is crucial—not only to minimize unnecessary occupancy of rehabilitation beds but also to set realistic therapeutic goals, allocate resources effectively, and forecast individual patient prognoses [7].

The objectives of this study were twofold: (1) to identify reliable prognostic factors at admission capable of classifying patients into subgroups characterized by no, low, or high response to rehabilitation, prolonged LOS, and likelihood of discharge to home among patients admitted for first-time SCI rehabilitation; and (2) to quantify the relative risk (RR) associated with each significant variable for poor or excellent prognosis regarding both Activities of Daily Living (ADL) and walking ability, length of stay and discharge destination.

2. Materials and Methods

We conducted a retrospective review of the medical records of SCI patients admitted to our facilities from 1997 onwards, collecting the following information:

- Sex and age;
- Etiology (traumatic or non-traumatic);
- Complications present at admission and those occurring during the rehabilitation stay;
- Level of independence in bladder and bowel management;
- Neurological status assessed according to the International Standards for Neurological Classification of Spinal Cord Injury [8], including evaluation of the ASIA Impairment Scale (AIS) and neurological level;
- Spinal Cord Independence Measure (SCIM) version II or III [9];
- Walking Index for Spinal Cord Injury (WISCI) [10].

The rehabilitation program consisted of individualized physiotherapy sessions lasting 60 minutes each, conducted twice daily (with one session on Saturdays) for six days a week. When necessary, patients also received respiratory training or speech and swallowing therapy [11]. Occupational therapy was provided 2-3 times per week to enhance patients' abilities in activities of daily living. Both physiotherapy and occupational therapy continued throughout the entire hospitalization.

Patients with excellent or poor prognosis in terms of ADL and mobility were identified based on their degree of deviation from the mean treatment effectiveness. This classification was grounded on the assumption that the range of mean $\pm$ 1 standard deviation (SD) encompasses approximately two-thirds of observations. Treatment effectiveness was calculated using the formula:

Effectiveness = [(discharge score – initial score) / (maximum possible score – initial score)] $\times$ 100 [4,12].

This metric represents the percentage of potential improvement achieved during rehabilitation; thus, a patient reaching the maximum score at discharge attains 100% effectiveness. Effectiveness was determined for both SCIM and WISCI scores.

Patients whose effectiveness fell within $\pm$ 1 SD of the mean were classified as standard responders. Those with effectiveness deviating beyond $\pm$ 1 SD were considered either excellent responders (high response group) or poor responders. The poor response group was further subdivided into “no response” (effectiveness equal to zero) and “low response” (effectiveness below

mean minus 1 SD but greater than zero) [12]. Length of stay (LOS) outliers were defined as patients whose rehabilitation duration exceeded the mean plus 1 SD [4]. Regarding discharge disposition, patients were categorized as either discharged home or transferred to a nursing home.

To control for the influence of lesion level and injury completeness, mean effectiveness and LOS were calculated separately for cervical, thoracic, and lumbar lesions, as well as for AIS A/B versus C/D groups. SCIM and WISCI outliers were identified based on their deviation from the mean effectiveness within these subgroups.

Data Analysis and Statistics

Multiple regression (forward stepwise) was performed to select the independent variables associated with high / low / no effectiveness, high LOS and destination discharge [4,12]. Independent variables: sex (female=0, male=1); age; etiology (non-traumatic=0 or traumatic=1); complications at admission and during rehabilitation stay (absent=0, present=1). For LOS and discharge destination we also considered SCIM at discharge, the independence in bladder and bowel management (independent=0, dependent=1). Then, we calculated the RR of high therapeutic response, high LOS and discharge destination.

3. Results

After excluding patients who died during the rehabilitation stay and those who were transferred before completing rehabilitation, a total of 1,059 patients were included in the analysis (739 males, mean age 50.8 ± 18 years, with 587 cases of non-traumatic etiology). At admission, 332 patients presented with complications. Regarding neurological characteristics, 93 patients had a cervical A/B lesion, 265 had a cervical C/D lesion, 254 had a thoracic A/B lesion, 243 a thoracic C/D lesion, 60 a lumbar A/B lesion, and 144 a lumbar C/D lesion. At admission 267 patients presented with complications (mainly pressure ulcers), and 318 patients developed complications during the rehabilitation stay. Mean LOS was 137 days. There were 132 outliers in length of stay (LOS), 163 patients showed a high SCIM response, and 144 were WISCI outliers. At discharge, 913 patients returned home, while the remaining 146 were transferred to a nursing home.

