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ORIGINAL ARTICLE

Multicenter study on predictors of rehabilitation outcome and home discharge in people with non-traumatic spinal cord injuries

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ABSTRACT

BACKGROUND: Non-traumatic spinal cord injuries (NTSCI) represent an increasing public health concern, particularly in aging populations, yet there is limited literature on rehabilitation outcomes and key predictors of home discharge in this population.
AIM: This study evaluates the impact of demographic and clinical characteristics on rehabilitation outcomes and home discharge rates in individuals with NTSCI.
DESIGN: Prospective observational cohort study.
SETTING: Thirty-one specialized SCI centers in 13 Italian regions.
POPULATION: Individuals with NTSCI.
METHODS: Demographic and clinical characteristics of 394 rehabilitation were recorded at admission (T1) and discharge (T2). The American Spinal Injury Association (ASIA) Scale and Spinal Cord Independence Measure (SCIM) were used to assess motor function and functional independence. Binary logistic regression was employed to develop a predictive model for home discharge, incorporating categorical and continuous variables. Two common metrics for this purpose are the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC). Predictive factors for home discharge were analyzed using logistic regression and ROC curves.
RESULTS: 80% of participants were discharged home. Key predictors of home discharge included higher SCIM scores, younger age, and being married. The SCIM score at discharge was a stronger predictor of home discharge than at admission. Length of stay (LOS) was also a significant factor, with longer stays associated with better functional outcomes, particularly in individuals with severe impairments.
CONCLUSIONS: SCIM scores at discharge, age, and marital status emerged as key predictors of home discharge, highlighting the importance of personalized rehabilitation strategies and structured discharge planning. Tailoring rehabilitation programs to maximize SCIM score improvements may enhance home discharge rates and long-term patient outcomes.
CLINICAL REHABILITATION IMPACT: This study emphasizes the importance of continuous functional assessment using SCIM during rehabilitation, allowing clinicians to optimize treatment plans and improve home discharge likelihood. Additionally, considering demographic factors such as age and marital status in discharge planning may facilitate better reintegration into home environments. Longer rehabilitation stays for individuals with more severe injuries (ASIA A/B) can significantly enhance outcomes. By incorporating these predictors into

everyday practice, rehabilitation clinics can better optimize patient care, increase home discharge rates, and improve overall quality of life post-rehabilitation.

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Key word: Spinal cord injuries; Rehabilitation; Length of stay; Recovery of function; Patient discharge.

Spinal cord injury (SCI) is a global health issue, affecting between 10.4 and 83 individuals per million each year.[1] Despite its significant burden on healthcare systems, comprehensive epidemiological studies remain limited.[2-4] Non-Traumatic Spinal Cord Injuries (NTSCI) encompass a diverse range of conditions unrelated to trauma, making their impact challenging to assess due to heterogeneous etiologies and underreporting in many countries. In developed nations, NTSCI has become more prevalent than traumatic spinal cord injuries (TSCI), with its incidence projected to rise due to aging populations.[5-7] This condition is associated with advanced age and can result from various causes, including degenerative spinal conditions, tumors, vascular disorders, infections, or inflammation. As the population ages, the incidence of NTSCI is expected to increase substantially in the coming decades.[1, 5, 8]

The rehabilitation of NTSCI has been widely recognized for its importance and effectiveness.[5-11] Despite this, practical guidelines for NTSCI rehabilitation remain relatively scarce in the literature.[1, 12] Although many aspects of rehabilitation for TSCI and NTSCI overlap, individuals with NTSCI exhibit unique characteristics related to degenerative, tumor-related, or infectious conditions. Functional improvements in this population are frequently measured using the spinal cord independence measure (SCIM). Notably, individuals with NTSCI often achieve lower rehabilitation outcomes compared to those with TSCI, as their condition is typically progressive, leading to delays in diagnosis and admission to specialized units.[9, 13, 14] A study by New *et al.* synthesized research on NTSCI rehabilitation and highlighted key challenges, including predictive factors for functional recovery, decisions regarding admission to specialized units, and secondary health complications.[9] These findings suggest that tailored rehabilitation programs could optimize functional recovery, including the development of rehabilitation strategies adapted to the specific needs of NTSCI individuals.[9, 10, 15, 16]

Several studies have highlighted a correlation between NTSCI etiology and rehabilitation outcomes.[7, 17] For instance, individuals with NTSCI due to vascular disorders or inflammation often require longer rehabilitation stays than those with other etiologies. Research has also shown that functional gains during rehabilitation may vary significantly depending on the underlying cause of NTSCI.[4] Individuals with degenerative SCIs tend to have the highest functional scores at both admission and discharge, whereas those with malignancy- or inflammation-related NTSCI experience poorer functional outcomes.[18] An Italian study by Citterio *et al.* on 330 individuals with NTSCI found that approximately 30% exhibited improvement according to the American Spinal Injury Association (ASIA) Impairment Scale.[14] This scale, originally designed for traumatic SCI, has recently been validated for NTSCI populations.[19, 20] Additionally, an increased prevalence of comorbidities such as obesity, diabetes, and cardiovascular diseases has been observed, potentially hindering neurological recovery and rehabilitation outcomes.[9]

The discharge destination following rehabilitation is a critical factor in NTSCI recovery. A Dutch study reported that 84% of individuals with NTSCI were discharged to private residences,[1] while an Italian study confirmed that home discharge is the most common outcome.[10] However, predicting neurological recovery, rehabilitation success, and survival in NTSCI remains challenging due to limited available research,[4, 6, 13, 18] highlighting the need for further studies.

Although numerous studies have identified predictors of rehabilitation outcomes in traumatic SCI, fewer have focused on NTSCI despite its increasing prevalence and significant impact on individuals. A systematic review explored predictive factors for home discharge but did not clearly distinguish between TSCI and NTSCI, limiting insights into the unique characteristics of these populations.[21] Some research has focused on specific predictors for NTSCI, such as caregiver support[22, 23] or mortality risk, but overall, the literature on NTSCI remains less extensive than that on TSCI.[24] This gap underscores the importance of further research to enhance rehabilitation strategies for individuals with NTSCI.

We hypothesized that demographic and clinical characteristics of individuals with NTSCI influence their likelihood of home discharge following intensive rehabilitation in specialized spinal cord injury centers. Furthermore, we posited that functional improvement is a key factor in home discharge outcomes: greater recovery of motor function significantly increases the probability of returning home.

