



ARTICLE

Impact of complications at admission to rehabilitation on the functional status of patients with spinal cord lesion

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Abstract

Study design Retrospective cohort study.

Objective Aim of the study is to evaluate the impact of complications at admission on the functional status of spinal cord lesions patients.

Setting Rehabilitation hospital in Italy.

Methods Two hundred and seven patients with complications (mostly pressure ulcers) at admission to rehabilitation were matched for neurological level of injury and AIS grade with 207 patients without complications. Measures: International Standards for Neurological Classification of Spinal Cord Injury, Spinal Cord Independence Measure, Rivermead Mobility Index, and Walking Index for Spinal Cord Injury. These measures were recorded at admission to rehabilitation and at discharge. We also recorded length of acute and rehabilitation stay and discharge destination. Statistics: Student's *T* test for paired samples, McNemar's chi-square test.

Results Patients with complications at admission suffered more often from a traumatic lesions. The functional status at admission and discharge of the patients without complications was significantly better than the functional status of patients with complications (Spinal Cord Independence Measure mean difference between the two groups 5.7 (CI 2.8–8.5) at admission, and 10 (CI 5.3–14.7) at discharge). Length of stay was significantly higher in patients with complications. Patients with complications were more often institutionalized than their counterparts (46/161 vs. 20/187, odds ratio 0.4 (CI 0.2–0.7)).

Conclusions Complications seem to be more frequent in patients with traumatic lesions. The presence of complications has a negative effect on patients' functional status at discharge and length of stay, and it determines a higher risk of being institutionalized.

Introduction

Traumatic and nontraumatic spinal cord lesions (SCL) occur at a rate of about 10–60 cases per million individuals depending on the country [1, 2] and may result in loss of independence and poor quality of life. Therefore, the

functional outcome is considered to be the most important outcome for patients with SCL [3]. As such, knowing the potential functional recovery and the factors that may affect it is of particular relevance to plan the rehabilitation treatment, set appropriate goals, decide how to allocate resources during inpatient rehabilitation and at discharge, and answer the questions from the patients [4].

Although the care of patients with SCL improved with time and has led to a high rate of survival, with only 3% of patients with traumatic SCL dying in the acute phase [5], this improvement in acute care is not paralleled by a comparable improvement of the prevention of complications [6]. Non-neurological complications are all the secondary conditions that develop after the initial injury and are not directly due to the trauma [7]. Typical complications reported after SCL are considered pressure ulcers, deep vein thrombosis, pulmonary embolism, heterotopic ossifications,

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respiratory complications, gastrointestinal and urological complications, pain, and spasticity. These secondary conditions are quoted in almost all articles dealing with complications after SCL although with different incidences depending on the phase of SCL, on the kind of complications taken into account, on the country and on the kind of center (specialized or non-specialized) [5, 7–22]. In developed countries the incidence of complications ranges from 32% of patients [8] to 71% [7] and does not seem to decrease with time [7, 8].

Although it is known that in general rehabilitation the presence of complications has a negative effect on functional outcome [23], in the field of SCL there is a relative paucity of studies in this area [8, 14, 15, 17, 19–22]. Furthermore, some of the available studies only assess the impact of complications on length of stay (LOS) and rehabilitation stay cost of patients with complications [8, 18] while others investigate the impact on functional status [14, 15, 17, 22, 24–27] and only a few evaluate the impact of complications on the neurological status [19, 27, 28].

The aim of this study is to evaluate the impact of the presence of some complications (pressure ulcers, deep vein thrombosis, pulmonary embolism, heterotopic ossifications, and urological complications) at admission to rehabilitation on the functional and neurological status of patients with SCL at admission and discharge.

