Prediction Model for the Presence of Complications at Admission to Rehabilitation After Traumatic Spinal Cord Injury

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Background: Complications frequently occur in patients with spinal cord injury (SCI) during acute care or rehabilitation and have an impact on rehabilitation outcomes. **Purpose:** The aim of this study was to determine the occurrence and risk factors for complications in recently injured SCI patients. **Methods:** Two hundred fifty patients with traumatic injuries with and without complications were counted for the following dichotomous parameters: gender (male/female), associated lesions (presence/absence), surgery (yes/no), American Spinal Injury Association Impairment Scale (AIS) grade (A/other categories), lesion level (lumbar/other levels), and lesion-to-admission time (less than/longer than 1 month). The odds ratio (OR) and 95% confidence interval were computed for all the parameters that influenced the presence of complications at admission. These factors have been included in a binary logistic regression analysis (forward stepwise). **Results:** Complications at admission were observed in 104 patients (41.6%), especially for males, lesion-to-admission time longer than 1 month, presence of associated lesions, AIS grade A, and motor completeness, whereas lumbar lesions were associated with a reduced presence of complications at admission. In the regression analysis, 4 factors entered into the model: motor completeness, lesion-to-admission time, associated lesions, and gender. The final model explained 74% of the variance of data. **Conclusions:** Despite advances in the acute management of patients with SCI, the study unveiled a high percentage of patients with complications at admission to rehabilitation. The risk factors identified in the study allow determination of the population of subjects who are at higher risk of developing complications and need special management. **Key words:** complications, prediction model, risk factors, spinal cord injury

Introduction

Traumatic spinal cord injury (SCI) is a condition that affects nearly one person out of a thousand each year (from 0.721 to 0.906 per thousand in the United States),^{1,2} especially in the younger ages (more than 50% of the subjects are ≤ 40 years).^{1,2} SCI involves and disrupts different areas of the human being, and all these areas are amenable to rehabilitation. Furthermore, SCI patients are prone to several complications both in the acute and chronic phases post injury, with a rate of about 58% of the cases reported in one study.³ The conditions that can be considered as “complications” are those conditions that are in a chronological relationship with the SCI and are more frequent in the SCI population.⁴ SCI complications include a variety of conditions that could be divided into those directly linked to the lesion (eg, neurogenic pain or spasticity) and those due to the loss of pulmonary function, bladder control, and mobility

(pulmonary embolism and pressure sores).⁴ It has been demonstrated that complications have a considerable impact on SCI patients, with reduced realization of the rehabilitation potential,⁵ increasing length of stay in rehabilitation,⁶ and increased re-hospitalization⁷ and mortality.⁸

Consequently, the study of the factors that are linked to the development of complications and that could therefore help the prediction of these consequences of SCI is particularly relevant. However, to our knowledge, most of the studies aim at assessing the risk of developing complications during the rehabilitation stay or in the long term.^{9,10} At present, there are only 2 studies that evaluate the risk of complications during the acute phase and only in patients with cervical SCI.^{11,12}

The aim of this study is to assess the factors associated with the risk of having complications at admission to a rehabilitation hospital and to develop a prediction model for complications.

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Methods

We retrospectively examined the charts of patients with traumatic SCI admitted to our Spinal Unit between 2006 and 2016 for their first rehabilitation. We recorded lesion-to-admission time (LTA; days) and injury variables (etiology, associated injury, medical complications at admission, and surgical intervention). Associated lesions were traumatic brain injury, nonvertebral 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. Medical complications were pressure sores, respiratory complications (pneumonia), deep vein thrombosis, pulmonary embolism, heterotopic ossification, and urological complications (excluding the urinary tract infection). According to the Gruppo Italiano Studio Epidemiologico Mielolesioni (GISEM) study,¹³ both associated lesions and medical complications were rated only as present/absent, without any rating of the severity. Neurological status was assessed by the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI)¹⁴ (with recording of neurological level, American Spinal Injury Association Impairment Scale [AIS] to assess the completeness/incompleteness of the lesion and motor completeness).