Therefore, this study investigates how patient characteristics at admission and discharge influence rehabilitation outcomes, particularly the severity of impairment assessed through the ASIA scale and SCIM. Additionally, we aim to identify key rehabilitation-related factors that may predict home discharge and analyze functional gains in SCIM scores to determine their impact on discharge outcomes.

Materials and methods

Study description

This prospective observational cohort study was carried out from February 1st, 2013, to October 31st, 2015, by the Italian Spinal Cord Injury (SCI) study group, involving 31 specialized SCI centers across 13 Italian regions. The study was approved and funded by the Italian Ministry of Health (grant code: CCM number 15756 dated 17-07-2012). The research adhered to the principles set out in the Declaration of Helsinki. Consent from all participants was obtained from all participants prior to their inclusion. A regional network for systematic data collection was established under the oversight of the National Agency for Regional Health Services (Age.Na.S.).

All individuals consecutively admitted for a first-time hospitalization in specialized SCI centers with clinical signs of SCI, complete or incomplete, at any level, were included in the study without restrictions on age, nationality, or disease duration. However, individuals with SCI due to spinal metastasis, central nervous system disorders, or multiple sclerosis were excluded. Persons with traumatic SCI were also not included in the study.

The physiatrists at each participating center, responsible for the research project, collected data prospectively at admission (T1) and discharge (T2) throughout the hospitalization period. At admission, demographic and social data collected included: age, gender, level of education, occupation, and marital status. Additionally, clinical data were gathered, including the etiological diagnosis, categorized into seven groups: inflammatory, vascular, neoplastic, infectious, degenerative, demyelinating, and others. The severity of the injury was assessed using the ASIA Impairment Scale (ASIA).

During their hospitalization, individuals with NTSCI received treatment in accordance with the system's regulations and the guidelines of the Italian Society of Paraplegia (SIMS).

At T1 and T2, the following information was collected: management of bowel and bladder function. Regarding bladder management, data were gathered and categorized into different groups: self-catheterization, indwelling catheter, suprapubic catheter, and spontaneous voiding. The presence or absence of a central venous catheter (CVC) was also recorded. Additionally, SCIM and ASIA scores were assessed.

At T2 only, data on LOS and type of discharge destination collected. Regarding the type of destination after each participant's discharge, participants were classified into two groups: home discharge ("Yes") and non-home discharge ("No"). The latter included individuals transferred to other healthcare facilities or those who passed away during hospitalization.

Statistical analysis

Data collection

Categorical and continuous variables at hospital admission and discharge were collected for 394 patients, including ASIA impairment grade and total SCIM score.

Descriptive statistics

The distribution of categorical and continuous variables was summarized using means, medians, and frequencies.

Statistical modeling

Binary logistic regression was used to develop a predictive model for home discharge, incorporating both categorical and continuous variables as predictors. Selecting the most appropriate model is essential to derive meaningful insights. Two widely used model selection criteria are the Akaike information criterion (AIC) and the Bayesian information criterion (BIC). Both criteria penalize models with excessive parameters to prevent overfitting, balancing model fit and complexity.

AIC and BIC

AIC and BIC produce non-negative values, where lower values indicate a better-fitting model. However, the absolute values are not directly interpretable; instead, the focus is on relative differences between AIC and BIC values among candidate models. The general rule is to select the model with the lowest AIC or BIC value.

ROC curve analysis

Receiver operating characteristic (ROC) curve analysis was conducted for total SCIM at admission and discharge, stratified by ASIA impairment grade at admission. These curves were compared on the same graph to determine the optimal SCIM cut-off for distinguishing between patients discharged home and those discharged elsewhere. An ideal ROC curve exhibits a high Area Under the Curve (AUC), indicating strong predictive performance.

Software

The statistical analysis was performed using Jamovi v2.5 and R version 4.3.2.[25, 26]

Results

Sample description

Demographic and clinical characteristic

Over nearly three years, data were collected on 394 individuals with NTSCI, out of 1827 consecutive admissions to 31 SCI specialized rehabilitation centers (Figure 1). Among them, 244 participants (62%) were men and 150 (38%) were women, with a mean age of 60.0±16.1 years at admission.

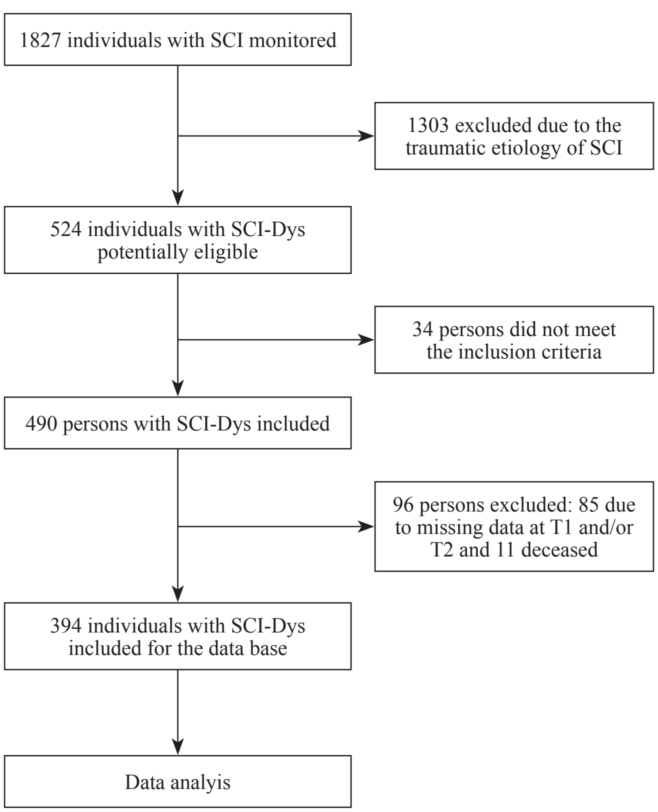


Figure 1.—CONSORT study flow chart.

Among the studied sample, 57% were married, 33% were unmarried, and 10% were classified as “other.” Regarding occupational status, 45% were retired, while 19% remained employed.

The most common causes of NTSCI were degenerative (28%), neoplastic (23%) and vascular (22%) etiologies. Infections cases accounted for 9%, inflammatory causes for 6%, while 12% were classified as having an unidentified etiology.

Concerning lesion level, 33% had tetraplegia, 63% had paraplegia, and 5% had an unspecified lesion level.

At admission, the most prevalent ASIA grades were AIS C (32%) and AIS D (39%), while AIS B and AIS A accounted for 15% and 12%, respectively. AIS E was the least common, representing only 1%.

Bladder management was also analyzed. The majority of the sample (66%, N.=262) used an indwelling catheter, while 28% practiced spontaneous bladder management.

