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ORIGINAL ARTICLE

Changes in injury level in pediatric patients with spinal cord trauma

Cambios en nivel de la lesión de pacientes pediátricos con trauma medular

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What do we know about the subject matter of this study?

In the pediatric population, traumatic spinal cord injury (TSCI) significantly affects functionality and participation. Scientific evidence on neurological recovery in this population is limited, especially regarding the description of changes in the Neurological Level of Injury (NLI) and the grade on the ASIA Impairment Scale (AIS).

What does this study contribute to what is already known?

This study provides insight into neurological recovery in a pediatric sample with TSCI. Most patients experienced changes, predominantly in NLI, over the deficiency grade of the AIS. Although complete TSCIs are unlikely to experience changes in AIS grade, improvements in NLI are possible in these cases.

Abstract

Traumatic spinal cord injury (TSCI) is uncommon in pediatrics but has a significant negative impact on children's quality of life. Currently, there is limited literature documenting neurological recovery in this population within the first few months after a TSCI. **Objective:** To describe changes in the neurological level of injury (NLI) and the ASIA Impairment Scale (AIS) score in pediatric patients following TSCI. A secondary objective was to explore associations between clinical variables and changes in NLI and AIS. **Patients and Method:** Observational, analytical, and retrospective study. Patients included were those aged 6 to 18 years diagnosed with TSCI and admitted between 2005 and 2022 at *Centro de Rehabilitación Fleni Escobar*. The primary variables were a change in the NLI and/or the AIS at discharge. Secondary variables evaluated were demographic data, injury etiology, vertebral involvement, associated injuries, surgery, and time of evolution. **Results:** The sample included 33 participants, with a mean age of 13.1 (SD 3.1) years. 57.6% were male and 21 individuals had complete TSCI on admission. At discharge, 63.6% of patients experienced favorable changes in NLI and/or AIS: 39.4% in NLI only, 6.1% in AIS only, and 18.2 % in NLI-AIS. Complete TSCI showed no significant changes in AIS; however, 57% of these individuals showed improvement in at least one NLI. When analyzing the relationship between clinical variables and changes in AIS, there were significant differences only according to injury severity

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(p = 0.02), with changes in 9.5% (2/21) of complete injury and 50% (6/12) of incomplete injury. **Conclusion:** Greater changes were observed in NLI compared to AIS scores. Although patients with complete TSCI are unlikely to experience changes in AIS, they may still show improvement in at least one NLI, which could positively impact functional outcomes.

Introduction

Traumatic spinal cord injury (TSCI) is rare in the pediatric population[1], compared to the adult population[2-4]. Although few cases are reported, this injury has a major negative impact on children, as it increases the probability of suffering complications and comorbidities, functional dependence, limitations in inclusive education, and social participation, as well as high economic costs at the health care level[5-8].

Studies in adult populations have observed that neurological recovery continues during the first few months after TSCI but slows down after 3 to 6 months[9,10,11]. In the case of incomplete injuries, between one-half and two-thirds of individuals achieved recovery within the first 2 months after injury[9-11].

In pediatrics, most studies only address the changes that occur in the ASIA Impairment Scale (AIS) during neurological recovery[12-15]. Bansal et al. observed that only 6% of their sample improved in AIS grade[12]. In other studies, a higher percentage of change in AIS grades was observed, with values ranging from 43% to 64% of the samples analyzed[13-15]. Although changes in the neurological level of injury (NLI) are relevant when reporting neurological recovery[16], they are still studied by a few authors[14]. Geuther et al. reported that 59% of cases with TSCI at the cervical level showed a change of at least one lesion level[14].

Given the scarce scientific evidence in pediatrics that reports neurological recovery in terms of changes in the NLI and AIS grade[12-15], it is common to extrapolate the outcomes obtained in the adult population when discussing the recovery prognosis in TSCI[9,11]. Additionally, studies in the pediatric population come mainly from primary-level care centers in European and North American countries[12-15]. The objective of this research was to describe the changes in NLI and the AIS grade in pediatric patients after TSCI, in a tertiary-level healthcare center in Argentina, as well as to explore the association between clinical variables and changes in NLI and the AIS grade.