Methods

We examined the charts of patients with either traumatic or nontraumatic SCL admitted to our Spinal Unit between 1996 and 2020 for their first rehabilitation treatment after the lesion. Patients were divided in two groups according to the presence or absence of complications at admission. According to previous studies [17, 21] we considered as complications the following: pressure ulcers, deep vein thrombosis, pulmonary embolism, heterotopic ossifications, and urological complications with the exclusion of urinary tract infection. We also considered the presence of associated lesions to the SCL (only for those with traumatic lesions). Associated lesions were traumatic brain injury, non-vertebral fractures requiring surgery, severe facial injuries affecting sense organs, major chest injury requiring chest tube or mechanical ventilation, severe hemorrhaging, or damage to any internal organ requiring surgery [21].

We recorded lesion to admission time (LTA, days) that represents the time spent in the acute ward, length of stay as rehabilitation in-patients (days), total length of stay (LTA + LOS, days), etiology of the lesion (traumatic or non-traumatic), and destination at discharge.

The neurological status was assessed by the International Standards for Neurological Classification of Spinal Cord

injury (ISNSCI) [29] with evaluation of total motor scores (MS), neurological level and ASIA Impairment Scale (AIS) grade. Neurological recovery was defined based on MS improvement and on AIS grade improvement of at least one grade.

The functional status at admission and discharge was assessed by:

- Spinal Cord Independence Measure (SCIM) version 2 or 3 for activities of daily-life independence [30, 31];
- Rivermead Mobility Index (RMI) for mobility [32];
- Walking Index for Spinal Cord Injury (WISCI) [33];
- MS, SCIM, RMI, and WISCI change scores were calculated based on the difference between discharge vs. admission. MS, SCIM, RMI, and WISCI scores efficiency was calculated as the ratio between the difference in scoring and the duration of the treatment (scales changes/rehabilitation stay). Efficiency score provides a basis for measuring the success of rehabilitation, in terms of both individual patient performances and rehabilitation center performance, and it has been already used as an outcome measure in patients with SCI [34].

We also calculated the number of patients who obtained an improvement of AIS grade between admission and discharge, the number of patients who achieved bladder management independency at discharge (either self-intermittent catheterization or spontaneous micturition) and the number of patients who achieved bowel management independency at discharge.

Walking capacity was also assessed, based on WISCI scale, as the percentage of patients unable to walk (WISCI II levels 0–3), those needing physical assistance to walk (WISCI II levels 4, 6, 7, 8, 10, 11, 14, and 17), and those walking without assistance (all the remaining WISCI levels) [35].

Finally we calculated the number of patients who developed a complication during the rehabilitation stay and the number of patients who were discharged home or transferred to other wards or nursing home.

Matching procedure

A preliminary analysis of the entire database showed that patients with complications had a higher percentage of AIS A lesions (158/287 vs. 144/743, $p < 0.001$). Therefore, because of the imbalance of the two groups and to avoid the confounding effect of lesion severity we adopted a matching procedure based on:

- AIS impairment: because AIS impairment seems to be the major determinant of both functional and

neurological outcomes, we decided to divide the patients according to each AIS grade.

- Level of lesion: according to previous studies, we divided the patients in three levels: cervical thoracic and lumbar [34].

The patients were not matched by age because in the entire group the age of patients with and without complications was comparable. Furthermore, we did not match based on gender because the effect of gender on SCI outcome is questionable [36].

Each patient was identified by an injury type (level and severity) and categorized by etiology (traumatic/non-traumatic). Patients were selected from each etiology group to create matched dyads on the basis of their classification. The matching was performed using R package MatchIt [37].

Statistical analysis

Descriptive data analysis: descriptive values, expressed as mean + SD, were supplied for all continuous clinical data. Data for the dyads were analyzed by means of paired *T*-test; McNemar's chi-square test was applied to assess contingency differences. Differences were taken as significant if $p < 0.05$.

Results

From our database of 1030 SCL patients we selected 715 patients with all available data (482 without complications and 233 with complications). In the entire cohort of 1030 patients, the distribution of patients with complication along time was as follows: 56/227 in the years 1996–2000 (25% of total admissions), 53/213 in the years 2001–2005 (25%), 60/176 in the years 2006–2010 (34%), 77/294 in the years 2011–2015 (26%), and 41/149 in the years 2016–2019 (27%).

