Original Article

TURKISH JOURNAL OF EMERGENCY MEDICINE

Access this article online
Quick Response Code:
Website:
https://turkjemergmed.com/
DOI:
10.4103/tjem.tjem_48_24

The relationship between magnetic resonance imaging, clinical findings, treatment modalities, and neurological outcomes in acute traumatic spinal cord injury in the emergency department

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Abstract:

OBJECTIVES: Spinal cord injury (SCI) can lead to motor, sensory, or autonomic dysfunction and is associated with increased morbidity and mortality. This study aimed to investigate the impact of magnetic resonance imaging (MRI) and clinical findings in the Emergency Department (ED) on neurological outcomes in patients with traumatic SCI.

METHODS: This observational study included 59 patients with traumatic SCI admitted to Dokuz Eylül University Hospital's ED between January 1 2009, and October 1, 2019. Clinical findings were assessed using the American Spinal Injury Association (ASIA) scale. Demographics, clinical findings, MRI parameters, treatment, and short-term (28 ± 7 days) neurological outcomes were compared between the complete (ASIA A) and incomplete (ASIA B, C, D, and E) injury groups.

RESULTS: The incidence of SCI was 98.7 per million. The median age was 37 years (IQR: 27-52), with 86.4% of the patients being male. Common causes included diving into shallow water (30.5%) and falling from heights (25.4%). Complete injury (ASIA A) was observed in 40.7% of cases, while incomplete injury (ASIA B, C, D, and E) was found in 59.3%. The most frequently affected levels were C4 (18.6%) and C5 (23.7%). No improvement was observed in the complete injury group, whereas 44% of the incomplete injury group showed improvement ($P < 0.001$). Common MRI findings included cord edema (96.6%), vertebral fracture/dislocation (86.4%), and soft-tissue injury (84.7%). Significant differences in MRI findings between the complete and incomplete SCI groups were observed in vertebral fracture/dislocation ($P = 0.016$), cord compression ($P = 0.003$), canal stenosis ($P = 0.008$), intramedullary hemorrhage ($P \leq 0.001$), hemorrhage/hemorrhagic contusion ($P \leq 0.001$), anterior ligament damage ($P = 0.001$), posterior ligament damage ($P = 0.01$), maximum canal compression (MCC) ($P = 0.006$), and lesion length ($P = 0.008$).

CONCLUSION: Traumatic SCI primarily affects young males, often resulting from activities such as diving into shallow water, falls from heights, and motor vehicle accidents. Initial clinical assessments are insufficient for predicting neurological outcomes. Although MRI findings are more frequent in complete SCI, lesion length, and MCC do not reliably predict short-term neurological improvement.

Keywords:

American Spinal Injury Association scoring, emergency department, magnetic resonance ımaging, traumatic spinal cord injury

Submitted: 08-03-2024
Revised: 26-11-2024
Accepted: 04-12-2024
Published: 01-04-2025

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How to cite this article: Ulusoy M, Çolak N, Küçük S, Sarı S, Balcı A. The relationship between magnetic resonance imaging, clinical findings, treatment modalities, and neurological outcomes in acute traumatic spinal cord injury in the emergency department. Turk J Emerg Med 2025;25:107-15.

Box-ED section

What is already known on the study topic?

- SCIs can result in various dysfunctions, prompting an investigation into the impact of MRI and clinical findings on neurological outcomes in patients with traumatic SCIs.

What is the conflict on the issue? Has it importance for readers?

- The conflict centers on the efficacy of initial clinical assessments in predicting neurological outcomes for patients with traumatic SCIs. This study critically evaluates the current approach to assessing clinical findings and radiological measurements, and their role in outcome prediction, which holds significant importance for readers in both clinical practice and research.

How is this study structured?

- The study employs an observational design, involving 59 patients with traumatic SCIs. Demographics and clinical findings using the American Spinal Injury Association scale, MRI parameters, and treatment were assessed, along with a comparison of neurological outcomes between complete and incomplete injury groups.

What does this study tell us?

- The study provides key insights into the demographics and causes of traumatic SCIs, emphasizing its prevalence among young males due to activities such as diving into shallow water, falls from heights, and motor vehicle accidents. It questions the effectiveness of initial clinical assessments in predicting neurological outcomes, noting an increase in MRI findings in complete SCI cases. However, it also highlights the limitations of specific MRI parameters in forecasting short-term neurological improvement, challenging established assumptions about the predictive role of MRI in traumatic SCI outcomes.

