Evaluation of the prognostic value of extraparenchymal changes in traumatic spinal cord injury, assessed by magnetic resonance imaging

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Abstract

Objectives. To analyze the relationship between neurological progression following traumatic spinal cord injury and Spinal Cord Compression (SCC) and Spinal Ligamentous Injury (LI) by magnetic resonance imaging.

Design. Retrospective observational study.

Setting. Spinal Cord Injury Unit (A Coruña, Spain).

Participants. Patients were admitted for traumatic spinal cord injury between January 2010 and December 2018 with a magnetic resonance imaging examination performed during the acute phase.

Intervention. Evaluation of SCC and LI by magnetic resonance imaging.

Outcome measures. Comparisons between neurological examination at admission and discharge were made, assessing ASIA Impairment Scale (AIS) grade and motor score.

Results. Data from 296 patients were collected. A relationship between SCC and LI and complete injuries were found ($P < 0.001$). Improvement of the AIS grade was observed in 31.6% of patients with SCC and 31.3% with LI versus 42.7% and 37.8% of subjects without these complications, respectively. Regarding motor score, patients with SCC had lower mean values at the beginning (46.9 ± 26.8 versus 61.1 ± 29.9 in the control group, $P < 0.001$), as well as less improvement when assessed by the percentage of change ($35.1 \pm 37.5\%$ versus $49.4 \pm 38.1\%$ in the control group, $P = 0.010$). Similar results were obtained in cases with LI: mean motor score at admission was 45.9 ± 26.7 versus 54.9 ± 29.4 in the control group ($P = 0.014$) and the percentage of change was $28.5 \pm 37.1\%$ in comparison to $46.0 \pm 37.5\%$ ($P = 0.001$) in the controls.
Conclusions. There is a relationship between SCC and LI and complete spinal cord injury. This patient population has lower possibilities of improving their AIS grade and motor score.

Keywords: Traumatic spinal cord injury, Magnetic resonance imaging, Prognosis, Spinal cord compression

Introduction

Determining the prognosis for spinal cord injury is challenging, but is key for decision-making during the initial months. The International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) are the safest way to diagnose and classify a spinal cord injury. It has shown the powerful capacity to predict the prognosis of Traumatic Spinal Cord Injury (TSCI),[1] either by assessing it globally or by focusing on specific aspects of the injury.[2]
Imaging techniques are also very useful when evaluating TSCI. Besides their utility to support the diagnosis and characterize concomitant injuries, some studies have examined their prognostic value.[3] Among the different imaging techniques, Magnetic Resonance Imaging (MRI) has been particularly useful in the study of TSCI due to its capacity to assess the spinal cord parenchyma and the disc-ligament system.[4] Moreover, the imaging patterns of parenchymatous injuries have been studied as prognostic factors of TSCI although, to date, the available evidence is low.[5]

Beyond the parenchymal injury patterns, different researchers have provided other possible MRI-related prognostic factors. In 1991, the authors of a study suggested worse neurological prognoses in cases with Spinal Cord Compression (SCC),[6] although their work was merely descriptive and no statistical analyses were included. In 1992, Silberstein et al.[7] reached similar conclusions by observing worse neurological functional status in patients with SCC. In subsequent years several authors analyzed this to either assess the evolution or, in other cases, to evaluate the importance of early decompression intervention.[8] Given the heterogeneity of the works and the used methods to determine and measure the degree of compression, a group of researchers led by Fehlings[9] developed a protocol for measuring stenosis within the spinal canal.

Fehlings' method is easy to use and has shown a Good inter-observer correlation, as confirmed by the creators in a subsequent study.[10] Moreover, it has proven to be useful for the assessment of spinal canal stenosis and the spinal cord. Nevertheless, later works, such as the review by Lammertse,[3] concluded that more reliable evaluations of the spinal canal are achieved using CT scans, while the spinal cord must preferably be analyzed by MRI.

After the publication of the article, different researchers used the same formula in their works. One of the valued elements was the possible relationship between SCC and neurological recovery following acute TSCI. The reviewed publications have shown divergent conclusions, some reporting statistically significant relationships,[11] while others have not been able to prove it.[12] The heterogeneity of the methods and objectives may partially explain these differences.