During hospitalization, 11 individuals (2.8%) passed away. The mean length of stay (LOS) was 91.1±62.7 days, ranging from 0 to 352 days.

Upon discharge, 80% (307 individuals) returned home, while 20% were transferred to acute care units or other healthcare facilities.

Variables at admission

Significant association have been found regarding the severity of the lesion and the different considered variables (Kruskal-Wallis rank sum test for continuous or ordinal data, and Pearson’s Chi-squared test for categorical variables; $P<0.001$) at admission as shown in Table I. It has been demonstrated a significant association between the occupational status and the level of impairment (ASIA) at T1. Specifically, the majority of the sample (45%; N.=177) consists of retirees, among whom 50% (N.=77 of 154) present an ASIA score corresponding to D. Moreover, it is also observed that there is a significant relation between SCIM score and the ASIA scores in individuals with NTSCI. Indeed, the mean SCIM score is higher for ASIA D and E scores. Data show a significant correlation between the etiology of NTDys and neurological impairment at admission, with the more severe neurological impairment at admission observed in vascular etiology. The majority of individuals with severe lesions (38%), classi-

TABLE I.—*Variables assessed at admission in relation to the level of impairment assessed by ASIA.*

Variables	ASIA impairment (T1)					Total (N.=394)	P value
	A (N.=50)	B (N.=60)	C (N.=126)	D (N.=154)	E (N.=4)		
SCIM, score							<0.001[a]
Mean (SD)	17.5 (11.8)	21.6 (15.3)	28.5 (18.4)	39.5 (25.2)	68.8 (23.0)	30.8 (22.2)	
Median	16.0	17.0	23.0	38.0	62.5	24.0	
Q1-Q3	10.0, 23.0	12.0, 29.0	16.2, 42.0	20.0, 60.8	52.2, 79.0	15.0, 45.0	
Age, years							0.228[a]
Mean (SD)	57.3 (16.6)	58.6 (16.6)	62.1 (13.2)	60.0 (17.7)	45.8 (15.8)	60.0 (16.1)	
Median	61.5	60.0	62.5	66.0	49.5	63.0	
Q1-Q3	51.5, 69.0	49.5, 71.2	54.0, 72.5	47.0, 74.0	37.8, 57.5	51.0, 72.8	
Gender							0.483[b]
Female	19 (38.0%)	29 (48.3%)	46 (36.5%)	55 (35.7%)	1 (25.0%)	150 (38.1%)	
Male	31 (62.0%)	31 (51.7%)	80 (63.5%)	99 (64.3%)	3 (75.0%)	244 (61.9%)	
Education							0.338[b]
Unknown	15 (30.0%)	9 (15.0%)	26 (20.6%)	22 (14.3%)	-	72 (18.3%)	
≥9 years	12 (24.0%)	16 (26.7%)	37 (29.4%)	45 (29.2%)	2 (50.0%)	112 (28.4%)	
<9 years	23 (46.0%)	35 (58.3%)	63 (50.0%)	87 (56.5%)	2 (50.0%)	210 (53.3%)	
Married							0.606[b]
Unknown	5 (10.0%)	5 (8.3%)	14 (11.1%)	15 (9.7%)	-	39 (9.9%)	
Yes	31 (62.0%)	33 (55.0%)	78 (61.9%)	79 (51.3%)	2 (50.0%)	223 (56.6%)	
No	14 (28.0%)	22 (36.7%)	34 (27.0%)	60 (39.0%)	2 (50.0%)	132 (33.5%)	
Occupation							<0.001[b]
Unknown	6 (12.0%)	3 (5.0%)	8 (6.3%)	16 (10.4%)	-	33 (8.4%)	
Yes	15 (30.0%)	25 (41.7%)	58 (46.0%)	50 (32.5%)	4 (100.0%)	152 (38.6%)	
No	29 (58.0%)	32 (53.3%)	60 (47.6%)	88 (57.1%)	-	209 (53.0%)	
Level of lesion							0.047[b]
ND	3 (6.0%)	2 (3.3%)	2 (1.6%)	10 (6.5%)	1 (25.0%)	18 (4.6%)	
Para	34 (68.0%)	45 (75.0%)	80 (63.5%)	87 (56.5%)	1 (25.0%)	247 (62.7%)	
Tetra	13 (26.0%)	13 (21.7%)	44 (34.9%)	57 (37.0%)	2 (50.0%)	129 (32.7%)	
Type non-traumatic							<0.001[b]
Degenerative	6 (12.0%)	11 (18.3%)	30 (23.8%)	61 (39.6%)	1 (25.0%)	109 (27.7%)	
Demyelinating	-	-	1 (0.8%)	-	-	1 (0.3%)	
Infective	6 (12.0%)	7 (11.7%)	14 (11.1%)	10 (6.5%)	-	37 (9.4%)	
Inflammatory	1 (2.0%)	4 (6.7%)	7 (5.6%)	12 (7.8%)	-	24 (6.1%)	
Neoplastic	14 (28.0%)	9 (15.0%)	30 (23.8%)	35 (22.7%)	1 (25.0%)	89 (22.6%)	
Vascular	19 (38.0%)	22 (36.7%)	22 (17.5%)	24 (15.6%)	-	87 (22.1%)	
Others	4 (8.0%)	7 (11.7%)	22 (17.5%)	12 (7.8%)	2 (50.0%)	47 (11.9%)	

[a]Kruskal-Wallis rank sum test; [b]Pearson's Chi-squared Test.

fied as ASIA A, predominantly have a vascular etiology. In contrast, among those with less severe lesions, classified as ASIA D, the majority (40%) have a degenerative etiology.

Figure 2A shows that a longer length of stay (LOS) is associated with an increased likelihood of home discharge, irrespective of ASIA score. More severe injuries are associated with lower home return probabilities. Specifically, 85% of individuals with mild injuries (ASIA D and E) return home, while only 73% and 72% of those with severe injuries (ASIA A and B) do so. Figure 2B indicates that higher SCIM scores are associated with a greater likelihood of returning home after hospitalization. Those who do not return home generally have lower SCIM scores.

Variables at discharge

At T2, as shown in Table II, the improvement in SCIM scores at the end of the rehabilitation period was assessed. A significant association was identified between the extent of SCIM score improvement and the severity of the lesion at discharge. Indeed, the average gain obtained by subjects with an ASIA D and E score is the highest. for persons with an ASIA D score at discharge, the mean improvement is 32.1±25.1. For patients with an ASIA E score, the mean improvement is 32.0±18.1. Moreover, there is also a significant association between the LOS and the severity of the injury. Indeed, individuals with severe injuries (ASIA A and B) have a longer average LOS (122 and 128 days) compared to those with less severe injuries.