Introduction

Traumatic spinal cord injury (SCI) results in a spectrum of motor, sensory, or autonomic dysfunction within the spinal cord. Its incidence, prevalence, causative mechanisms, severity, and sex distribution vary across nations and geographical regions. The incidence is documented at 40 million per year in developed countries and 25.55 million per year in developing countries.[1]

Primary SCI, caused directly by trauma such as contusion, compression, or transection, is followed by secondary injury involving spinal cord edema due to hypoxia and an inflammatory process that develops within minutes to hours.[2] Distinguishing between complete and incomplete SCI is crucial for determining prognosis. This evaluation is most accurately performed using the International Standards for Neurological Classification of Spinal Cord Injury (ISNCSCI) examination form, updated and standardized by the American Spinal Injury Association (ASIA) in 2013.[3]

Although computed tomography (CT) provides some information about the paravertebral soft tissue and spinal cord in patients with SCI, its effectiveness is lower compared to Magnetic Resonance Imaging (MRI). If CT findings suggest possible SCI or ligament injury, an MRI should be performed for a more accurate assessment. MRI is highly effective in revealing spinal cord compression, disc pathologies, and ligament injuries, as well as intramedullary injuries such as hemorrhage, edema, and cystic formations. A systematic review of the case series found that 5.8% of patients with normal CT images had SCI detected on MRI scans.[4] MRI remains the gold standard for spinal cord evaluation, with quantitative measures such as maximum canal compression (MCC), maximum spinal cord compression (MSCC), and lesion length being crucial for assessing SCI on MRI images.[5]

The early mortality rate for traumatic SCI patients is reported to range from 4% to 20%.[6,7] Significant improvements are observed in patients with incomplete injuries, those without known comorbidities, and those without complications such as infection.[8] Our study aimed to investigate the impact of MRI, clinical findings, and primary treatments on neurological outcomes. Based on the data obtained, we seek to contribute to the emergency management of these patients and to guide actions aimed at protecting them from secondary damage.

Methods

This retrospective, observational, cross-sectional study was conducted at the Dokuz Eylul University Hospital Adult Emergency Department (ED) from January 1, 2010, to October 1, 2019. Patients with acute traumatic SCI whose spinal MRI images were obtained in the ED were identified from the Hospital Information Management System. Nontraumatic SCI patients, those who could not be examined due to concurrent traumas (e.g., traumatic brain injury, intracranial hemorrhage, mass lesions, and diffuse axonal injury), and patients with inaccessible archival data were excluded. The study commenced after receiving approval from the Dokuz Eylul University Faculty of Medicine Ethics Committee, dated November 18, 2019, with reference number 2019/28-28.

Collection of data

The data collection form recorded patients' age, gender, vital signs, trauma mechanisms, concomitant traumas, MRI findings, treatments administered during the acute phase (including steroid therapy at trauma doses and surgical interventions), ASIA scores, and outcomes at days 0, 7, and 28 (ASIA 0: at admission, ASIA 7: on the 7^{th} day, and ASIA 28: on the 28^{th} day). The ASIA 0 scores were derived from consultation forms completed by the surgical team during the acute phase and by physical therapy and rehabilitation specialists during the follow-up period (ASIA 7 and ASIA 28). The ASIA classification was defined as follows:

- -ASIA A: Complete loss of sensory and motor function below the level of injury, including S4–S5
- -ASIA B: Incomplete injury with preserved sensory function but absent motor function below the level of injury, including S4–S5
- -ASIA C: Incomplete injury with preserved motor function below the level of injury, where most muscles below the injury level have a grade of <3
- -ASIA D: Incomplete injury with preserved motor function below the level of injury, where at least half of the muscles below the injury level have a grade of 3 or higher
- -ASIA E: Normal sensory and motor function.

Spinal MRI images were assessed by a neuroradiologist who was a member of the study team. MRI findings were categorized as cord edema, cord compression, hemorrhage/hemorrhagic contusion, canal stenosis, ligament injury, fracture/dislocation, transection, disc herniation, and soft-tissue injuries (including abnormal thickening and muscle edema/hemorrhage/strain).