Other groups studied TSCI evolution regarding vertebral ligamentous system injuries. In 1988, Kulkarni et al.[13] suggested a worse prognosis in subjects with vertebral Ligamentous Injury (LI), although their data did not allow to show a significant relationship. The small sample size and the poor quality of the images at the time may have been limitations to their study.

Years later, Martínez-Pérez led several studies that aimed to assess the influence of LI on neurological prognosis. In these works, the integrity of the yellow ligaments (ligamentum flavum), anterior longitudinal and posterior longitudinal ligaments was examined by MRI due to their known relevance regarding spinal cord stability and the correlation between their lesions and changes in spinal cord alignment.[14] In the first article[15] the authors found a relationship between ruptures of the yellow ligament and worse evolution, although non-significant in the case of the anterior longitudinal ligament. In a subsequent study,[16] a worse prognosis was determined in cases with injuries of both components, this not being the case when the affected ligament was the posterior longitudinal. While these studies allowed the opening of a new research line, they have hardly had an impact and we found no subsequent related publications during the conduction of the present study.

There is great interest in determining prognostic factors in TSCI. Here we aimed to examine the relationship between these extra-parenchymal changes (SCC and LI) and the neurological prognosis in TSCI patients.

Material and methods

Study setting

This study was carried out in the Spinal Cord Injury Unit (SCIU) of Complexo Hospitalario Universitario in A Coruña, a reference center for the treatment of spinal cord injuries in Galicia (Spain) that serves a population of around 2,750,000 inhabitants.

Characteristics of the study

An observational descriptive study with retrospective follow-up.

Selection of cases

Patients admitted to the SCIU between 2010 and 2019 were selected for the study.

Inclusion criteria: ≥18 years, admitted to the unit due to acute TSCI, MRI examination over the first seven days following the injury.

Exclusion criteria: severe comorbidity that prevented the performance of a correct neurological exploration, undergoing rehabilitation and/or, assessment of the MRI examination (i. e. patients with symptomatic neurological disorders, limb amputation, chronic spinal cord injury, and instrumentation before the TSCI).

The following variables were analyzed: age, sex, SCC, LI, associated spinal cord injuries, injuries at other levels, admission to the Intensive Care Unit (ICU), exitus, and characteristics of spinal cord injury at admission and at discharge (including the level of injury, ASIA Impairment Scale (AIS) grade, and motor score (MS)).

Images were analyzed in collaboration with a physician specialized in neuroradiology. We evaluated the SCC and its percentage (Fehlings' method), as well as the existence of disruption in any of the following liga- ments of the posterior ligament system: anterior and posterior longitudinal and yellow ligament system.

The characteristics of spinal cord injuries were determined according to the ISNCSCI and neurological progression evaluating changes in the AIS score and MS from the baseline exploration until the patient's discharge. To simplify the analyses, levels of the lesions were categorized as tetraplegia or paraplegia.

During the hospital stay, all study patients were treated following the same protocols and receiving the same number of therapy hours (physiotherapy and occupational therapy).

Analyses of the images

MR imaging was performed following standard protocols, using sagittal and axial T1, sagittal and axial T2, sagittal STIR, and sagittal gradient echo T2 sequences. Intera 1.5 (from 2010 to 2016) and Ingenia 1.5 (from 2016 to the present) were magnetic resonance devices.

Fehlings' method was chosen to assess SCC. This method consists in measuring the sagittal view of the spinal cord the point with the smallest diameter of the stenosed area (D2) and next the two nearest points free from compression at cranial (D1) and caudal (D3) levels (see Fig. 1). To determine the percentage of compression, the following formula was used to introduce the obtained measures.

$$\%stenosis = 1 - \frac{D2}{D1 + D3\frac{1}{2}} \times 100\%$$

LI was considered in SCI cases in which at least one of the following components had suffered disruption: anterior longitudinal ligament, posterior longitudinal ligament, and yellow ligamentous system.