Statistical analysis

The number of patients with and without complications has been counted for the following dichotomous parameters: gender (male vs female), associated lesions (presence vs absence), surgery (yes vs not), and motor completeness (yes vs no). Other parameters were dichotomized as well. AIS grade was divided in A versus other categories because about half of our patients had an AIS grade A lesion. To avoid cross-correlation with AIS grade, level of lesion was dichotomized into lumbar versus other levels (cervical and thoracic) based on an empirical observation that patients with lower level lesions had less complications. LTA was dichotomized into less versus longer than 1 month based on our previous work¹⁵ in which we demonstrated that patients admitted within 1

month had better functional outcomes compared to those admitted later. For all these parameters, the chi-square test was used to compare the numbers of patients with and without complications at admission.

Only 2 parameters were not dichotomized. Age was not dichotomized because it is a continuous variable. Age differences between patients with and without complications were analyzed by means of Student's *t* test for independent samples. The other parameter not dichotomized was the type of accident, because 7 categories were taken into account for this parameter. For this parameter, the chi-square test had been used to compare the number of patients with and without complications at admission.

The odds ratio (OR) and 95% confidence interval were computed for all the parameters significantly influencing the presence of complications at admission. Dichotomized factors that significantly influenced the presence or absence of complications at admission were included into a binary logistic regression analysis (forward stepwise). Data analysis was performed using SPSS software. A *p* value threshold of .05 was chosen for significance.

Results

Data were collected in 274 patients. Twenty-four patients were excluded because of some absent data. Therefore, data of 250 patients have been analyzed. There were 209 males and 41 females. Mean age was 40.6 ± 17.3 years. Mean LTA time was 49 ± 54 days. Complications at admission were observed in 104 patients (41.6%) (**Table 1**). **Table 2** shows the results of the analyses of the factors influencing the presence of complications at admission. The complications at admission were observed more frequently for males (OR = 3), LTA longer than 1 month (OR = 3.4), presence of associated lesions (OR = 3.1), AIS grade A (OR = 4.5), and motor completeness (OR = 4.5), whereas lumbar lesions were associated with a significantly reduced presence of complications at admission (OR = 0.3).

According to these results, the following parameters were included into the model: gender, LTA, associated lesions, AIS grade, motor completeness, and lesion level. A binary

Table 1. Complications at admission

Type	No.
Pressure ulcers	90
Heterotopic ossification	9
Respiratory complications	14
Deep vein thrombosis	5
Pulmonary embolism	1
Urological complications	1
No. of complications per patient	No. of subjects
1	89
2 or more	15

logistic regression was performed on the above parameters, and its results are shown in **Table 3**. Motor completeness was entered in the model already at the first step, explaining 66% of the variance of the data, followed by LTA (second step), associated lesions (third step), and gender (fourth step). Conversely, at the last step of the

iterative regression, 2 factors (AIS grade and level of lesion) did not enter in the model.

The final model explained 74% of the variance of data. With the exception of gender, all the other factors influenced in a highly statistically significant manner ($p < .01$) the presence of complications at admission, with relevant OR between 2.4 and 5.4.

Discussion

Patients with traumatic SCI are particularly prone to the development of complications such as urinary tract infections, pressure ulcers, pneumonia, and thromboembolic complications from the time of lesion through the rest of their lives.¹⁶ The incidence of complications during the initial hospitalization after SCI is reported to range from 44% to 77%.^{13,17} The occurrence of complications during the hospital stay after SCI increases the complexity of care of these patients and may result in increased hospital length of stay, complex treatments, increased risk of further complications, and significant economic and social costs. As the occurrence of complications