The matching procedure produced two cohorts of 207 patients each comparable for age, neurological level, and AIS impairment (Fig. 1 and Table 1). There was a slightly higher number of males in the group with complications, but this difference did not reached the statistical significance (M/F ratio = 157/50 in the group with complications and 139/68 in the group without complications, $p > 0.05$) (Table 1). Patients with complications at admission suffered more often from a traumatic lesions (T/NT ratio = 125/82 in the group with complications and 103/104 in the group without complications, $p < 0.05$) and had more often associated lesions (35/68 patients with traumatic lesions in the no complications group and 75/50 patients in the complications group) (Table 1).

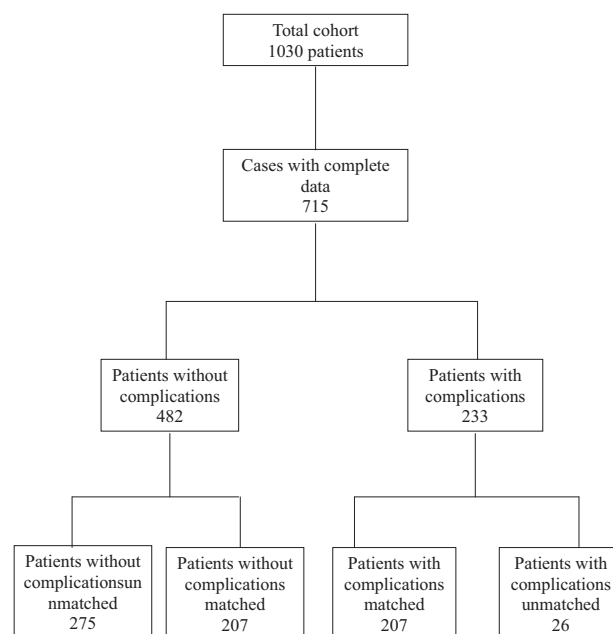


Fig. 1 The flow chart depicts the selection of the matching dyads from the entire cohort. Flow chart of the selection of cases.

Table 1 Demographic and clinical features of the patients of the matched cohorts with and without complication.

	No complications ($n = 110$)	Complications ($n = 110$)
Mean age (SD)	47.9 (18.5)	50.8 (18.4)
Males	139 (67%)	157 (76%)
Traumatic/non-traumatic	103/104	125/82
Presence of associated lesions only for those with traumatic lesions (yes/no)	35/68	75/50
NLI/AIS grade		
C/A	16 (7%)	16 (7%)
C/B	12 (6%)	12 (6%)
C/C	27 (13%)	27 (13%)
C/D	11 (5%)	11 (5%)
T/A	70 (34%)	70 (34%)
T/B	11 (5%)	11 (5%)
T/C	23 (11%)	23 (11%)
T/D	7 (76%)	7 (76%)
L/A	12 (6%)	12 (6%)
L/B	4 (2%)	4 (2%)
L/C	8 (4%)	8 (4%)
L/D	6 (3%)	6 (3%)

SD standard deviation, NLI neurological level of injury, AIS American Spinal Injury Association Impairment Scale.

Complications were mainly represented by pressure ulcers (87%). Ninety-two percent of the patients presented only one complication (Table 2).

Table 2 Complications at admission.

	Entire group	Matched dyad
Type	No. 284	No. 207
Pressure ulcers	251	180
Heterotopic ossifications	14	9
Respiratory complications	25	18
Deep vein thrombosis	6	6
Pulmonary embolism	2	2
Urological complications	4	3
No. of complications per patient		
1	229	191
2 or more	32	16

