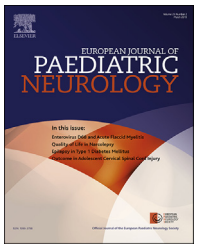
Official Journal of the European Paediatric Neurology Society



Original article

Functional outcome after traumatic cervical spinal cord injury is superior in adolescents compared to adults

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ARTICLE INFO

Article history:
Received 14 June 2018
Accepted 5 December 2018

Keywords:
Spinal cord injury
Cervical spine
Outcome
Children
Adolescents

ABSTRACT

Objective: Determining differences in neurological and functional outcome between adolescents and adults after acute traumatic spinal cord injury (SCI).
Design: Retrospective, multi-center case–control study.
Methods: 100 cases of patients under 18 years at accident with acute traumatic cervical SCI admitted to SCI centers participating in the European Multi-center study about SCI (EMSCI) between January 2005 and April 2016 were reviewed. According to their age at accident, age 13 to 17, patients were selected for the adolescent group. After applying in- and exclusion criteria 32 adolescents were included. Each adolescent patient was matched with two adult SCI patients for analysis.
Outcome measures: ASIA Impairment scale (AIS) grade, neurological, sensory, motor level, total motor score, and Spinal Cord Independence Measure (SCIM III) total score.

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[1] European Multicenter Study on Human Spinal Cord Injury.
https://doi.org/10.1016/j.ejpn.2018.12.001

Results: Mean AIS conversion, neurological, motor and sensory levels as well as total motor score showed no significantly statistical difference in adolescents compared to the adult control group after follow up of 6 months. Significantly higher final SCIM scores ($p < 0.05$) in the adolescent group compared to adults as well as a strong trend for a higher gain in SCIM score ($p < 0.061$) between first and last follow up was found.
Conclusions: Neurological outcome after traumatic cervical SCI is not superior in adolescents compared to adults in this cohort. Significantly higher SCIM scores indicate more functional gain for the adolescent patients after traumatic cervical SCI. Juvenile age appears to be an independent predictor for a better functional outcome.

1. Introduction

Traumatic spinal cord injury (SCI) leads to life-changing and often permanent disabilities in the affected individuals. Predictors for functional and neurological recovery are needed in order to provide adequate therapy and to improve the care for these patients. In adolescent patients, SCI has a severe impact on the ongoing maturation process.[1]

Due to anatomic and therefore biomechanical differences caused by the osseous immaturity of the pediatric spine, injury mechanisms and healing processes in children are distinct from those of adults, while adolescents with advanced maturation converge in both aspects with adults.[2–6]

To date limited experience is available regarding the neurologic outcome for these patients. Comparing available pediatric studies is difficult as age margins are set differently and outcome measures differ widely.[7–9]

The minimal age for inclusion in most studies is often set at 18 years.[9,10] Hence, the adolescent group is either included in the children cohort, not evaluated separately or completely excluded. Between children and adults, the adolescents should be regarded as a separate entity of its own with skeletal maturation nearing completion.[2,5,6]

For a valid comparison of the neurological outcome of adolescent and adult patients after traumatic cervical SCI the American Spinal Injury Association Impairment Scale (AIS scale) alone fails to capture the full spectrum of impairments as a primary outcome parameter. Therefore, in this study the Spinal Cord Independence Measure (SCIM III), validated for assessing activities of daily living (ADL) and mobility tasks, was chosen as primary outcome measure.[11]

The following study aims to investigate, how adolescents differ in their neurological recovery after traumatic cervical SCI compared to adults, as the hypothesis was that neurological and functional outcome are superior in adolescents compared to adults.

2. Methods

2.1. Setting

This analysis was performed at the Trauma Center Murnau (Germany), a cross-regional level I trauma center with a specialized SCI department. We participate in the EMSCI (European Multicenter Study about Spinal Cord Injury) project since 2004. The EMSCI project aims to establish a multi-center basis for future therapeutic interventions in human SCI by testing and documenting patients within a fixed time schedule after SCI.