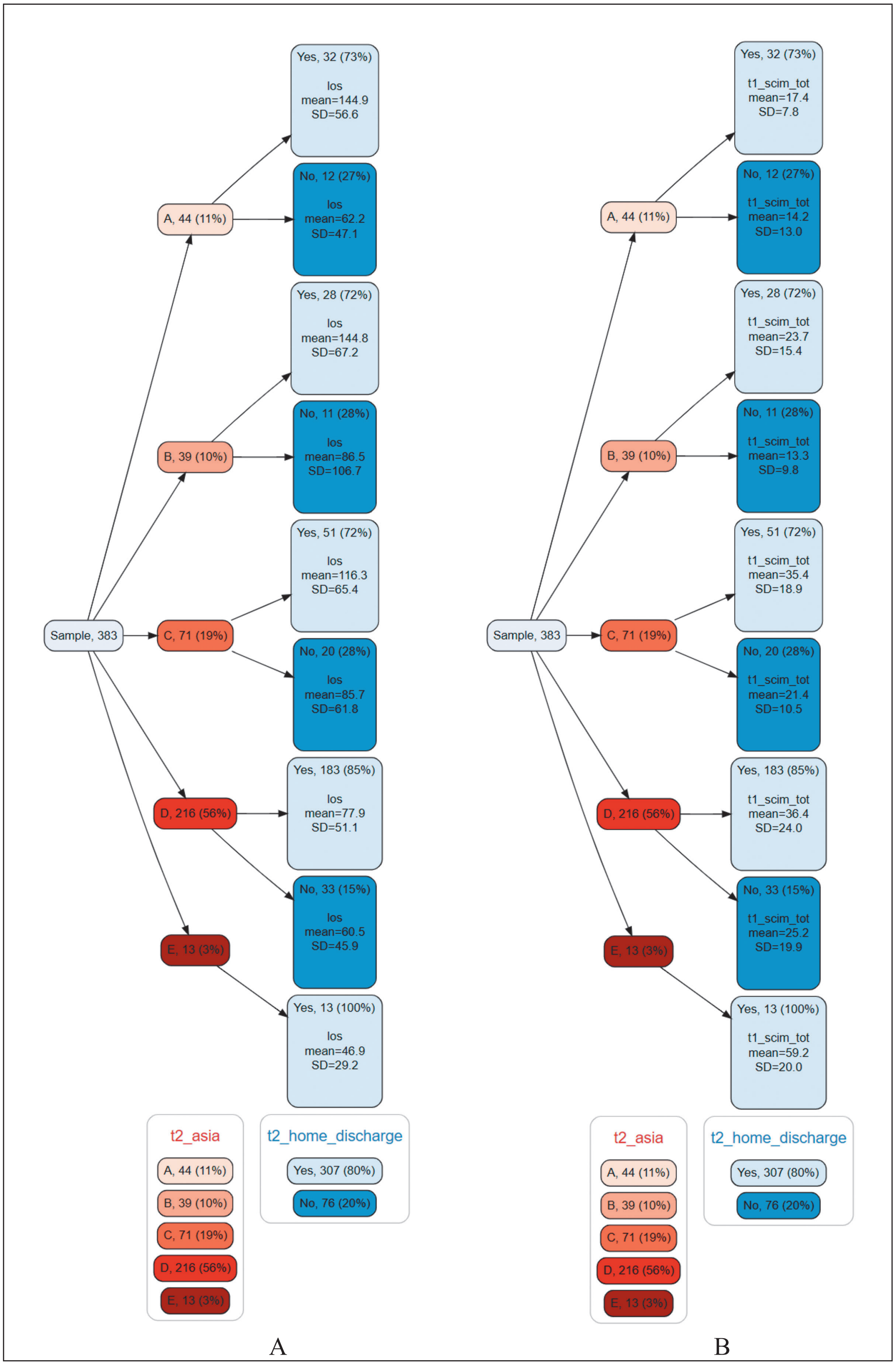


Figure 2.—figure 2.—a) Sample Description: ASIA and LOS for discharge home (VtrEE); b) Sample Description: ASIA(T2) an SCIM(T1) for discharge home (VtrEE).

Table II.—*Variables assessed at discharge.*

Variables	ASIA impairment (T2)					Total (N.=383)	P value
	A (N.=44)	B (N.=39)	C (N.=71)	D (N.=216)	E (N.=13)		
LoS, days							<0.001[a]
Mean±SD	122.4±65.3	128.3±83.1	107.6±65.4	75.3±50.7	46.9±29.2	91.1±62.7	
Median	117.5	134.0	94.0	63.5	52.0	79.0	
Q1-Q3	76.8, 166.2	55.5, 174.0	67.0, 134.5	38.8, 105.8	20.0, 62.0	43.0, 121.5	
SCIM, score							<0.001[a]
Mean±SD	35.4±24.6	36.7±26.3	54.9±25.2	66.8±29.8	91.2±9.7	58.7±30.7	
Median	37.0	32.0	62.0	78.0	97.0	69.0	
Q1-Q3	14.0, 56.5	14.0, 63.5	37.5, 73.0	54.8, 87.0	83.0, 100.0	36.0, 84.0	
SCIM, gain							<0.001[a]
Mean±SD	18.9±22.9	15.9±17.8	23.4±19.5	32.1±25.1	32.0±18.1	27.3±23.7	
Median	15.5	12.0	22.0	30.0	35.0	25.0	
Q1-Q3	0.0, 38.2	0.0, 31.0	9.0, 37.5	14.0, 52.2	17.0, 44.0	7.0, 44.0	
SCIM (change)							0.009[b]
+	4 (9.1%)	3 (7.7%)	4 (5.6%)	3 (1.4%)	-	14 (3.7%)	
=	9 (20.5%)	12 (30.8%)	7 (9.9%)	33 (15.3%)	1 (7.7%)	62 (16.2%)	
-	31 (70.5%)	24 (61.5%)	60 (84.5%)	180 (83.3%)	12 (92.3%)	307 (80.2%)	
Discharge at home							0.015[b]
Yes	32 (72.7%)	28 (71.8%)	51 (71.8%)	183 (84.7%)	13 (100.0%)	307 (80.2%)	
No	12 (27.3%)	11 (28.2%)	20 (28.2%)	33 (15.3%)	-	76 (19.8%)	
ASIA (T1)							<0.001[b]
A	40 (90.9%)	3 (7.7%)	2 (2.8%)	2 (0.9%)	1 (7.7%)	48 (12.5%)	
B	1 (2.3%)	35 (89.7%)	7 (9.9%)	11 (5.1%)	-	54 (14.1%)	
C	3 (6.8%)		61 (85.9%)	56 (25.9%)	3 (23.1%)	123 (32.1%)	
D	-	1 (2.6%)	1 (1.4%)	147 (68.1%)	5 (38.5%)	154 (40.2%)	
E	-	-	-	-	4 (30.8%)	4 (1.0%)	
Non-traumatic types (T1)							<0.001[b]
Degenerative	5 (11.4%)	7 (17.9%)	15 (21.1%)	79 (36.6%)	2 (15.4%)	108 (28.2%)	
Demyelinating	-	-	1 (1.4%)	-	-	1 (0.3%)	
Infective	5 (11.4%)	3 (7.7%)	12 (16.9%)	14 (6.5%)	1 (7.7%)	35 (9.1%)	
Inflammatory	1 (2.3%)	1 (2.6%)	4 (5.6%)	16 (7.4%)	2 (15.4%)	24 (6.3%)	
Neoplastic	12 (27.3%)	5 (12.8%)	14 (19.7%)	49 (22.7%)	4 (30.8%)	84 (21.9%)	
Vascular	17 (38.6%)	18 (46.2%)	10 (14.1%)	38 (17.6%)	2 (15.4%)	85 (22.2%)	
Others	4 (9.1%)	5 (12.8%)	15 (21.1%)	20 (9.3%)	2 (15.4%)	46 (12.0%)	