Both at admission and discharge patients without complications showed a significantly higher level of independence in the activities of daily life: SCIM mean difference between the two groups 5.7 (CI 2.8–8.52) at admission and, 10 (CI 5.3–14.7) at discharge (Table 2). Mobility and walking were also better in patients without complications: RMI mean difference between the two groups 0.6 (CI -0.5–1.7) at admission and 1.6 (CI 0.7–2.5) at discharge; WISCI mean difference between the two groups 0.5 (CI -0.9–1.1) at admission and 1.3 (CI 0.7–2.7) at discharge (Table 3). Lesion to admission interval, length of rehabilitation stay, and total hospital stay were significantly longer in patients with complications (Table 3). The number of patients who developed a complication during the rehabilitation stay was comparable in the two cohorts (26 in the group without complications and 31 in the group with complication, odds ratio 1.2, CI 0.7–2.1). More patients without complications showed an AIS improvement, independence in bladder management, and independence in bowel management than those with complications (Table 4). With regard to WISCI levels, at admission the number of subject not walking/walking with assistance/walking without assistance was comparable in the two cohorts. At discharge there were 162 patients unable to walk, 14 walking for assistance, and 42 walking without assistance in the cohort with complication and 114 patients unable to walk, 17 walking with assistance, and 76 walking without assistance in the cohort without complication ($p < 0.001$). Patients with complications at admission were more often institutionalized (46/161 vs. 20/187, odds ratio 0.4 (CI 0.2–0.7)) than their counterparts without complications (Table 4).

As the majority of complications were represented by pressure ulcers, we repeated the analysis including only the patients with pressure ulcers and their matched counterparts. The results of this analysis are comparable to those of the complete dyads comparison (Table 5).

Discussion

The present work aims at assessing the impact of complications at admission to inpatient rehabilitation on the functional and neurological status of patients with SCL.

The demographic features of our cohort reflected what previously reported [8, 9, 14]. In the entire group of 1030 patients with SCL, about 28% presented with one or more complication to admission to our rehabilitation facility. The kinds of complications are also in line with previous data, with pressure ulcers representing the most common one [8, 14, 21]. Patients with complications had a higher frequency of traumatic lesions and a higher frequency of AIS A lesions. Furthermore, they also had a significant longer LTA. The data are comparable to those already reported in a previous study [21] in which we studied the risk of having a complication at admission to rehabilitation. Longer LTA could be explained by the severity of the lesion but also by organizational problems, and, in particular, the availability of beds in the spinal unit [21]. The lack of sufficient resources for the rehabilitation of patients with SCL could also be a cause why, at least in the present study, despite the advances in the acute care of patients with SCL, the incidence of complications did not decrease along time. In fact, as this is a study assessing patients admitted during a 24 years period, we examined in the entire cohort of 1030 patients the admissions of patients with complications in five periods of 5 years and found that the number of patients with complications admitted during each period did not change.

Patients with traumatic lesions in the complications group also showed a higher number of associated lesions than their counterparts. The presence of complications could be another confounder for the outcome of patients with SCL. However, the possible impact of associated lesions on SCL rehabilitation outcomes is still a matter of debate. Stephan [38] found that in patients with SCL, a high injury severity was associated with worst functional outcome (as assessed by the Glasgow Outcome Scales). Macciocchi [39] reported that concomitant brain injury was associated with low Functional Independence Measures scores in patients with paraplegia, but not in those with tetraplegia. However, other works [17, 40, 41] did not report any impact of brain injury or other associated lesions on the functional outcomes of patients with SCL. Rather, as reported in our previous study [21] we would suggest that immobility, determined by the severity of the lesion, by the neurosurgical/orthopedic workout, by the need to stay in an intensive care unit, and by the presence of associated lesions could be one of the factors that facilitate the development of complications during the acute phase.

In the matched cohorts, patients with complications showed a lower functional status (in terms of daily-life

Table 3 Dyads comparison (Student's *T* test for paired samples).