2.2. Patients

This study represents a retrospective chart review of SCI patients who were admitted to Trauma Center Murnau and all other EMSCI participating centers between January 2005 and April 2016. Clinical data were collected prospectively within a predefined time schedule according to established standards of the EMSCI project.

After analyzing the study protocol, the responsible ethics committee of the Bavarian Medical Board waived the requirement for a detailed ethical consultation (16016) for this study.

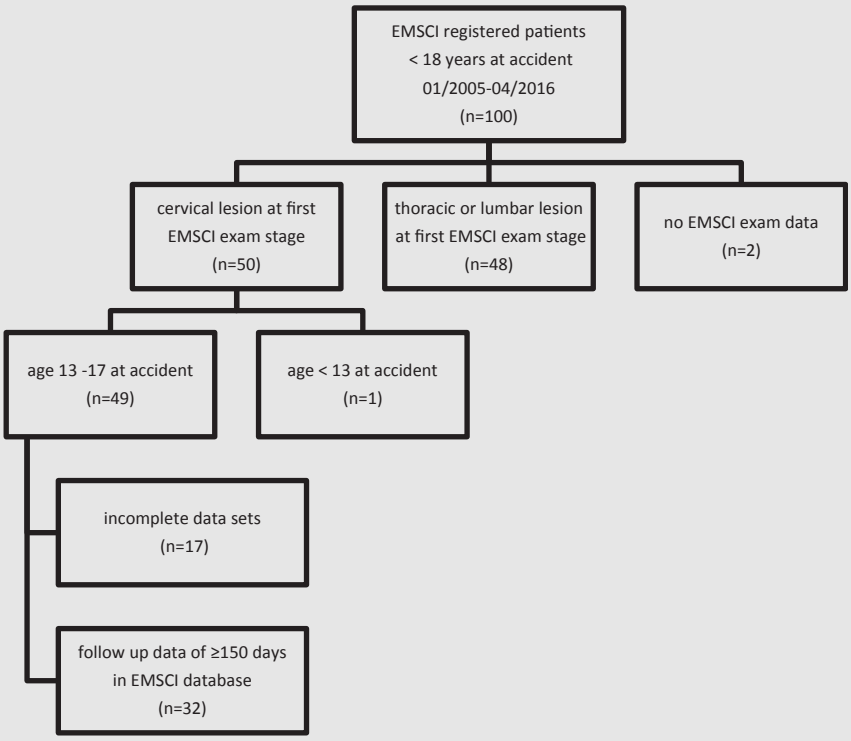
We included patients with traumatic SCI with cervical lesion from C0 to Th1, age between 13 and 17 years (adolescents) at the date of injury and adequate follow-up data available in the EMSCI database (Table 1).

The following baseline outcome parameters were assessed via extraction from the EMSCI database: age, gender, length of stay in rehabilitation, AIS grade, neurological, sensory, and motor level as well as total motor score (tMS) (range 0–100) according to ISNCSCI (International Standards for Neurological Classification of Spinal Cord Injuries) and SCIM total score (tSCIM, range 0–100). According to the EMSCI-study program; the AIS performed according to ISNCSCI between exam stages very acute (0–15 days) and chronic (≥300 days) were accepted. The functional test data was collected according to SCIM III.

In order to obtain an adequate control group, we selected SCI patients from the EMSCI database with the following predefined criteria: traumatic cervical SCI, age over 18 (adults) and follow up data with at least 150 days (EMSCI exam stage acute III). Each adolescent patient was then matched with two adult patients from the control group according to neurological level of injury, initial AIS grade and tSCIM. Matching regarding tSCIM was achieved by grouping tSCIM scores into five categories of 20 (0–20, 21–40, 41–60, 61–80, 81–100).

Table 1 – In- and exclusion criteria.