[a]Kruskal-Wallis rank sum test; [b]Pearson's Chi-squared Test.

The analysis identified a significant factor related to injury severity: the presence of a CVC. Indeed, the majority of the sample (94%) did not exhibit a CVC, and most of these individuals had an ASIA score of D. In contrast, among those with a CVC, the majority had a more severe ASIA score. Another significant factor related to the severity of the injury is bladder management. It has been observed that patients with the highest ASIA scores (D and E) manage their bladders spontaneously. In contrast, among those using an indwelling catheter (18% of the sample), a majority have lower ASIA scores, with 50% having an ASIA score of A. Additionally, it was noted that the spontaneous bowel management was significantly associated with the severity of the injury.

Univariate analysis

The univariate analysis (Table III) conducted on individuals discharged home compared to those not discharged revealed several statistically significant differences between the two groups.

Firstly, the participants discharged home had a significantly higher total SCIM score at discharge (median 29.0) compared to those not discharged (median 18.0). This suggests that a better functional score is associated with a higher likelihood of being discharged home. Secondly, the average age of the individuals discharged home was significantly lower (median 62.0 years) compared to those not discharged (median 67.0 years), indicating that younger participants have a higher probability of being discharged home. The third significant factor pertains to marital status: a higher percentage of married individuals were discharged home (184/307) compared to those not discharged (35/76), suggesting that having family support can positively influence the likelihood of being discharged home. Another finding concerns the presence of CVC. Those not discharged had a significantly higher proportion

TABLE III.—*Cross table for dependent (univariate analysis).*

Variables	Discharge at home		Test statistic
	Yes	No	
	N. (%), median [IQR]		
Sample	307 (80.2%)	76 (19.8%)	
SCIM tot (T1)	29.0 [34.5]	18.0 [14]	$F_{1,381}$=24.14, P<0.01[c]
Age	62.0 [21.0]	67.0 [20.5]	$F_{1,381}$=5.93, P=0.02[c]
Gender, male	188 (61.2%)	48 (63.2%)	$\chi^2(1)$=0.09, P=0.76[b]
Occupation			$\chi^2(2)$=1.71, P=0.43[b]
No	157 (51.1%)	45 (59.2%)	
Yes	125 (40.7%)	25 (32.9%)	
Unknown	25 (8.1%)	6 (7.9%)	
Married			$\chi^2(2)$=8.38, P=0.02[b]
No	100 (32.6%)	28 (36.8%)	
Yes	184 (59.9%)	35 (46.1%)	
Unknown	23 (7.5%)	13 (17.1%)	
Level of lesion			$\chi^2(2)$ =0.42, P=0.81[b]
ND	13 (4.2%)	2 (2.6%)	
Para	194 (63.2%)	49 (64.5%)	
Tetra	100 (32.6%)	25 (32.9%)	
ASIA impairment (T1)			$\chi^2(4)$=3.12, P=0.54[b]
A	35 (11.4%)	13 (17.1%)	
B	43 (14.0%)	11 (14.5%)	
C	98 (31.9%)	25 (32.9%)	
D	127 (41.4%)	27 (35.5%)	
E	4 (1.3%)		
Type non-traumatic			$\chi^2(6)$=8.56, P=0.20[b]
Degenerative	95 (30.9%)	12 (15.8%)	
Demyelinating	2 (0.7%)		
Infective	26 (8.5%)	9 (11.8%)	
Inflammatory	20 (6.5%)	4 (5.3%)	
Neoplastic	65 (21.2%)	19 (25.0%)	
Others	35 (11.4%)	11 (14.5%)	
Vascular	64 (20.8%)	21 (27.6%)	
CVC, Yes	27 (8.8%)	20 (26.3%)	$\chi^2(1)$=17.37, P<0.01[b]
Bladder management (T1)			$\chi^2(4)$=22.22, P<0.01[b]
Catheterization	16 (5.2%)	3 (3.9%)	
Indwelling time	185 (60.3%)	67 (88.2%)	
Spontaneous	104 (33.9%)	6 (7.9%)	
Suprapubic	2 (0.7%)		
Spontaneous bowel management, yes	76 (24.8%)	14 (18.4%)	$\chi^2(1)$=1.36, P=0.24[b]

[a]Kruskal-Wallis; [b]Pearson; [c]Wilcoxon.

of CVCs (26%) compared to those discharged (9%), indicating that the need for a CVC may reduce the likelihood of being discharged home.

Logistic regression

Binomial logistic regression (Table IV, V, VI) was conducted to examine the predictors of discharge destination (at home *vs.* not at home) among individuals with non-traumatic spinal cord injury (SCI) at baseline (T1) and after the completion of rehabilitation treatment (T2). Model fit measures indicated that the model provided a good fit to the data, with a significant overall model test (χ^2=97.5, df=12, P<0.0001) and an explained variance (R^2_{McF}=0.255, R^2_T=0.287) of approximately 25.5%.