	Patients without complications Mean (SD)	Patients with complications Mean (SD)	Differences between the two groups Mean (95% CI)	<i>p</i>
LTA (days)	47.8 (52.4)	61 (50.1)	13.3 (3.1–23.5)	0.01
LOS (days)	154.5 (84.8)	180.4 (93)	25.8 (8.1–43.5)	0.04
Total LOS	203.2 (95.3)	237.5 (110.6)	34.3 (13.5–55.1)	0.001
SCIM admission	21.8 (16.5)	16.1 (12.4)	5.7 (2.8–8.5)	0.001
SCIM discharge	57.9 (23.2)	47.9 (25)	10 (5.3–14.7)	0.001
SCIM increase	35.7 (20.5)	31.9 (20.3)	3.8 (0.14–7.8)	0.06
SCIM efficiency	0.3 (0.3)	0.2 (0.2)	0.07 (0.02–0.12)	0.01
RMI admission	1.4 (4.9)	0.8 (3.7)	0.6 (–0.5–1.7)	0.3
RMI discharge	4.7 (3.8)	3.1 (3.5)	1.6 (0.7–2.5)	0.001
RMI increase	3.7 (3.2)	2.6 (2.9)	1.1 (0.3–1.8)	0.04
RMI efficiency	0.03 (0.04)	0.02 (0.04)	0.01 (0.01–0.02)	0.04
WISCI admission	0.8 (3.5)	0.3 (2)	0.5 (–0.9–1.1)	0.09
WISCI discharge	5.8 (7.1)	3.2 (5.9)	1.3 (0.7–2.7)	0.0001
WISCI increase	4.9 (6.6)	2.8 (5.6)	2.1 (0.9–3.4)	0.001
WISCI efficiency	0.04 (0.07)	0.03 (0.06)	0.02 (0.004–0.03)	0.01
MS admission	50.5 (18.3)	49.5 (17.8)	1 (–3.4–5.4)	0.6
MS discharge	59.7 (20.9)	55.7 (20.7)	4 (–1–9.1)	0.1
MS increase	9.3 (13.6)	6.2 (9.8)	3.2 (0.3–6)	0.03
MS efficiency	0.07 (0.1)	0.05 (0.09)	0.03 (0.003–0.5)	0.04

LTA lesion to admission time, *LOS* length of rehabilitation stay, *Total LOS* *LTA* + *LOS*, *SCIM* Spinal Cord Independence Measure, *RMI* Rivermead Mobility Index, *WISCI* Walking Index for Spinal Cord Injury, *MS* total Motor Scores.

Table 4 Dyads comparison (McNemar's Square Chi test).

	Patients without complications	Patients with complications	Odds ratio (95% CI)	<i>p</i>
Discharged home	187/207	161/207	0.4 (0.2–0.7)	<0.001
AIS improvement	68/207	48/207	0.5 (0.3–0.8)	<0.05
Bladder management independence	161/207	132/207	0.5 (0.3–0.8)	<0.05
Bowel management independence	146/207	105/207	0.4 (0.3–0.6)	<0.05
New complications development	26/181	31/176	1.3 (0.7–2.1)	>0.05
Walking without assistance	76/131	42/165	0.4 (0.3–0.7)	<0.001

independence, mobility, and walking) than their counterparts without complications. The impact of complications on functional status is still a matter of debate both in general rehabilitation and in the field of SCL. In a retrospective analysis of the inpatient rehabilitation facilities data of the United States, Wang reported that patients with pressure ulcers had a lower Functional Independence Measure gain during their stay than the patients without pressure ulcers [23]. In the field of SCL there is a relative paucity of studies assessing the impact of complications on rehabilitation outcomes. New in 2004 [42] evaluated the impact of

pressure ulcers on the outcome of patients with nontraumatic SCL and did not find any difference in Functional Independence Measure at admission and discharge between patients with and without pressure ulcers. Hastings [15] reported in a South-African population that individuals with pressure ulcers at admittance to inpatient rehabilitation achieved 9% lower SCIM scores than those without this complications. In 2016 we examined the effect of several clinical features on the realization of the rehabilitation potential using the Spinal Cord Injury-Ability Realization Measurement Index and found that the presence of

Table 5 Dyads comparison (Student's *T* test for paired samples) (only for patients with pressure ulcers).