Patients and Method

Design and participants

Observational, analytical, retrospective study in pediatric patients with TSCI who were admitted to the *Centro de rehabilitación FLENI*, Escobar, Argentina, between January 1, 2005, and December 31, 2022. This study was approved by the Institution's Ethics and Research Committee (#005/23, approved in June 2023). All relatives or legal guardians of the participants signed the informed consent.

Eligibility Criteria

Patients between 6 and 18 years of age with clinical symptoms compatible with TSCI and who were evaluated according to the International Standards for Neurological Classification of Spinal Cord Injuries[17] (ISNCSCI) examination at admission and discharge from the intensive rehabilitation program in the pediatric inpatient area were included. The following patients were excluded: those with a lesion duration longer than 3 months, those presenting symptoms consistent with cauda equina syndrome, those who had suffered a traumatic brain injury with persistent altered consciousness upon admission to the institution, patients with psychiatric conditions, pre-existing systemic diseases, or genetic syndromes, and those whose medical records lacked data on key variables of interest.

Data collection

The clinical information of interest was collected from medical records and the institutional database, according to the International SCI Core Data Set (version 3.0) recommendations[16,18,19]. The data were coded and tabulated into an Excel spreadsheet designed for this study with exclusive access by the research team.

Primary variable

Our primary variable was defined as a change in NLI and/or in the AIS grade, being this "change" understood exclusively as an improvement in the condition assessed at admission.

The neurological status in patients with SCI is assessed using the ISNCSCI examination. This tool evaluates motor and sensory function on each side of the body and determines the NLI, defined as the most caudal segment of the spinal cord with intact sensation and antigravity muscle function, as long as both sensory and motor function are normal (intact) in all segments above. In addition, it classifies spinal cord injury into grades of dysfunction according to the ASIA Impairment Scale (AIS) as follows: A (complete injury,

with no motor or sensory function in the S4-S5 segments); B (incomplete sensory injury, with preserved sensory function in the sacral segments and no motor function more than three levels below the NLI); C (incomplete motor injury, with preserved motor function in the caudal sacral segments with voluntary anal contraction, or meeting the criteria for incomplete sensory injury with motor function present in more than three segments below the NLI, less than half of the key muscles below the NLI have a muscle grade ≥ 3); D (incomplete motor injury, similar to C, but with at least half or more of the key muscle function below the NLI having a muscle grade ≥ 3), and E (normal, sensory and motor function are normal in all segments in a patient who previously had deficits)[17].

Secondary variables

The following variables were recorded: sex, age at the time of injury (grouped into age ranges), injury etiology (due to 'sports or recreational physical activities', 'assault', 'transportation-related', 'fall', and 'other traumatic cause, including birth injury' or 'unknown'), vertebral injury (whether there were fractures, dislocations, or fracture-dislocation at the spinal level), associated injuries (at the time of TSCI, whether there was the presence of 'traumatic brain injuries', 'non-vertebral or facial fractures', 'severe thoracic injuries', 'traumatic limb amputations' or 'severe bleeding or internal organ damage'), and spinal surgery (whether the patient required any type of stabilizing or decompressive spinal surgery during the acute phase). Also, the time of evolution (days between the date of injury and the date of admission to our rehabilitation center) and length of stay in rehabilitation (days between the date of admission and discharge from our center) were calculated[16,18,19].

Upon admission to our institution, all relatives or legal guardians of the participants signed informed consent for the use of clinical data for research purposes.

Statistical analysis

Categorical variables were expressed as absolute frequencies. Continuous variables were presented as mean and standard deviation (SD) when normally distributed and as median and interquartile range (IQR) otherwise. The Shapiro-Wilk test was applied to assess the assumption of normality.

In order to explore whether there is an association between changes in NLI as well as AIS grade and different clinical variables, the following variables were dichotomized: age ("6-12" or "13-18 years")[14], injury level ("tetraplegia" or "paraplegia"), severity of injury ("complete" or "incomplete"), time of evolution ("< 45 days" or "≥ 45 days") (10,20), and rehabilitation stay ("< 6 months" or "≥ 6 months")[11]. The chi-square test (X^2) or Fisher's exact test was used, as appropriate. Values of $p < 0.05$ were considered statistically significant. All statistical analyses were performed using SPSS software (version 26).