Omnibus likelihood ratio tests revealed significant associations between discharge destination and several predictors at both T1 and T2 evaluations. Specifically, length of stay (LOS) (T1: χ^2=28.2274, P<0.0001; T2: χ^2=28.3083, P<0.0001) and baseline spinal cord independence measure total score (T1_SCIM_tot) (T1: χ^2=14.6633, P=0.0001) significantly influenced discharge destination.

ROC curves

The analysis of the ROC (receiver operating characteristic) curves was conducted to evaluate the predictive accuracy of the total SCIM variables measured at admission (T1_

TABLE IV.—*Binomial logistic regression: model fit measures.*

Model	Deviance	AIC	BIC	R2McF	R2T	Overall model test		
						χ2	df	P value
1	284.137	310.137	361.461	0.255	0.287	97.502	12	<0.001

Models estimated using sample size of N.=383.

TABLE V.—*Binomial logistic regression: model coefficients, discharge at home.*

Predictor	Estimate	SE	Z	P value	OR	95% CI	
						Lower	Upper
Intercept	0.049	0.847	0.058	0.954	1.050	0.200	5.519
LOS	0.014	0.003	4.723	<0.001	1.015	1.008	1.021
Age	-0.001	0.010	-0.123	0.902	0.999	0.979	1.019
SCIM tot (T1)	0.032	0.009	3.601	<0.001	1.033	1.015	1.051
Gender							
M – F	-0.278	0.322	-0.863	0.388	0.757	0.403	1.424
ASIA (T2)							
B – A	-0.542	0.598	-0.906	0.365	0.582	0.180	1.877
C – A	-1.110	0.546	-2.032	0.042	0.329	0.113	0.961
D – A	-0.239	0.512	-0.466	0.641	0.787	0.289	2.149
E – A	15.070	1012.62	0.015	0.988	3.51e+6	0.000	Inf
Bladder management (T2) [ref. level: self-catheterization]							
Indwelling time	-1.410	0.496	-2.841	0.004	0.244	0.092	0.646
Catheterization	-0.660	0.567	-1.165	0.244	0.517	0.170	1.570
Suprapubic	15.939	1976.111	0.008	0.994	8.36e+6	0.000	Inf
Spontaneous	0.698	0.466	1.497	0.134	2.010	0.806	5.011

Estimates represent the log odds of "Discharge at home = yes" *vs.* "Discharge at home = no".
The cut-off value is set to 0.5.

TABLE VI.—*Binomial logistic regression: predictive measures.*

Accuracy	Specificity	Sensitivity	AUC
0.859	0.434	0.964	0.823

The cut-off value is set to 0.5.

SCIM_tot) and at discharge (T2_SCIM_tot) for the outcome of home discharge in individuals with NTSCI. The data were analyzed according to the ASIA grades at admission, excluding grade E due to insufficient cases (Figure 3).

For the total sample of 387 individuals, 77.78% were discharged home. The AUC (area under the curve) for T1_SCIM_tot was 0.696 with a 95% confidence interval of 0.648 to 0.742. In comparison, the AUC for T2_SCIM_tot was 0.785 with a 95% confidence interval of 0.741 to 0.825. The difference between the two AUCs was significant (P=0.0004), with an area difference of 0.0884 (95% CI: 0.0392-0.138). This indicates that T2_SCIM_tot has a superior predictive performance compared to T1_SCIM_tot.

Analyzing the data by individual ASIA grades, the following observations were made. For subjects with grade A (N.=49), 71.43% were discharged home. The AUC for

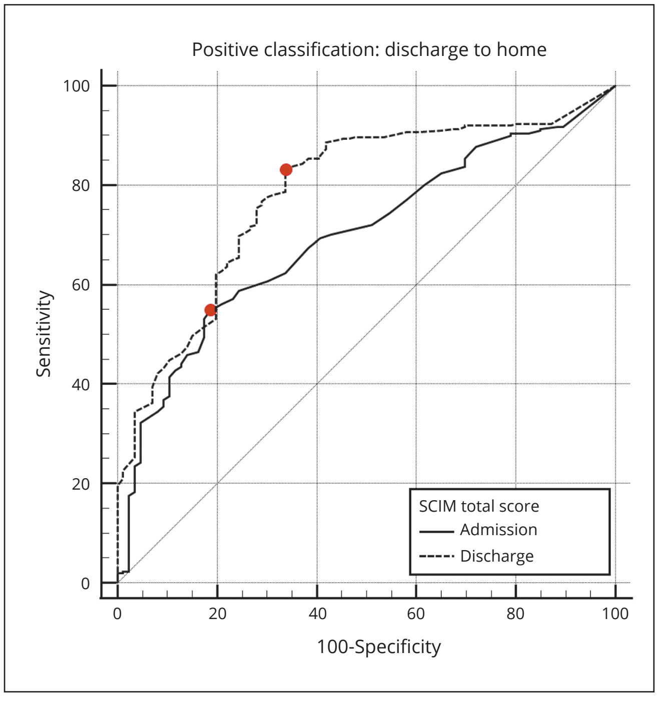


Figure 3.—Pairwise comparison of ROC curves (SCIM).

T1_SCIM_tot was 0.645 (95% CI: 0.495-0.776), while for T2_SCIM_tot it was 0.861 (95% CI: 0.732-0.943). The difference between the two AUCs was significant (P=0.0225), with an area difference of 0.216 (95% CI: 0.0305-0.402), suggesting that T2_SCIM_tot is a significantly better indicator for predicting discharge to home.

In the case of persons with grade B (N.=58), 70.69% were discharged home. The AUC for T1_SCIM_tot was 0.753 (95% CI: 0.622-0.857), and for T2_SCIM_tot it was 0.852 (95% CI: 0.734-0.932). The area difference between the two ROC curves was 0.0990 (95% CI: 0.000470-0.198), with a P=0.0489, highlighting that T2_SCIM_tot has a slightly better predictive performance compared to T1_SCIM_tot.

For individuals with grade C (N.=126), 77.78% were discharged home. The AUC for T1_SCIM_tot was 0.635 (95% CI: 0.545-0.719), and for T2_SCIM_tot it was 0.747 (95% CI: 0.662-0.820). The difference between the AUCs was 0.112 (95% CI: 0.0197-0.203), with a P=0.0173, indicating that T2_SCIM_tot had a significantly better predictive capability compared to T1_SCIM_tot.

Finally, for subjects with grade D (N.=149), 82.55% were discharged home. The AUC for T1_SCIM_tot was 0.717 (95% CI: 0.637-0.787), and for T2_SCIM_tot it was 0.780 (95% CI: 0.705-0.844). The area difference was 0.0633 (95% CI: -0.0401-0.167), with a P=0.2300, suggesting that there was no significant difference in the predictive capability between T1_SCIM_tot and T2_SCIM_tot for this group.