Statistical analyses

Statistical analyses were performed with IBM® SPSS® Statistics V19 (IBM Corp, 2010, Armonk, NY. USA). Descriptive and comparative analyses of the variables were carried out. Quantitative variables are expressed as mean ± standard deviation. An estimate of its 95% confidence interval was made.

Mean comparisons were made using Student's *t*-test, after checking the normality of the variables with the Kolmogorov-Smirnov test. To determine the relationship between qualitative variables the Chi-square test or Fisher's exact test was used.

Results

General characteristics

Over the study period, 720 patients were admitted for acute spinal cord injury, of which 296 met the inclusion criteria. The mean age was 60.1 ± 19.9 years; the male: female ratio was 2.65:1. From the total number of cases, 68.2% had tetraplegia (21.5% with complete injuries) and 31.8% paraplegia (54.2% with complete injuries). Overall mortality was 10.8%.

SCC was present in 68.9% of study patients (n = 204). Compression was under 50% in 86.2% of the cases. LI was identified in 39.9% of the cases (n = 117), with two patients not accounted for because the team did not reach unanimity on LI. When both variables were overlapped, 81.2% of the subjects with LI also had SCC, with a statistically significant relationship between them ($P < 0.001$)

Intergroup analysis

No intergroup significant differences were found between the presence or not of SCC by age (P = 0.157), sex (P = 0.240), level of the lesion (P = 0.255), or incidence of concomitant injuries (P = 0.543). On the other hand, significant differences were observed in the incidence of bone injury (P = 0.028), with a higher percentage in SCC subjects; the same was seen for the need to be admitted to the ICU (P = 0.013) and mortality (P = 0.001) (Table 1).

Intergroup comparisons revealed notable differences in patients with LI (Table 2). Whereas no differences were found by sex, significant differences were seen by age, *i.e.* patients with LI were younger than those without it. Similarly, the percentage of tetraplegia was lower among subjects with LI, although in both groups tetraplegia was more frequent than paraplegia (P = 0.002). Moreover, there were more spinal cord fractures (P < 0.001), concomitant injuries (P = 0.009), need for ICU (P < 0.001), and mortality (P = 0.046) in the LI group.

Significant differences were detected in baseline AIS grade, with more complete injuries in SCC and LI patients in comparison to subjects without these com- plications (P < 0.001 for both cases), as seen in Fig. 2.

Evolution of the level of injury based on extra- parenchymal changes

The assessment of neurological progression showed a lower trend toward changes in the AIS score in SCC patients in comparison to individuals without this complication. Thirty-one point six percent (31.6%) of SCC cases improved their grade during hospital stay versus 42.7% of the non-compression group. Differences were, however, non-significant (P = 0.075).

In the analysis of the different AIS grades, a higher percentage of improvement among subjects without SCC was seen, except for an AIS grade B (the least numerous group). The results were statistically signifi- cant for an AIS grade C (Table 3).

Among all AIS grades, the least improvement was seen in individuals with an AIS grade D with an overall percentage of subjects who improved their AIS grade below 10%. Similarly, the distribution of AIS D among the established groups was quite different, which may cause a bias due to a ceiling effect. Thus, by removing AIS grade D from the analysis, the overall percentage of patients who improved their AIS grade rose to 57.5% in SCC cases and to 68.0% in the controls, with statistically significant differences (P = 0.002).

Evolution of the degree of injury based on ligamentous injury

When the above analysis was repeated considering the LI, less improvement was again observed in patients with LI: 31.3% of the cases improved their AIS grade in comparison to 37.8% of subjects with ligament integ- rity, with no statistical difference (P = 0.286). In the analysis by grades, the above-described pattern was repeated, *i.e.* AIS D injuries barely improved, and in all AIS scores percentages of improvement were greater among patients without LI. Individual results for each AIS grade were not significant (Table 3). Repeating the previous approach, AIS grade D indi- viduals were removed from the analysis. This way, overall percentages of improvement increased notably; 37.8% of the subjects with LI improved their injury degree versus 60.2% of the subjects without LI, with statistically significant differences (P = 0.002).