Inclusion criteria
Traumatic cervical spinal cord injury
Age under 18 at accident
Follow up data (≥150 days) in EMSCI database available
Exclusion
Non-traumatic spinal cord injuries
Thoracic or lumbar lesion level
Age >18 at accident



Abbreviations: EMSCI: European Multicenter Study about Spinal Cord Injury

2.3. *Statistical analysis*

All statistical analyses were done using SPSS Statistics 19 (IBM, New York) software. Baseline characteristics were compared for differences between each matched pair with non-matched analysis. For normally distributed (assessed by the Shapiro–Wilk test) continuous variables t-tests were done (for others Mann-Whitney-U tests). For categorical variables (e. g. sex, AIS grade, or neurological levels) chi-square and Fisher exact test were used for comparison. For each outcome parameter of the study, a stratified analysis using a conditional logistic regression was done to test for differences between the matched groups.

3. Results

3.1. *Study population*

During the observation period, 32 adolescent patients (27 males) fulfilled inclusion and exclusion criteria (Table 1).

The median age at accident within the adolescent cohort was 16 years (13–17, Inter Quartile Range (IQR) = 2). Most adolescents in this group were 17 years old (n = 14, 43.8%). The control group (n = 64) varied in age between 19 and 72, averaging a median of 46 years at accident (IQR = 30). Demographical data showed a majority of male adolescents (male:female ratio approximately 5:1). The predominant initial neurological level was C4 (n = 15, 46.9%). We observed a trend towards higher tSCIM levels at baseline in the adolescent cohort compared to the control group ($p < 0.068$) (Table 2).

3.2. *Neurological recovery and functional outcome*

Adolescent patients and their control group were evaluated with a mean follow up after 315 (adolescents) and 316 (control group) days (Table 3). Median AIS conversion was 0.75 (range: 0–3) in adolescents and 0.81 (range: −1–3) in the adult control group with no significant difference between the two groups. Although neurological, motor, sensory level and tMS improved in both groups, we found no trend for either group. Assessed outcome parameters are presented in Table 3.

We identified a significantly higher tSCIM ($p < 0.021$) in the adolescent group compared to adults as well as a strong trend for a higher tSCIM difference ($p < 0.061$) between first and last follow up of the adolescents (Table 4).

Table 2 – Compared demographic data on group of tetraplegic patients under age 18 at accident (n = 32) and tetraplegic control group age minimum 18 years (n = 64).

	tetraplegic patients <18 years		control group ≥18		p value
number of patients	32		64		
age					
age at accident (years) [median (IQR)]	16 (2)		46 (30)		
	age	number of patients [n (%)]	age group	number of patients [n (%)]	
	13	2 (6.3%)	18–19	3 (4.7%)	
	14	3 (9.4%)	20–29	14 (21.9%)	
	15	8 (25.0%)	30–39	6 (9.4%)	
	16	5 (15.6%)	40–49	15 (23.4%)	
	17	14 (43.8%)	50–59	13 (20.3%)	
			60–69	12 (18.8%)	
			70–79	1 (1.6%)	
Gender					p < 1.000
female	5 (15.6%)		10 (15.6%)		
male	27 (84.4%)		54 (84.4%)		
length of stay in hospital unit (days) [median (IQR)]	188 (86)		175 (46)		p < 0.491
baseline neuro level of injury					p < 1.000
C1	1 (3.1%)		2 (3.1%)		
C2	0 (0.0%)		0 (0.0%)		
C3	5 (15.6%)		10 (15.6%)		
C4	15 (46.9%)		30 (46.9%)		
C5	9 (28.1%)		18 (28.1%)		
C6	2 (6.3%)		4 (6.3%)		
baseline AIS					p < 0.945
A	16 (50.0%)		36 (56.3%)		
B	13 (40.6%)		22 (34.4%)		
C	1 (3.1%)		2 (3.1%)		
D	2 (6.3%)		4 (6.3%)		
baseline tSCIM score [median (IQR)]	10 (10)		5 (10)		p < 0.068
baseline sensory level [median (IQR)]	C4 (1)		C4 (1)		p < 0.977
baseline motor level [median (IQR)]	C5 (1)		C5 (1)		p < 0.759
baseline total motor score [median (IQR)]	11 (17)		10 (18)		p < 0.984

Abbreviations: AIS: American Spinal Injury Association Impairment Scale.
tSCIM score: total Spinal Cord Independence Measure score.