Regarding the independence in activities of daily living, regression analysis identified age, lesion level, complications at admission and during rehabilitation, and male gender as factors associated with being a low or non-responder on the SCIM; conversely, these same factors showed an opposite association with being a SCIM outlier (Table 1).

Table 1. Regression analysis model for SCIM no or low responders and SCIM outliers.

SCIM RESPONDERS	NO					
Model		Non standardized coefficients		Standardized coefficients	t	Sign .
		T	Errore std	Beta		
	(Costant)	0,005	0,021		0,24 1	0,80 9
	complicati ons during rehabilitat ion	0,062	0,012	0,16	5,28 9	<0.0 01

	age	0,001	0	0,094	3,077	0,002
	level	-0,023	0,008	-0,094	-3,079	0,002
	sex	-0,024	0,012	-0,063	-2,049	0,041
R=0.223						
SCIM LOW RESPONDERS						
	(Costant)	-0,11	0,037		-2,959	0,003
	age	0,005	0,001	0,258	8,777	<0.001
	complications during rehabilitation	0,094	0,024	0,119	3,94	<0.001
	complications at admission	0,095	0,025	0,117	3,871	<0.001
	sex	-0,065	0,024	-0,082	-2,761	0,006
R=0.336						
SCIM OUTLIERS						
	(Costant)	0,5	0,035		14,143	<0.001
	age	-0,004	0,001	-0,214	-7,295	<0.001
	level	-0,101	0,015	-0,198	-6,756	<0.001
	complications at admission	-0,085	0,024	-0,105	-3,477	0,001

	complications during rehabilitation	-0,077	0,024	-0,098	-3,247	0,001
R=0.322						

Age, complications both at admission and during rehabilitation, and traumatic etiology were linked to being a low or non-responder on the WISCI. The same factors, with inverse effects, were associated with being a WISCI outlier (Table 2).

Table 2. Regression analysis model for WISCI no or low responders and WISCI outliers.

WISCI NO RESPONDERS						
Model		Non standardized coefficients		Standardized coefficients	t	Sign.
		T	Error std	Beta		
	(Constant)	0,203	0,08		2,528	0,012
	age	0,006	0,001	0,237	6,223	<0.001
	complications at admission	0,213	0,044	0,177	4,798	<0.001
	complications during rehabilitation	0,141	0,038	0,134	3,69	<0.001
	AIS	-0,086	0,022	-0,142	-3,823	<0.001
	etiology	-0,125	0,035	-0,133	-3,55	<0.001
	level	-0,065	0,021	-0,113	-3,121	0,002
R=0.431						
WISCI LOW RESPONDERS						

	(Constant)	-0,012	0,006		- 1,942	0,053
	level	0,02	0,005	0,16	4,048	<0.001
	complications at admission	0,028	0,011	0,105	2,656	0,008
R=0.184						
WISCI OUTLIERS						
	(Constant)	0,15	0,03		5,015	<0.001
	AIS	0,109	0,008	0,39	12,982	<0.001
	age	-0,004	0,001	-0,192	- 6,549	<0.001
	complications during rehabilitation	-0,047	0,022	-0,063	- 2,155	0,031
R=0.411						

The presence of complications during rehabilitation, discharge SCIM score, independence in bladder management, and traumatic etiology were related to longer LOS (Table 3).

Table 3. Regression analysis model for LOS outliers.

LOS OUTLIERS						
Model		Non standardized coefficients		Standardized coefficients	t	Sign.
		T	Errore std	Beta		
	(Costant)	0,056	0,053		1,055	0,292
	complications during rehabilitation	0,089	0,023	0,124	3,824	<0.001
	SCIM at discharge	-0,002	0,001	-0,16	- 3,528	<0.001

	micturition independence	0,084	0,035	0,106	2,437	0,015
	etiology	0,063	0,022	0,095	2,842	0,005
	age	0,001	0,001	0,08	2,314	0,021
R=0.230						

Finally, discharge SCIM score, presence of fecal incontinence, and male gender were associated with a higher likelihood of discharge to home (Table 4).

Table 4. Regression analysis model for discharge destination.

DISCHARGE DESTINATION						
	(Costant)	0,722	0,037		19,726	0
	SCIM at discharge	0,003	0	0,238	6,769	0
	faecal incontinence	-0,095	0,033	-0,101	-2,879	0,004
	sex	-0,055	0,022	-0,074	-2,493	0,013
R=0.315						

4. Discussion

Our results confirm the high variability of therapeutic response in spinal cord injury rehabilitation. About 60% of the subjects of the present cohort had a standard therapeutic response on activities of daily living (as assessed by the SCIM) and mobility (as assessed by the WISCI), while the remaining 40% had either a poor or an excellent prognosis.