Evolution of the motor score based on extra- parenchymal injuries (Table 4)

Significant differences (P < 0.001) were seen within the established groups with or without of SCC, although the difference in MS improvement among SCC patients at discharge was not statistically significant (P = 0.231), despite being worse than in the group without SCC. However, to correct the error due to the different initial values, we calculated percentages of change. This way differences were more apparent, the percen- tage of change being almost 15% greater in the group without SCC. According to Student's *t*-test, differences were statistically significant (P = 0.010).
Regarding LI, baseline values were significantly superior in the group without LI (P = 0.014). MS vari- ation in LI subjects was discretely lower in cases with LI, without statistically significant differences (P = 0.061). As per the percentage of change, differences were again noticeable, and the contrast of hypothesis showed statistically significant differences (P = 0.001).

Discussion

A decisive factor, when assessing the extra-parenchymal changes examined in this study, is the energy of the triggering trauma. In our study sample, 68.9% of the patients suffered SCC, with a much higher frequency among subjects who concurrently presented spinal cord bone injury, as well as in cases with LI.

Ligaments provide a large part of their resistance to the spinal cord structure; thus, the energy required to cause a LI is very high.[17] For this reason, these patients have more bone fractures and associated injuries and the rate of mortality is higher. This explains the higher percentage of complete injuries detected among patients with SCC or LI. However, the data extracted from this analysis show that TSCI evolution is worse in cases with SCC or LI, regardless of the AIS grade, although the mean age and length of hospital stay in both groups were lower, and the intensive rehabilitation period was higher. This was not observed in AIS B cases with SCC, although the sample size of these groups was not big enough to conclude.

A review published in 2017 in which SCC was assessed among other prognostic factors,[18] was not able to determine any level of evidence on its influence on neurological prognosis in TSCI patients. Some of the reasons argued by the authors were that the consulted studies included small sample size and measure- ments were taken using heterogeneous methods.

Martineau *et al.*[19] using a methodology similar to that adopted by our team but only including patients with cervical injuries, examined SCC using Fehlings' protocol and compared the outcome with the evolution of the MS and AIS grade. In their work, SCC was significantly associated with lower MS changes, which was not seen with grade changes. By contrast, Miyanji *et al.*[20] concluded there were significant differences regarding the evolution of the AIS score when assessing spinal canal compression as well as in spinal cord compression, although there was a closer relationship with the intramedullary hemorrhage and AIS grade at admission, as they were considered the most relevant prognostic factors.

In the review by Tarawneh *et al.*[21] on MRI- and TSCI-related prognostic factors, a significant relation- ship between neurological progression and SCC was observed in two of the three examined works. Like in our study, SCC was associated with worse neurological progression.

Farhadi *et al.*[22] with a methodology similar to that of our study, the authors showed the prognostic value of medullary and canal stenosis. However, they observed that its influence was much lower in comparison to intraparenchymal injury patterns.

A recent article assessed the TSCI prognosis considering several factors related to MRI and TC scans with a mean follow-up of 30 months.[23] The univariate analy- sis showed a good relationship between the AIS grade at admission and SCC, not observed in spinal cord canal compression. This relationship was not shown in the multivariate analysis, where the length of intramedullary edema was the only significant factor. No significant association was seen in the evolution during hospital admission with either SCC or spinal canal compression, with, again, the length of intramedullary edema being the only factor with significant influence.

A possible general confounding factor observed when assessing SCC is the greater percentage of complete injuries among patients with this complication, which is three-fold higher in the sample analyzed in the study. This occurrence was also described by Skeers *et al.*[24] in a population of paraplegic patients and by Ter Haar *et al.*[11] with tetraplegics. In the present study, unlike the rest of the evaluated works, a breakdown of the AIS grade was done, observing that in all grades, except for AIS B (low sample size), there was a lower per- centage of improvement in SCC cases, albeit significant differences were only shown for AIS C.

A difference between this work and most of the reviewed articles during the completion of our study is that most MRI studies were carried out over the first 24 h following TSCI, while in the other works, in most cases, it took between 24 and 72 h. This can be compared to a study carried out in an Emergency department,[25] in which the authors conclude that the SCC was associated with a worse neurological prognosis, although it should be considered that the sample size was small (55 subjects) and their analyses were very basic.