4. Discussion

This study investigates the neurological and functional outcome after traumatic cervical SCI in adolescents compared to adults. Neurological outcomes were assessed prospectively in acute phase after trauma and in the chronic phase, with at least 150 days follow up. To the best of our knowledge, this study is the first to compare the neurological and functional outcome by matching adolescent patients to adults.

Only limited data of adolescent SCI regarding demographics and outcome exist due to varying national health care systems, inconsistent availability of SCI registries, different data collection systems and classification systems.[9] Most epidemiological reports of pediatric SCI are derived from the United States and Europe.[2] The consensus is that pediatric and adolescent SCI is relatively rare.[6–8,10,12,13] The upper age limit stratifying patients into pediatric SCI studies varies from 15 to 20 years often including adolescent patients undifferentiated. Our decision to set the age limit for the adolescent group from 13 to 17 years of age was due to the osseous maturation of the cervical spine. With start of ossification in the 3rd fetal month, the osseous maturation begins at the age of 10. With the full onset of puberty, the maturing spine decreases its ligamentous laxity and shows continuous anatomical and biomechanical convergence with the adult spine and proneness to spinal injury mechanisms similar to those in adults.[2–5,13]

The median age at injury in the adolescent group was 17 years of age. Males were predominately affected (n = 27, 84.4%). Interestingly, Vogel et al. described a male:female ratio of 80% among adolescents, similar to the adult SCI population, and noted that the male prevalence decreases with age at injury.[2] The most prevalent initial neurological level in our study was C4 supporting previously published typical levels for tetraplegia in older children, adolescents and adults (C4 to C6).[14] The adolescent patients showed predominantly motor complete injuries at baseline (AIS grades A or B) indicating relatively severe injuries.

Noteworthy, we observed a trend for higher tSCIM scores in the adolescent cohort compared to the control group at baseline tSCIM score (p < 0.068). Allen et al. analyzed the Functional Independence Measure (FIM) motor score development in 941 children (age range 0–21 years). The FIM motor score and SCIM III are comparable concerning validity.[11] In their retrospective analysis FIM motor scores at admission were negatively correlated with age amongst other parameters. FIM gains from admission to discharge had a weak association with age at injury with children 15 years or younger.[15]

Table 3 – Compared follow up on group of tetraplegic patients under age 18 at accident (n = 32) and tetraplegic control group age minimum 18 years (n = 64).

	tetraplegic patients <18 years	control group ≥18	p value
number of patients	32	64	
follow up			
mean follow up (range) days	315 (156–558)	316 (150–684)	
AIS conversion			
mean AIS conversion (range)	0.75 (0–3)	0.81 (−1–3)	p < 0.732
AIS conversion			
−1	0 (0.0%)	1 (1.6%)	
0	17 (53.1%)	30 (46.9%)	
1	7 (21.9%)	16 (25.0%)	
2	7 (21.9%)	14 (21.9%)	
3	1 (3.1%)	3 (4.7%)	
neuro level (NL) of injury			
NL difference [median (IQR)]	1 (2)	0 (1)	p < 0.220
NL difference			
−2	1 (3.1%)	3 (4.7%)	
−1	2 (6.3%)	3 (4.7%)	
0	10 (31.3%)	27 (42.2%)	
1	10 (31.3%)	19 (29.7%)	
2	6 (18.8%)	9 (14.1%)	
3	2 (6.3%)	3 (4.7%)	
4	1 (3.1%)	0 (0.0%)	
motor level (ML)			
ML difference [median (IQR)]	1 (2)	1 (1)	p < 0.517
sensory level (SL)			
SL difference [median (IQR)]	1 (2)	1 (3)	p < 0.633
total motor score (tMS)			
mean tMS difference [median (IQR)]	11 (48)	9 (35)	p < 0.194

Abbreviations: AIS: American Spinal Injury Association Impairment Scale.