Results

A total of 41 patients with TSCI were admitted during the study period. Of these, 8 cases that met at least one of the predefined exclusion criteria were excluded. Finally, the sample analyzed consisted of 33 subjects. Figure 1 shows the flow diagram of the participants.

The mean age of the sample was 13.1 (SD 3.1) years, and 19 (57.6%) patients were male. 21 (63.6%) participants had a complete TSCI, considering both tetraplegia and paraplegia cases. The main cause of injury in 13 (39.4%) cases was sports or recreational physical activities, with head-first diving into shallow water being the most frequently reported injury within this category (n = 7). The most frequently associated injury was traumatic brain injury, followed by non-vertebral fractures and internal organ injuries.

Of the total, 32 (97%) cases presented vertebral injury (fracture, dislocation, or fracture-dislocation) and 27 (81.8%) required spinal surgery to decompress the spinal cord and/or reduce the fractures. On admission to the institution, the median time of evolution was 37 days (IQR 18-55). Table 1 presents the characteristics of the participants at admission.

The median length of stay in our rehabilitation center was 5.1 (IQR 2.8-7.8) months. A total of 21 (63.6 %) patients showed changes in NLI and/or AIS grade: 13 (39.4 %) cases only in NLI, 2 (6.1 %) cases only in AIS, and 6 (18.2 %) cases in both NLI and AIS. Table 2 details the relationship between injury level at discharge and change in NLI. At discharge from the institution, 12 (36.3 %) cases showed no change (10 complete lesions and 2 incomplete lesions).

Table 3 presents the association between the level of injury at discharge and the change in AIS grade. Out of 21 patients admitted with complete TSCI (grade A) with either tetraplegia or paraplegia, 19 (90%) were discharged with the same grade of dysfunction. The one case identified as spinal cord injury without radiological abnormality (SCI-WORA) showed no change in AIS grade (AIS grade D at discharge). However, the patient did show improvement in NLI, from C2 to C4.

Table 4 presents the relationship between different clinical variables and changes in NLI as well as the AIS grade. Statistically significant differences were only observed when relating the severity of the lesion and the change in AIS grade ($p = 0.02$).

Discussion

Our study is the first to describe the neurological recovery observed in pediatric patients with TSCI in a tertiary healthcare center in Argentina, considering both changes in NLI and AIS grade. The main finding was that greater change was observed in the NLI, compared to the AIS grade.

As for the NLI, change was observed at one, two, and up to three levels below the lesion, with the highest rate of change at one level. Geuther et al. reported similar results when studying changes in the AIS grade and NLI where they saw greater change at one level of injury[14]. The importance of change in the NLI lies in the rehabilitation of these patients since improvement in at least one neurological level could result in greater functionality and independence for the patient[10]. We have found no other literature specifically describing change in NLI. However, some studies do address the change in motor level, which impacts motor recovery in TSCI patients[9].

Regarding the AIS grade, a greater change was observed in patients who presented incomplete lesions, particularly those initially classified as AIS grade C, coinciding with the results of other authors[15]. The percentage of AIS change was 24%, which was lower than that reported by previous research[13,14,15], but higher than the study by Bansal et al. (6%)[12]. The discrepancy in these results could be because these investigations presented a higher incidence of cases of SCI-WORA[21], a pathophysiological entity that is usually associated with a higher rate of improvement in AIS[22,23]. However, in our study, there was only one case of SCI-WORA with no change in AIS grade (AIS grade D at discharge), but in NLI (C2 to C4). Although this progress is positive, it does not reflect a significant change in AIS classification.

When considering the changes in NLI and the AIS grade simultaneously, only 18% of the patients improved, and cervical levels with incomplete lesions predominated. We have not found reports documenting changes in these two variables together[5,12,13,14,15].

Scivoletto et al. evaluated the association between clinical variables and neurological recovery in adults and found that complete lesions were associated with a lower rate of change in AIS grade[20]. In our sample, 90% of complete TSCIs continued to present the same grade of dysfunction at discharge, a rate similar to that reported in both pediatric[12,13,15] and adult populations[11,20]. It should be noted that, although these patients do not change their grade of dysfunction, they are likely to improve at least one level of injury, generating a possible improvement in their functionality and independence[10].