As to LI, a few studies have assessed the evolution of acute TSCI. Firstly, it might be worth considering the reliability of MRI to assess these structures. MRI is the only routinely used study that allows reliably check- ing of the integrity of vertebral ligaments, depending on the assessed ligament, reliability between 91% and 100% has been calculated,[14] even though other studies have reduced significantly these figures. However, the emergence of new image sequences and improved definitions of the instruments have facilitated the assessment of LI in recent years.[26] In 2020, Henninger *et al.*[27] compared

MRI features against intraoperative observations on 21 patients with cervical spine hyperextension trauma. The authors observed a 90.9% correlation when short tau inversion recovery (STIR) was used, a sequence that is part of the MRI protocol in our center.

The value of LI as a neurological prognostic factor was referred to for the first time by Song *et al.*,[28] who developed a classification to assess vertebral soft tissue damage. The authors found more injuries in spinal parenchyma in cases in which ligament damage was more severe. Later, Boese *et al.*[29] analyzed a large sample of patients with SCIWORA and also observed that patients with LI had more severe injuries.

After the abovementioned articles, Martínez-Pérez *et al.* proposed a relationship between soft tissue damage and TSCI prognosis. Currently, and to the best of our knowledge, Martínez-Pérez has published only three articles that exclusively analyze this point. All the works were carried out in patient populations with cervical spinal cord injuries. In the first study, lesion length with regard to the damage to ligament structures was examined.[30] The authors showed a relationship and extrapolated it to other publications that associated the length of the injury with the prognosis for recovery. The authors argue that the great advantage of the study on soft tissue damage is that LI is not a dynamic process and is not as influenced by possible delays in getting the necessary tests as occurs in cases of changes in spinal cord signals, which commonly show important variations during the most acute phase of TSCI.

In 2017, two other studies by this team were published. One included 48 patients with cervical SCIWORA and improvements in the AIS grade were evaluated.[15] The work showed a greater improvement in subjects whose ligaments were not affected, although possibly due to the small sample size, significance was only observed for yellow ligaments ($P = 0.05$). In the second study, patients with incomplete TSCI and bone injury were included and improvements in the grade were also assessed.[16] Univariate analyses showed the influence of yellow and anterior longitudi- nal ligaments on the prognosis of the injury, as well as the size of the edema and facet joint dislocation. However, multivariate analyses did not show its super- iority over the other cited factors.

In our sample, soft tissue damage positively affects AIS grade and MS. We could, however, argue that the two analyzed groups of patients (with and without LI), had several important differences; the groups were comparable by sex but showed significant differences in age, degree of injury, and the rest of assessed variables. However, the reason for these differences seems to be associated with the intensity of the trauma that caused the injury.

Concerning the AIS grade, there is uneven grade distribution between both groups. This could be misleading to assess if there is an improvement or not, so we carried out separate analyses of the different groups and the percentage of patients who improved was always greater among those without LI, even despite their higher mean age. Differences in initial MS are mostly due to the larger percentage of complete injuries in patients with soft tissue damage, even though there are fewer subjects with tetraplegia in comparison to the control group. The results of the present analyses suggest that both extra-parenchymal changes (SCC and LI) may help in the prognosis of SCI progression, which may be useful to better direct the process of rehabilitation and make decisions when prescribing therapies toward certain objectives, perhaps allowing to reduce hospital stay and patient's frustration by setting more realistic objectives.

Conclusions

SCC is associated with a higher frequency of vertebral fractures and ligament tearing. Patients who suffer from SCC have an increased risk of mortality and need for ICU.

LI is more frequent in younger patients and usually associated with polytrauma with spine fractures.

In TSCI cases, SCC or LI associates with complete injuries and lower MS in comparison to subjects without these complications. Regardless of the grade of injury, these patients have lower possibilities of improving their degree of injury and MS.