The ROC curve analysis comparing ASIA scores at admission (T1) and discharge (T2) further supports the significance of these assessments. As shown in Figure 4, the ASIA scores at discharge generally demonstrated better predictive accuracy for home discharge, particularly in individuals with ASIA grades A, B, and C. This suggests that the ASIA score at discharge is a critical factor in predicting rehabilitation success and the likelihood of home discharge.

In conclusion, the ROC curves show that the total SCIM variables measured at admission (T1_SCIM_tot) and at discharge (T2_SCIM_tot) have significant predictive capability for discharge to home in people with spinal cord injuries. However, T2_SCIM_tot generally shows superior performance compared to T1_SCIM_tot, with more pronounced differences in persons with ASIA grades A, B, and C, while for grade D, the difference was not significant. These results suggest that T2_SCIM_tot might be a more reliable indicator for predicting the outcome of discharge to home in these persons.

Discussion

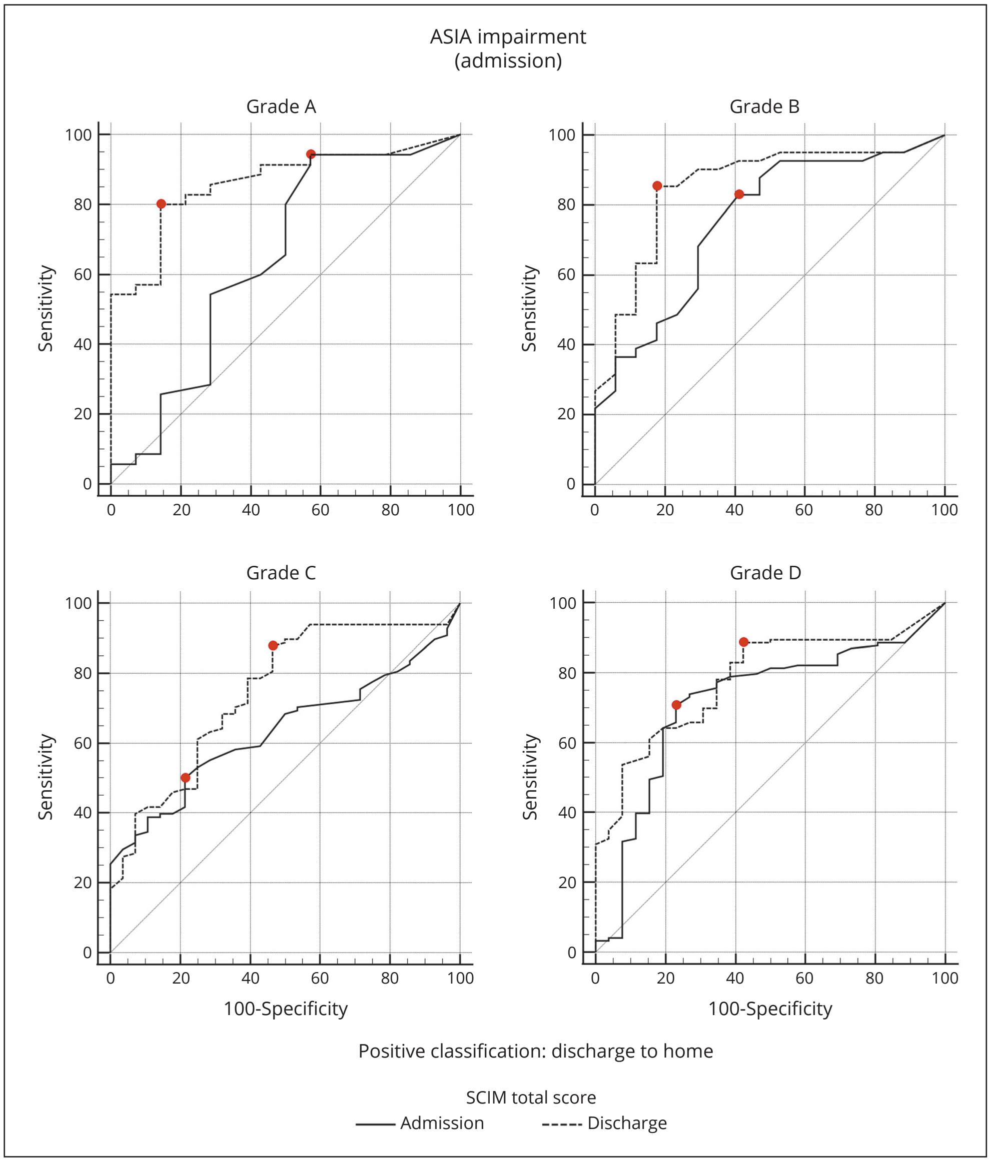
This prospective observational cohort study included 394 individuals with NTSCI, selected from 1827 consecutive admissions across 31 specialized SCI centers over nearly three years. The study aimed to investigate the impact of demographic and clinical characteristics at both admission and discharge on rehabilitation outcomes, particularly home discharge. Specifically, we assessed the predictive value of ASIA and SCIM scores in determining home discharge probability.

A key finding of this study was the strong predictive power of SCIM scores at discharge (T2) compared to admission (T1) in determining home discharge. The ROC curve analysis demonstrated that SCIM scores at discharge were significantly more predictive than those at admission, particularly for individuals with severe (Figure 3). Similarly, ASIA scores at discharge showed greater predictive capability than admission scores, particularly for more severe cases (Figure 4).

Moreover, the ROC analysis identified SCIM and ASIA cut-off values, helping clinicians detect patients at risk of failing to return home. This highlights the importance of functional assessment throughout the rehabilitation process, as SCIM scores measure improvements in activities of daily living essential for independent living. These results align with Vervoordeldonk *et al.*, who emphasized SCIM as a crucial indicator of home discharge in NTSCI individuals.[1] Similarly, New *et al.* underscored the importance of tailoring rehabilitation strategies based on SCIM and ASIA classifications to optimize functional recovery.[9] However, our study suggests that SCIM scores at discharge hold significantly greater predictive value than admission scores, reinforcing the necessity of continuous monitoring during rehabilitation.