We have not identified clinically important differ-

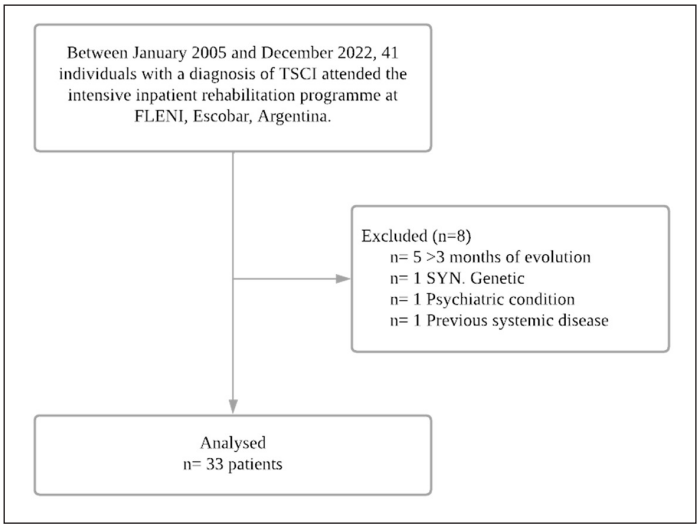

Figure 1. Participants' Flow Diagram. Abbreviations: TSCI, traumatic spinal cord injury; SYN, syndrome.

Table 1. Participants characteristics upon admission

Variables	Total n = 33
Age, mean (SD), years	13.1 (3.1)
Gender, n (%), male	19 (57.6)
Injury classification, n (%)	
Complete tetraplegia*	12 (36.4)
Incomplete tetraplegia	8 (24.2)
Complete paraplegia **	9 (27.3)
Incomplete paraplegia	4 (12.1)
Etiology of injury, n (%)	
Sports and leisure activities	13 (39.4)
Aggression	6 (18.2)
Transport activities	12 (36.4)
Fall	0 (0)
Other traumatic cause	1 (3)
Sciwora	1 (3)
Spinal injury, n (%)	32 (97)
Associated injuries, n (%)	
TBI	9 (27.3)
Non-vertebral fractures	5 (15.1)
Severe facial injuries	1 (3)
Severe chest injuries	2 (6.1)
Severe bleeding or internal organ damage	5 (15.1)
Spinal surgery, n (%)	27 (81.8)
Evolution time, median (IQR), days	37 (18.5-55.5)

*Includes C1-C8; ** Includes T1-S3. Abbreviations: SD, standard deviation; IQR, interquartile range; TBI, traumatic brain injury.

Table 2. Association between level of injury upon discharge and change in NLI*

Change in NLI	Injury level upon discharge			Total
	C1-C4	C5-C8	T1-S3	
No change	6	2	6	14
1 level	5	3	6	14
2 levels	2	2	-	4
≥ 3 levels	-	-	1	1
Total	13	7	13	33

*Change" is defined as an improvement in the condition assessed at admission. Abbreviations: NLI, Neurological level of injury.

ences in the rate of neurological recovery according to the time of evolution. It has been reported that a shorter period of evolution is associated with a higher probability of recovery[20]. We believe that even patients with longer evolution times could benefit from rehabilitation.

In our study, we observed a higher proportion of recovery in younger patients, which may be related to both true neurological recovery and lack of cooperation during

Table 3. Association between the level of injury upon discharge and the change in AIS grade

AIS Admission > Discharge	Injury level upon discharge			Total
	C1-C4	C5-C8	T1-S3	
A > A	9	2	8	19
A > B	-	1	-	1
A > C	-	-	1	1
A > D	-	-	-	0
B > B	-	1	-	1
B > C	-	1	-	1
B > D	-	-	-	0
C > C	-	-	-	0
C > D	1	2	2	5
D > D	3	-	2	5
Total	13	7	13	33

Abbreviations: AIS, ASIA Impairment Scale; NLI, Neurological Level of Injury.