Ethical approval

Data were collected from the SCIU electronic clinical records, and subsequently codified and anonymized in a database. All information was treated following the guidelines of the Galicia Research Ethics Committee (*Consellería de Sanidade, Xunta de Galicia*) in compliance with the Organic Law 3/2018, of December 5, Protection of Personal Data and Guarantee of Digital Rights, as required in Spain. The Ethics Committee (registration code 2020/370) approved the study.

Disclaimer statements

Contributors None.

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Conflicts of interest Authors have no conflict of interests to declare.

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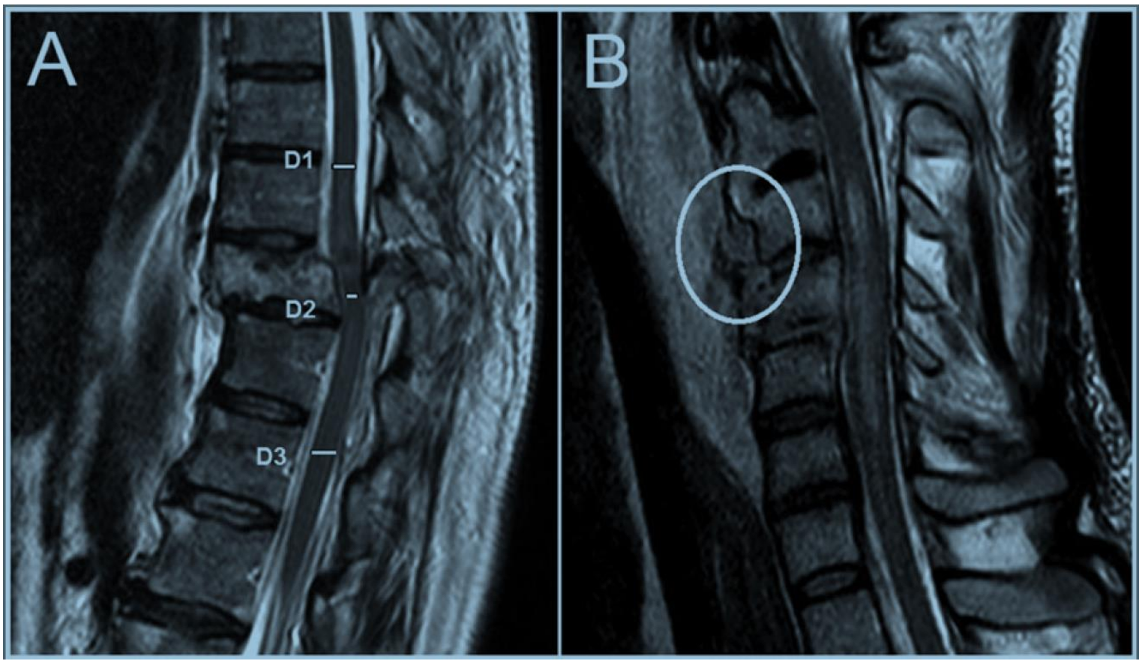

Figure 1 Analyses of the image: (A) Measurement of spinal cord stenosis (Fehling's method). (B) Ligament disruption (anterior longitudinal ligament)

Table 1 Characteristics of the established groups based on spinal cord compression.

	Spinal cord compression: no		Spinal cord compression: yes		P
	Mean ± SD		Mean ± SD		Student's t-test
Age	57.7 ± 18,2		61.1 ± 20.6		0.157
Length of hospital stay (days)	104.3 ± 88.6		143.9 ± 76.1		<0.001
Sex	N	%	N	%	Chi-squared test
Male (n = 215)	71	77.2	144	70.6	0.240
Female (n = 81)	21	22.8	60	29.4	
Level of injury	N	%	N	%	Chi-squared test
Tetraplegia (n = 202)	67	72.8	135	66.2	0.255
Paraplegia (n = 94)	25	27.2	69	33.8	
Vertebral fracture	N	%	N	%	Chi-squared test
Yes (n = 194)	52	56.6	142	69.6	0.028
No (n = 102)	40	43.5	62	30.4	
Spine surgery (*)	N	%	N	%	Chi-squared test
Yes (n = 145)	37	71.2	108	81.2	0.136
No (n = 40)	15	28.8	25	18.8	
Associated injuries	N	%	N	%	Chi-squared test
Yes (130)	38	41.3	92	45.1	0.543
No (166)	54	58.7	112	54.9	
Intensive care unit	N	%	N	%	Chi-squared test
Yes (154)	38	41.3	116	56.9	0.013

Table 1 Characteristics of the established groups based on spinal cord compression.