	Patients without complications Mean (SD)	Patients with complications Mean (SD)	Differences between the two groups Mean (95% CI)	<i>p</i>
LTA (days)	48.5 (54)	64 (51.5)	15.5 (4.2–26.8)	0.07
LOS (days)	152 (82)	182.9 (90.3)	30.8 (12.4–49.3)	0.001
Total LOS	201.9 (95.2)	241.7 (107.8)	39.8 (17.8–61.8)	0.001
SCIM admission	21.9 (15.9)	15.3 (10.6)	6.5 (3.7–9.4)	0.001
SCIM discharge	57.4 (23.3)	46.2 (24.2)	11.1 (6.1–16.1)	0.001
SCIM increase	35.1 (20.5)	31.1 (19.6)	4 (0.2–8.2)	0.06
SCIM efficiency	0.3 (0.2)	0.2 (0.2)	0.07 (0.02–0.12)	0.003
RMI admission	1.4 (4.5)	0.6 (3.7)	0.6 (–0.5–1.8)	0.3
RMI discharge	4.6 (3.7)	2.9 (3.2)	1.6 (0.7–2.5)	0.001
RMI increase	3.7 (3.2)	2.6 (2.8)	1.1 (0.3–1.9)	0.005
RMI efficiency	0.03 (0.03)	0.02 (0.03)	0.01 (0.01–0.02)	0.03
WISCI admission	0.6 (2.7)	0.2 (1.5)	0.4 (–0.1–0.9)	0.1
WISCI discharge	5.5 (6.9)	2.5 (5.4)	3 (0.7–2.7)	0.0001
WISCI increase	4.9 (6.5)	2.3 (5)	2.6 (1.6–4.4)	0.0001
WISCI efficiency	0.04 (0.07)	0.02 (0.05)	0.02 (0.008–0.04)	0.007
MS admission	50.3 (18.3)	48.7 (16.8)	1.6 (–2.9–6.1)	0.5
MS discharge	59.4 (18.3)	54.5 (19.2)	4.9 (–0.3–10.1)	0.07
MS increase	8.8 (12.6)	5.8 (9.9)	2.9 (0.1–5.9)	0.05
MS efficiency	0.08 (0.1)	0.04 (0.08)	0.03 (0.006–0.6)	0.02

LTA lesion to admission time, *LOS* length of rehabilitation stay, *Total LOS* *LTA* + *LOS*, *SCIM* Spinal Cord Independence Measure, *RMI* Rivermead Mobility Index, *WISCI* Walking Index for Spinal Cord Injury, *MS* total motor scores.

complications was negatively correlated with the SCI-ARMI scores at discharge [17]. Richard-Denis [22] and Facchinello [27] reported that the presence of complications and, in particular of pressure ulcers, was one of the predictors of the SCIM score at 6 months and 1 year after the lesion. Stampas [28] compared patients with SCL who developed urinary tract infections during their rehabilitation stay and those who did not develop infections and found that the first group had lower Functional Independence Measure scores at admission and discharge than the group without infections. In a very recent study Donhauser [29] examined the outcomes of a small group of 28 patients with SCL with grades 3 and 4 pressure ulcers that required surgical management with a matching procedure similar to the present one. He found that patients with pressure ulcers had a significantly lower SCIM score after 1 year from the lesion than patients without pressure ulcers. As pressure ulcers in this and in other works seem to be some of the most frequent, if not the most frequent complications after a SCL, this issue deserves some discussion. While the timing (as soon as the ulcer is discovered) and the kind of treatment (surgical or non-surgical or both, depending on the staging

of the ulcer) are relatively well established [43], emphasis has always been put on the prevention of this complication. In this sense, recent studies [44] questioned the validity of standard prevention protocols for pressure ulcers and suggest that the risk of developing an ulcer is individualized and needs flexible strategies of prevention based on the characteristics of each patients. Although this individualized approach would probably increase the costs of SCI care, it could probably be the way to optimize the prevention of these common complications.