Table 2. Factors influencing the presence of complications at admission

Parameter	Complications (n=104)	No complications (n=146)	p^a	Odds ratio (95% CI)
Age, years	42.14 $\pm$ 16.82	38.04 $\pm$ 17.49	.064	Not computed
Gender (M/F)	95/9	114/32	.005	3.0 (1.3-6.5)
Lesion to admission time (<1/>1 month)	27/77	67/79	<.001	3.4 (1.9-5.8)
Associated lesions (yes/no)	76/28	68/78	<.001	3.1 (1.8-5.4)
Surgery (yes/no)	95/9	128/18	.413	1.5 (0.6-3.4)
AIS grade (A/BCD)	70/34	51/95	<.001	4.5 (2.6-7.9)
Motor completeness (yes/no)	79/25	60/86	<.001	4.5 (2.6-7.9)
Lesion level (L/CT)	12/92	41/105	.002	0.3 (0.2-0.7)
Type of accident, n				
Car accident	27	47	.670	Not computed
Motorcycle accident	33	34		
Sport accident	5	12		
Gunshot wound	4	8		
Falls	28	37		
Suicide attempt	3	3		
Other	4	5		

Note: AIS = American Spinal Injury Association Impairment Scale; CT = cervical and thoracic; L = lumbar.

^aThe chi-square test was used to compare the numbers of patients with and without complications at admission. Age differences between patients with and without complications were analyzed by means of Student's *t* test for independent samples.

Table 3. Results of binary logistic regression

Factors		β	S.E.	p	exp(β) Odds ratio	95% CI for exp(β)		R^2	%
						Lower	Upper		
Step 1	Motor completeness	1.511	.285	<.001	4.529	2.593	7.911	0.12	66%
	Constant	-1.235	.227	<.001	.291				
Step 2	LTA	1.552	.314	<.001	4.721	2.553	8.730	0.21	73%
	Motor completeness	1.804	.314	<.001	6.075	3.283	11.239		
	Constant	-2.342	.346	<.001	0.096				
Step 3	LTA	1.431	.320	<.001	4.183	2.234	7.831	0.23	73%
	Associated lesions	.816	.306	.008	2.261	1.241	4.122		
	Motor completeness	1.720	.319	<.001	5.584	2.989	10.431		
	Constant	-2.715	.390	<.001	0.066				
Step 4	LTA	1.462	.327	<.001	4.314	2.272	8.189	0.25	74%
	Gender	1.115	.454	.014	3.051	1.252	7.434		
	Associated lesions	.856	.311	.006	2.354	1.280	4.327		
	Motor completeness	1.679	.325	<.001	5.363	2.836	10.140		
	Constant	-3.691	.586	<.001	0.025				

Note: The effects of factors included into the forward binary logistic regression model: motor completeness, lesion to admission time (LAT), associated lesions, gender, American Spinal Injury Association Impairment Scale grade, lesion level. The values of the effect of the factor on the presence of complications at admission (β), standard error (S.E.), probability (p), odds ratio, 95% confidence interval of odds ratio, coefficient of determination of the model (R^2), and percentage of variance explained by the model (%) are reported.

is considered to be due to a less than optimal standard of care (among several different factors),¹⁸ the aim of the present study is to highlight the risk factors for the development of complications during the acute phase of SCI so that patients with these factors may receive better assistance during the acute care stay.

The demographic and clinical characteristics of the population are comparable to those of the only study examining the Italian reality.¹³ The results of the study show an incidence of complications comparable to those of previous studies,^{11,13} with 41% of our patients experiencing one or more complications. The risk factors analysis partially confirmed the results of Wilson,¹¹ increased the generalizability of their findings, and allowed the development of a prediction model explaining 74% of the variance.