	Spinal cord compression: no		Spinal cord compression: yes		P
No (142)	54	58.7	88	43.1	
Mortality	N	%	N	%	Chi-squared test
Yes (n = 32)	2	2.2	30	14.7	0.001
No (n = 264)	90	97.8	174	85.3	

(*) Patients who died in the first seven post-injury days have not been counted in this section

Table 2 Characteristics of the established groups based on vertebral ligamentous injury.

	Ligamentous injury: no		Ligamentous injury: yes		P
	Mean ± SD		Mean ± SD		Student's t-test
Age	62.6 ± 18.8		56.6 ± 20,8		0.011
Length of stay hospital (days)	117.1 ± 80.7		152.5 ± 82.1		0.001
Sex	N	%	N	%	Chi-squared test
Male (n = 213)	128	72.7	85	72.6	0.988
Female (n = 80)	48	27.3	32	27.4	
Level of injury	N	%	N	%	Chi-squared test
Tetraplegia (n = 201)	133	75.6	68	58.1	0.002
Paraplegia (n = 92)	43	24.4	49	41.9	
Vertebral fracture	N	%	N	%	Chi-squared test
Yes (n = 192)	84	47.7	108	92.3	<0.001
No (n = 101)	92	82.3	9	7.7	
Spine surgery (*)	N	%	N	%	Chi-squared test
Yes (n = 143)	57	69.5	86	85.1	0.011
No (n = 40)	25	30.5	15	14.9	
Associated injuries	N	%	N	%	Chi-squared test
Yes (n = 128)	66	37.5	62	53.0	0.009
No (n = 165)	110	62.5	55	47.0	
Intensive care unit	N	%	N	%	Chi-squared test
Yes (n = 152)	75	42.6	77	65.8	<0.001

Table 2 Characteristics of the established groups based on vertebral ligamentous injury.

	Ligamentous injury: no		Ligamentous injury: yes		P
No (n = 141)	101	57.4	40	34.2	
Mortality	N	%	N	%	Chi-squared test
Yes (n = 32)	14	8.0	18	15.4	0.046
No (n = 261)	162	92.0	99	84.6	

(*) Patients who died in the first seven post-injury days have not been counted in this section