To explain the impact of complications on functional outcome a number of factors have been proposed, mainly related to the “immobility” needed to heal the complications (in particular pressure ulcers). This approach may delay the reaching of the sitting position, the use of the wheelchair and ultimately the accomplishment of rehabilitation goals [45]. However, in our opinion, this delay should be counterbalanced by the increase of the length of stay that is reported in all the studies evaluating the impact of complications. But this does not seem to be the case as patients with complication do not achieve the same level of independence of patients without complications neither at the

end of their rehabilitation stay (see the present data), nor at a longer time from injury (see Donhauser and Facchinello [27, 29]). Other possible explanations, that need to be verified with appropriate studies are: (1) the patients with complications have a longer length of stay but nonetheless receive less hour of rehabilitation or less intensive rehabilitation than their counterparts without complications. (2) As it has been demonstrated [46] that complications, in particular pressure ulcers induce a chronic inflammatory state with anemia, low serum iron, hypoproteinemia, and hypoalbuminemia, it is possible that this long-lasting suffering disrupts the functional potential of the patients.

With regard to neurological status, we found a difference in neurological outcome of our patients with patients without complications having a significantly higher MS gain and a higher percentage of AIS grade conversion than patients without complications. These results are in contrast with recent studies [19, 29] in which the authors reported that the presence of complications does not affect the neurological outcomes of patients with SCL. However, in 2012, Failli [26] reported that patients with pneumonia and surgical wound infections had a lower percentage of AIS grade conversion and lower MS gain and that these differences lasted a long time. They attributed this phenomenon to the systemic inflammation induced by infections as demonstrated also by experimental models [47]. As other complications and, in particular, pressure ulcers (that represented the most frequent complications in our database) may induce a chronic inflammatory state [46], it is possible that other complications beside infections may negatively impact on neurological recovery. However, this hypothesis needs to be verified in further specific studies, because we cannot exclude that this result could be due to the effect of other confounders.

In agreement with several previous studies [8, 14, 15, 24], our data show that patients with complications have a longer length of rehabilitation stay (mean 26 days) than those without complications. Although this increase in LOS is probably effectively due to the presence of complications and related problems and care, we would question the utility of LOS as an outcome measure. A survey from ten countries all over the world [48] reported that LOS may depend on factors different from clinical ones and in particular to barriers to discharge (for example waiting for nursing home bed, home modification, equipment funding). Therefore, basing conclusions on LOS may be a cause of bias unless the above mentioned factors are carefully evaluated.

The main strength of the present study is that it is specifically designed to assess the impact of complications on the functional and neurological outcome of patients with SCL. Furthermore it is based on a much larger sample of patients than most of the previous studies

and with a large set of validated measure assessing different aspects of function. It also has some limitations: (1) the databased on which this work is based started in 1996 and included only the associated lesions and the complications cited in the methods. We acknowledge that there are other complications (for example pain, spasticity, cardiovascular complications, and urinary tract infections) that need to be addressed in other studies. Furthermore, both associated lesions and complications were only categorized as present/absent without an assessment of their severity which obviously could make a difference. For the same reason we do not provide a formal assessment of injury severity (for example with the Injury Severity Score). (2) The study is from a single center which could limit the generalizability of the results to other realities. Furthermore, although we matched our patients to control for two key confounders, it is still possible that our findings are further confounded. A possible way to answer this question comprehensively is to start with a directed acyclic graph (DAG) that allows a visual representation of the causal pathway and the identification of confounders and colliders [49], then prospectively collect the appropriate data (as identified in the DAG) and use modeling to get at the cause–effect relationship between complications on admission and the various outcomes at discharge.

Conclusions

By using a set of specific functional and neurological measures, a large number of patients and a specific methodology to correct for some confounders (lesion level and severity) our study, in agreement with previous ones, demonstrates that the presence of complications at admission to inpatient rehabilitation has a negative impact on patients' neurological and functional status at discharge and possibly length of stay, and it determines a higher risk of being institutionalized.

This datum could be useful not only to answer the questions of patients with SCL and to decide the allocation of economical resources, but also to support previous articles on the need of optimizing acute care with regard to the prevention of these complications and, in particular of pressure ulcers that continue to represent a common complication despite specific prevention protocols.

Data availability

Data are available as Supplementary material.

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Author contributions All authors equally contributed to the study.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethics statement We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers/animals were followed during the course of this research.

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