Tabla 4. Association between clinical variables and changes in NLI as well as in AIS

	n	Change in NLI		Change in AIS	
		Present	Absent	Present	Absent
Age, years					
6-12	11	8 (73)	3 (27)	2 (18)	9 (82)
13-18	22	11 (50)	11 (50)	6 (27)	16 (73)
P value		0.28		0.69	
Injury level					
Tetrapléjicos	20	13 (65)	7 (35)	5 (25)	15 (75)
Parapléjicos	13	6 (46)	7 (54)	3 (23)	10 (77)
P value		0.47		0.99	
Severity of injury*					
Completa	21	12 (57)	9 (43)	2 (10)	19 (90)
Incompleta	12	7 (58)	5 (42)	6 (50)	6 (50)
P value		0.99		0.02	
Time of evolution, days					
< 45	21	13 (62)	8 (38)	4 (19)	17 (81)
≥ 45	12	6 (50)	6 (50)	4 (33)	8 (67)
P value		0.72		0.42	
Rehabilitation stay, months					
< 6	20	11 (55)	9 (45)	5 (25)	15 (75)
≥ 6	13	8 (62)	5 (38)	3 (23)	10 (77)
P value		0.99		0.99	

*Severity of injury upon discharge. Numerical values express counts (n) and percentages (%). Abbreviations: AIS, ASIA Impairment Scale; NLI, Neurological level of injury.

the ISNCSCI examination. This tool is suitable for children older than 6 years, but its accuracy improves significantly after the age of 10 years, due to increased cognitive development[24,25]. Therefore, although the ISNCSCI is a valuable tool in both adults and pediatrics, it is essential to consider these limitations when interpreting the results in the pediatric SCI population[26].

This study has several limitations. First, the sample analyzed is small despite covering more than 15 years. This may be because patients with TSCI are not exclusively referred to our rehabilitation center. However, the sample size is similar to that of previous studies[13,14,15]. Second, given the retrospective nature of the study, we did not have key variables, such as motor and sensory level, which would have provided a better understanding of the change in NLI and its impact on functional recovery. Future studies should explore this relationship, which would provide valuable information on the effectiveness of rehabilitation, functional adaptations implemented, and potential neurological recovery in pediatric patients with TSCI. Third, we did not have ISNCSCI examinations during the acute phase of the injury (< 7 days), which would have provided information on the possibility of neurological recovery[9] as well as allowed us to observe whether there was recovery between the acute phase and their admission to rehabilitation. Finally, although several authors have noted that most neurological recovery occurs within the first 6 to 9 months following TSCI[9,10], we were unable to precisely determine when such recovery took place, as in our institution ISNCSCI assessments are conducted upon admission, at one month (excluded from analysis due to data loss), and at discharge, in order to avoid exposing children to the frustration of not recovering or to the discomfort of evaluating intimate areas.

Considering which are the possible changes in the NLI or AIS grade that have an impact on neurological recovery in pediatric patients with TSCI, it would be possible to foresee or anticipate what their evolution will be, always taking their initial neurological status as a starting point. This information allows for establishing appropriate therapeutic objectives and strategies for each stage of rehabilitation, optimizing intervention through the early prescription of assistive or adaptive devices, family training on daily care, home accessibility adaptations, and the planning of in-home therapeutic assistance, among others. These measures could improve the personalized care, clinical outcomes, and overall well-being of pediatric TSCI patients.

Conclusions

The results of our study indicate that neurological recovery of pediatric TSCI patients is best evidenced by a change in NLI compared to AIS grade. Although complete TSCIs are unlikely to experience a change in AIS grade, the observed improvement at least at one neurological level suggests a possible positive impact on functional independence. These findings underscore the importance of assessing multiple aspects of neurological recovery to provide greater insight into the rehabilitation and quality of life of TSCI patients.

Ethical Responsibilities

Human Beings and animals protection: Disclosure the authors state that the procedures were followed according to the Declaration of Helsinki and the World Medical Association regarding human experimentation developed for the medical community.

Data confidentiality: The authors state that they have followed the protocols of their Center and Local regulations on the publication of patient data.

Rights to privacy and informed consent: The authors have obtained the informed consent of the patients and/or subjects referred to in the article. This document is in the possession of the correspondence author.

Conflicts of Interest

Authors declare no conflict of interest regarding the present study.

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