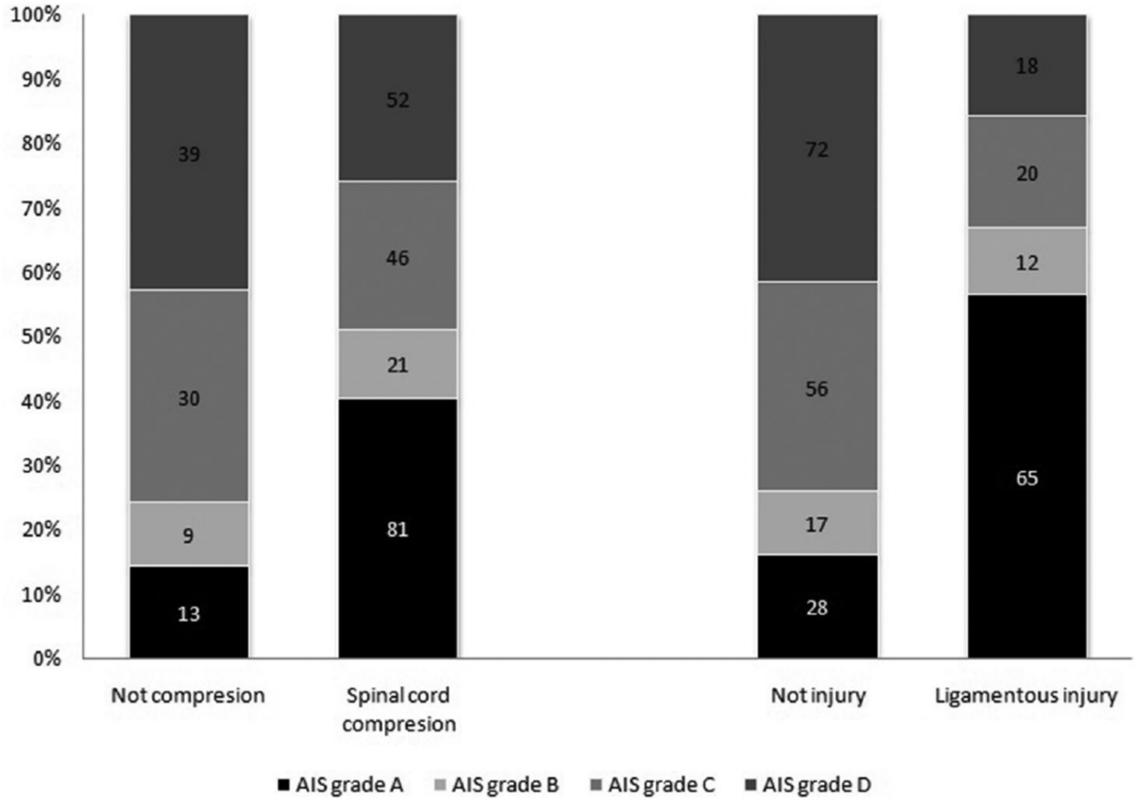

Figure 2 Distribution of AIS grades within the study groups.

Table 3 Neurological improvement by AIS grade based on spinal cord compression and ligamentous injury.

		Spinal cord compression			Ligamentous injury		
		No	Yes		No	Yes	
		N (%)	N (%)	P	N (%)	N (%)	P
Grade A	Improvement	5 (41.7)	15 (23.4)	Fishers's test	7 (31.8)	13 (24.5)	Chi-squared test
	No improvement	7 (58.3)	49 (76.6)	0.282	15 (68.2)	40 (75.5)	0.516
Grade B	Improvement	4 (50.0)	13 (72.2)	Fishers's test	10 (66.7)	6 (60.0)	Fisher's test
	No improvement	4 (50.0)	5 (37.8)	0.382	5 (33.3)	4 (40.0)	1.000
Grade C	Improvement	25 (83.3)	26 (57.8)	Chi-squared test	39 (69.6)	12 (63.1)	Chi-squared test
	No improvement	5 (16.7)	19 (42.2)	0.020	17 (30.4)	7 (36.9)	0.601
Grade D	Improvement	4 (10.2)	2 (4.3)	Fishers's test	6 (8.6)	0 (0.0)	Fisher's test
	No improvement	35 (89.8)	46 (95.7)	0.401	64 (91.4)	16 (100.0)	0.588

Table 4 Motor score changes within the groups based on extra-parenchymal damage.

Spinal cord compression (SCC)			Ligamentous Injury (LI)		
	Mean ± SD	P		Mean ± SD	P
	MS at admission			MS at admission	
SCC: no	61.1 ± 29.9	Student's t-test	LI: no	54.9 ± 29.4	Student's t-test
SCC: yes	46.9 ± 26.8	<0.001	LI: yes	45.9 ± 26.7	0.014
	MS at discharge			MS at discharge	
SCC: no	79.4 ± 24.7	Student's t-test	LI: no	73.6 ± 27.6	Student's t-test
SCC: yes	62.7 ± 29.6	<0.001	LI: yes	58.3 ± 29.3	<0.001
	MS variation			MS variation	
SCC: no	19.3 ± 21.1	Student's t-test	LI: no	18.8 ± 20.3	Student's t-test
SCC: yes	15.9 ± 20.2	0.231	LI: yes	13.7 ± 20.5	0.061
	Percentage of MS change			Percentage of MS change	
SCC: no	49.4 ± 38.1%	Student's t-test	LI: no	46.0 ± 37.5%	Student's t-test
SCC: yes	35.1 ± 37.5%	0.010	LI: yes	28.5 ± 37.1%	0.001

MS = motor score; SCC (spinal cord compression).