Furthermore, our results indicate that it is possible to recognize with some confidence subgroups of patients at the beginning of treatment with different therapeutic responses.

In particular, different therapeutic groups can be identified at admission on the basis of different prognostic factors.

For some of these factors (for example the level and severity of the lesion) the effect is self-explaining and at present there is no possibility to improve these factors. The correlations observed between SCIM and WISCI at discharge and lesions at the lumbar or thoracic spinal cord (i.e., less severe injuries) and younger age align with previously published data. Both the level and severity of spinal cord injury (SCI) significantly impact rehabilitation outcomes, with existing literature highlighting the crucial role of injury location in determining functional recovery and quality of life [12]. Individuals with cervical SCI generally face more rehabilitation challenges than those with thoracic or lumbar injuries, primarily due to the more profound effects on upper limb function and overall mobility [13]. Additionally, the severity of the injury, as measured by the ASIA impairment scale, is linked to the extent of functional impairment and the potential for meaningful recovery [14]. Individuals classified as AIS A, B, or C tend to show better improvements in functional independence if the SCI occurs at a caudal level rather than at the cervical level. Similarly, those with complete SCI (AIS A) exhibit higher SCIM scores when the injury is located at a caudal level [14].

Studies on the effect of age on SCI rehabilitation outcomes indicate that younger individuals typically experience better recovery than older adults. This enhanced recovery in younger patients is often attributed to greater neural plasticity and a lower prevalence of comorbid conditions, which support their ability to adapt to injury [15]. In contrast, older adults with SCI face greater challenges

due to age-related factors such as reduced muscle mass, lower bone density, and the presence of comorbidities, all of which can hinder the rehabilitation process and limit functional recovery. Furthermore, slower neurological regeneration in older patients may restrict the extent of improvement achievable through rehabilitation efforts [16].

The negative effect of traumatic etiology could probably be explained by the fact that this group of subjects could have associated lesions (brain, chest or bone injuries) that may represent an obstacle to functional achievement or slow down the rehabilitation process [17].

Gender was identified as a statistically significant prognostic factor, though it had the smallest influence among the factors considered. This result may align with the mixed findings in the literature, where gender shows a small but sometimes significant effect. To date, there is no widespread agreement on the correlation between gender and prognosis for recovery. Previous studies, including one involving 281 patients, found that gender does not appear to affect rehabilitation outcomes, despite significant epidemiological differences between males and females. Women with SCI had a lower frequency of traumatic injuries and complications at admission, but a higher incidence of incomplete injuries (ASIA impairment C) [18]. On the other hand, some research suggests that gender significantly influences the severity of SCI and the eventual recovery of motor function. Specifically, motor function recovery tends to be higher in females, potentially due to oestrogen's effects on pathophysiological processes, though the gender-specific mechanisms of neuroprotection remain unclear [19].

Our study aligns with previous research showing that complications at admission and during hospitalization, particularly pressure sores, negatively affect patients' functional status at discharge [20–22]. To fully understand this relationship, it is important to consider various factors, especially the role of "immobility" required for healing complications. This is especially relevant for pressure ulcers, as the need for immobility may delay achieving a sitting position, using a wheelchair, and reaching broader rehabilitation goals [23]. Additionally, complications like pressure ulcers can lead to a chronic inflammatory state, which includes anemia, low serum iron, hypoproteinemia, and hypoalbuminemia [24]. These conditions can severely impair the functional potential of patients [25]. Moreover, patients with complications typically experience longer hospital stays, receiving fewer hours or less intensive rehabilitation compared to those without complications [25].

With regard to LOS and discharge destination, these two variables are clearly influenced by other factors that are not clinical or demographic. A number of «barriers to discharge» (such as psychological and social status, economic support, having a house or not, the presence of architectonic barriers at home) have not been taken into account because of the retrospective nature of this work.

Author Contributions: For research articles with several authors, a short paragraph specifying their individual contributions must be provided. The following statements should be used "Conceptualization, G.S.; methodology, L.B., F.T.; validation, S.V.C.; formal analysis, G.S.; investigation, E.L., V.P., S.T.; data curation, L.B. writing—original draft preparation, G.S., C.F.; writing—review and editing, F.T.; project administration, G.S. All authors have read and agreed to the published version of the manuscript."

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