Initially, we assumed that after SCI adolescents show a higher potential for neurological recovery than adults as often stated in the pediatric SCI literature.[10,12] However, with our matched pair analysis we were not able to confirm any statistical differences between the adolescent and adult groups in respect to AIS conversion, improvement of neurological, motor, and sensory level as well as tMS. Interestingly, in respect to functional outcome we identified statistically significant higher final tSCIM scores (p < 0.021) in the adolescent group compared to adults.

When interpreting the results of this study, some limitations need to be acknowledged. First, by including patients from the EMSCI register and not only patients treated in one hospital, we have no data about the individual patient treatment, such as performed stabilizing operation and early decompression, which seems to show a beneficial effect on functional outcome.[17] Therefore also data about intensive care and SCI related treatment, e. g. blood pressure augmentation or different surgical and rehabilitative treatment approaches could not be correlated to neurological recovery.[18–20] As we performed a retrospective study, the disadvantage of missing values and exclusion of patients due to incomplete data sets also have to be noted. Fortunately, SCI in children and adolescents is rare.[21] Hence the small number of patients that we could extract from EMSCI register is a further limitation to our study.

Table 4 – Compared tSCIM in follow up on group of tetraplegic patients under age 18 at accident (n = 32) and tetraplegic control group age minimum 18 years (n = 64) and logistic regression (stratified).

		tetraplegic patients <18 years		control group ≥18	p value
tSCIM					
last tSCIM score [median (IQR)]		39 (32)		24 (31)	p < 0.021
tSCIM difference [median (IQR)]		27 (30)		19 (30)	p < 0.061
logistic regression (stratified)					
Last tSCIM [median (IQR)]		predictor	p value	odds ratio	confidence interval (95%)
	model 1: p < 0.009	last tSCIM	p < 0.021	1.031	1.005–1.059
	model 2: p < 0.046	baseline tSCIM	p < 0.070	1.093	0.993–1.203
		last tSCIM	p < 0.021	1.032	1.005–1.060
tSCIM difference	model 1: p < 0.046	tSCIM difference	p < 0.061	1.022	0.999–1.046

Abbreviations: tSCIM score: total Spinal Cord Independence Measure score.

Further prospective studies with inclusion of more patients collecting additional data about pediatric and adolescent SCI are needed. For example, in Germany the implementation of a SCI registry connected to the established TraumaRegister DGU® could provide further insights into pediatric and adolescent SCI.

There is call for common data elements (CDE) structure for pediatric SCI to provide longitudinal monitoring, standardization for collection of data and enable the comparison of results between and across studies.[16] Functional tests and outcome measurements are mostly validated for adults and then field-tested in children with SCI. Outcome instruments covering the pediatric-adolescent age span that generate comparable results to adult outcome measurements are needed.[16]

In conclusion, this study shows that neurological outcome after traumatic cervical SCI is not superior in adolescents compared to adults in our cohort. Clinically we found no evidence for a superior neuroplasticity in adolescents within our study population. Significantly higher tSCIM scores indicate more functional gain for the adolescent patients after traumatic cervical SCI under similar rehabilitation procedures as adults. Juvenile age appears to be an independent predictor for a higher follow up tSCIM score. Therefore, to tap their full potential specific rehabilitation approaches for adolescent patients are indicated.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Author Disclosure Statement

The authors declare no conflict of interest. No competing financial interests exist.

Acknowledgments

The authors acknowledge the support of the European Multicenter study about Spinal Cord Injury. The authors thank all colleagues at the Trauma Center Murnau and other participating EMSCI centers who were involved in patient care.

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