In our model, we had 4 factors: motor completeness, LTA, gender, and the presence of

associated lesions. Motor completeness alone accounts for 66% of the variance, demonstrating that it is one of the most important predictive factors for the development of complications. This result traces a previous study on the severity of the lesion¹² and highlights the importance of the loss of mobility in determining complications. This factor, together with other non-neurological factors (see below, the presence of associated lesions) that contribute to the immobility of the patients, is particularly relevant in the present series where about 86% of complications were represented by pressure ulcers. It is recommended that patients be repositioned every 2 hours to obtain an efficacious prevention of pressure ulcers.¹⁹ In the acute wards, due to suboptimal ratio of nurses to patients, this frequency of bed-turning is often difficult or impossible. This may also explain why the second factor that entered our model is the lesion-to-admission time. The longer this time, the higher

the risk of developing complications. This is of particular relevance, as this is the only modifiable factor. As stated before, in the acute wards the attention to the prevention of complications may be less than optimal, and a delay in admission to a dedicated unit may be detrimental for SCI patients. The study was conducted in a pure rehabilitation hospital where patients are admitted after a period of time that may vary depending on several factors. These factors primarily include clinical ones (eg, the neurosurgical/orthopedic workout, the need to stay in an intensive care unit), organizational problems, and, in particular, the availability of beds in the spinal unit, which is a recognized problem all over the world.²⁰ Unfortunately, the patients who often need a longer stay in the acute wards are those who have a complete lesion and have less mobility and therefore are more exposed to the development of complications.²⁰

Gender is a factor that did not enter previous models. In the present series, males have a significantly higher risk of being admitted to rehabilitation with complications. We could not offer an explanation for this datum. However, it could be postulated that, as males are exposed to high-energy lesions and, therefore, have a higher percentage of complete lesions,²¹ they have an increased risk of immobilization that in turn is linked to an increased risk of complications.

The fourth factor entering our model is the presence of associated lesions. As per the GISEM study,¹³ our study included only severe associated lesions that could add disability to that already determined by the SCI. In a previous work, we demonstrated that the presence of associated lesions is linked to a low level of mobility and independence at admission to rehabilitation.²² It seems reasonable that patients with associated lesions are more “immobile” than those without associated lesions. Furthermore, the presence of associated lesions makes the prevention of complications more troublesome (eg, the difficulty of turning a patient with thoracic trauma and thoracic tube or with multiple fracture every 2 or 3 hours to prevent pressure ulcers). Finally, some associated lesions are linked *per se* with complications (eg, lower limb fractures are associated with a higher risk of deep vein thrombosis).²³

Another important finding of the present work is the lack of effect of lesion level. The study of Wilson¹¹ examined the risk of complications only in patients with cervical SCI and, according to the authors, that could limit the generalizability of their results. Here we demonstrated that the risk of developing a complication is independent from the level. Also for this finding we could offer as an explanation the lack of mobility. For the lesions at the thoracic level, it has been demonstrated that, as the thoracic spine is “protected” by the chest and rib cage, high-energy trauma is needed to produce a vertebral lesion, and this often results in complete spinal cord lesions²⁴ with severe loss of mobility.

Another difference with the work by Wilson is that, in the present study, age did not enter the prediction model. According to Wilson, older patients are more at risk of developing complications because they present with reduced vital capacity (also because they have more comorbidities) compared to young subjects.¹¹ In the present study, patients are relatively young and the 2 groups (with and without complications) did not show any age difference. Furthermore, the effect of reduced vital capacity and comorbidities is counterbalanced by the fact that younger subjects are more exposed to high-energy lesions (high-speed street accidents or high-level falls)²⁵ and therefore present more frequently with complete lesions.²⁶

This work has some limitations. Due to the retrospective nature of the study based on the GISEM study,¹³ associated lesions have only been dichotomized (present/absent) without an assessment of their nature and severity. It is possible that some associated lesions have a closer relationship with the presence of complications. For the same reason, we did not include some complications such as urinary tract infections and neuropathic pain. Furthermore, we did not assess the severity of the different complications at admission, although the database is designed to capture only major complication events with the potential to impact clinical outcomes. Finally, we did not assess the effect of the pharmacological therapies in the acute phase and the presence of comorbidities, and this makes our work less comparable to the results of Wilson.

The present study demonstrates that the loss of mobility and all the factors that contribute to immobilization are the main determinants of

complications. For patients with very reduced mobility, special nurse care and early admission to specialized SCI units are needed.

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