The LOS also emerged as a key determinant of discharge outcomes. While our findings indicate that a longer LOS was associated with a lower likelihood of home discharge, particularly in individuals with severe lesions, they also suggest that extended hospitalization can lead to better rehabilitation outcomes for those with more severe impairments. This aligns with the study by Citterio *et al.*, which reported that longer LOS, especially in patients with significant neurological impairments, correlated with reduced chances of home discharge.[15, 27] Similarly, Alito *et al.* found that individuals with non-traumatic spinal cord injuries and severe impairments often experienced prolonged hospital stays and less favorable discharge outcomes.[2] However, our results suggest that lesion severity

Figure 4.—Pairwise comparison of ROC curves (ASIA).



may be a more decisive factor than rehabilitation duration alone. The ROC curve analysis further supports this, demonstrating a correlation between the predictive accuracy of discharge scores and LOS, particularly in patients with severe injuries. These findings highlight the importance of balanced discharge planning, where extended stays are complemented by targeted interventions to optimize functional recovery without unnecessarily prolonging hospitalization.

The study also reinforced the significant role of NTSCI etiology in rehabilitation outcomes. Specifically, vascular etiologies were associated with greater neurological impairment at admission, a trend consistent with previous literature.[15] This finding aligns with international studies such as those by New *et al.*, which found that individuals with vascular or neoplastic NTSCI had poorer functional outcomes compared to those with degenerative or inflammatory etiologies.[9, 28] These findings suggest that rehabilitation strategies should be tailored according to etiology to optimize patient outcomes.

Demographic and social factors also played a significant role in home discharge probability. Younger individuals, those who were married, and those without a CVC had a higher likelihood of being discharged home. These results are consistent with previous findings that highlight the role of social support – particularly marital status – in facilitating home discharge.[1, 9]

On the other hand, although occupational status was analyzed as a potential predictor of home discharge, it did not reach statistical significance in the analysis (P=0.432). Therefore, no strong association was found between employment status and the likelihood of home discharge. Studies on occupational status have focused more on traumatic SCI populations compared to NTSCI populations.[29] However, a recent study highlighted that while there are specific types of occupational status within SCI populations, it did not address the influence of occupational status on returning home.[30] This indicates that its impact on discharge outcomes remains inconclusive and further research is needed.

In terms of clinical characteristics, the presence of a CVC and bladder management methods were also associated with home discharge outcomes. Those requiring more intensive medical interventions, such as CVC use, were less likely to be discharged home, indicating the importance of addressing these medical needs in rehabilitation planning.

A comparative analysis with an Italian study conducted two decades ago highlights notable shifts in NTSCI characteristics. The earlier study reported a male prevalence of 63%, similar to our study (62%), and an average age of 55 years, compared to 60 years in our cohort. In terms of etiology, the previous study identified vascular and neoplastic causes as the most prevalent (25% each), while our study found degenerative (28%) and neoplastic (23%) causes to be the most frequent. These differences may reflect an aging population and evolving medical advancements. Additionally, the length of stay increased from 73.5 days to 91.1 days, potentially due to a higher incidence of cervical injuries leading to tetraplegia, which increased by 10% compared to the previous study. This shift suggests that rehabilitation needs have evolved, necessitating more intensive medical management before discharge. Notably, home discharge rates improved from 73% to 80%, reflecting enhanced pre-discharge planning and better coordination of community-based care.

When compared to international contexts, our findings reflect similar challenges observed in NTSCI rehabilitation. Studies from the Netherlands and the United States have reported that tailored rehabilitation programs addressing the specific needs of individuals with NTSCI significantly improve outcomes.[1, 9] However, variations in healthcare systems, discharge planning, and community support services necessitate localized approaches to optimize post-discharge reintegration.

Limitations of the study

While this study provides valuable insights into rehabilitation outcomes in NTSCI, certain limitations must be acknowledged. Although the sample covers almost all Italian regions, healthcare services in Italy are managed at the regional level, potentially introducing variations in rehabilitation practices that could influence outcomes. This variability may limit the generalizability of our findings to other healthcare systems.

Another limitation is the lack of long-term follow-up data. While this study focuses on rehabilitation outcomes at discharge, further research is needed to assess long-term functional gains, quality of life, and reintegration into home and community settings. Future studies should explore these post-discharge outcomes which are essential for guiding and optimizing the planning of rehabilitation pathways and to better understand the sustained impact of rehabilitation interventions.

Additionally, grouping NTSCI into a single category presents challenges, as this population includes individuals with fundamentally different pathologies. Variability in etiology, disease progression, and response to rehabilitation may influence outcomes, and future studies should investigate specific NTSCI subgroups to refine rehabilitation strategies further.

Finally, while this study identifies key predictors of home discharge, unmeasured factors – such as psychological well-being, social support, and access to post-rehabilitation services – may also play a significant role in patient outcomes. Incorporating these variables into future analyses could provide a more comprehensive understanding of factors influencing rehabilitation success.

Conclusions

This study demonstrates that both demographic and clinical characteristics significantly influence rehabilitation outcomes and discharge destinations in individuals with NTSCI. In particular, SCIM and ASIA scores at admission and discharge were strong predictors of home discharge, with discharge assessments showing superior predictive value. These findings emphasize the importance of continuous functional evaluation throughout rehabilitation to optimize patient outcomes.

The results highlight the need for structured, individualized rehabilitation programs that consider key predictors such as functional gains, length of stay, and social support. Younger age, marital status, and the absence of a CVC were also associated with higher home discharge rates, suggesting that social and medical factors should be integrated into discharge planning.

Furthermore, this study underscores the importance of balancing rehabilitation duration with the effectiveness of interventions, ensuring that extended stays are complemented by targeted therapies to maximize functional recovery.

Future research should investigate long-term outcomes and refine discharge planning strategies, with a focus on personalized rehabilitation pathways tailored to specific NTSCI subgroups. Developing evidence-based guidelines for rehabilitation and home discharge planning could enhance care for this growing population and improve post-rehabilitation quality of life.

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Conflicts of interest
The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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Authors' contributions
Marco Franceschini, Carrie-Louise Thouant, Maria C. Pagliacci, and Sanaz Pournajaf have made substantial contributions to the conception and design of the manuscript. Authors Salvatore Ferro, Jacopo Bonavita, Maria C. Pagliacci, and the Italian SCI Study Group were responsible for the collection of the data. Maurizio Agosti performed the statistical analysis and supervised the data interpretation in the manuscript throughout. Marco Franceschini, Sanaz Pournajaf, Maria C. Pagliacci and Carrie-Louise Thouant interpreted the data. All Authors participated in drafting the manuscript, while Francesca Gimigliano, Salvatore Ferro, Jacopo Bonavita, and Maria C. Pagliacci critically contributed in the revision of the manuscript. All authors read and approved the final version of the manuscript.

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