Quantitative MRI findings in SCI included:

- MCC: Calculated as (1-(Di/((Da + Db)/2)) × 100%)), where Di is the diameter of the cord at the center of the lesion, Da is the diameter of the closest intact tissue above the lesion, and Db is the diameter of the closest intact tissue below the lesion, obtained from the T1 sequence
- MSCC: Calculated as (1-(di/((da + db)/2)) × 100%) where di is the diameter of the cord at the center of the lesion, da is the diameter of the closest intact tissue above the lesion, and db is the diameter of the closest intact tissue below the lesion, obtained from the T2 sequence
- Length of lesion: Represented by the difference (da–db) in spinal cord signal intensity change [Figure 1].

Statistical analysis

The data were recorded in the Statistics Program for the Social Sciences (SPSS 24.0, IBM Corporation, Armonk, New York, United States). The normality of the variables was evaluated with the Kolmogorov–Smirnov test. While the mean ± standard deviation and minimum–maximum values were given for normally distributed data, median and interval of quartiles (interquartile range [IQR]) values were given for abnormally distributed variables. The *t*-test or Mann–Whitney *U*-test was used to compare measurements. The Chi-square or Fisher's exact test was used to compare categorical data. $P < 0.05$ was considered significant.

Figure 1: Measurement points of maximum canal compression (MCC) on T1 sequence and maximum spinal cord compromise (MSCC) on T2 sequence. Measurement points for MCC value on mid-sagittal T1-weighted imaging (left) include the spinal cord diameter at the level of injury (Di), the first unaffected level above the injury (Da), and the first unaffected level below the injury (Db). Measurement points for MSCC on mid-sagittal T2-weighted imaging (right) include the spinal cord diameter at the level of injury (di), the first unaffected level above the injury (da), and the first unaffected level below the injury (db)

Results

During the study period, a total of 1,074,103 patients were admitted to the emergency department (ED). Out of these, 13,604 patients presented with trauma, and 106 were diagnosed with SCI. The incidence of SCI was calculated to be 98.7 per million. Six patients were excluded due to artifacts in MRI images, and 41 patients were excluded because their neurological status could not be assessed due to concomitant injuries.

Demographic data

The study included 59 patients. Of these, 51 (86.4%) were male, resulting in a male-to-female ratio of 6.4:1. The median age of the patients was 37 years (IQR: 27–52). Among the patients, 24 (40.7%) had a complete SCI, and 35 (59.3%) had an incomplete SCI. There was no significant difference between the median ages of patients with complete SCI and those with incomplete SCI.

Mechanisms of trauma

The trauma mechanisms observed were as follows: 18 (30.5%) patients had diving injuries into shallow water, 15 (25.4%) patients fell from a height, 17 (28.8%) patients were involved in traffic accidents, 7 patients fell from the same level, one patient was assaulted, and one patient was injured by being crushed under a collapsed building.

Physical examination characteristics

The Glasgow Coma Scale score was 15 in 56 patients and 14 in 3 patients. The mean systolic blood pressure, mean diastolic blood pressure, heart rate, and respiratory rate were 121.0 ± 24.8 mmHg (range: 60–211 mmHg), 75.0 ± 18.0 mmHg (range: 36–138 mmHg), 79.3 ± 17.0 beats per minute (range: 33–128 bpm), and 21.1 ± 3.7 breaths per minute (range: 16–36 bpm), respectively.

Neurological injury levels

The most common sensory level was C4 in 11 (18.6%) patients, the most common motor level was C5 in 14 (23.7%) patients, and the most common neurological level was C4 in 11 (18.6%) patients.

Concomitant injuries

Twenty-four patients (40.6%) had at least one additional systemic injury. The distribution of these injuries was as follows: thoracic trauma in 14 (23.7%) patients, extremity trauma in 9 (15.3%) patients, head trauma in 8 (13.6%) patients, pelvic trauma in 2 (3.4%) patients, and abdominal trauma in 1 (1.7%) patient.

Imaging results

MRI findings are summarized in Table 1. The most common MRI finding was spinal cord edema (n = 57, 96.6%), followed by vertebral fracture/dislocation (n = 51, 86.4%) and soft-tissue injury (n = 50, 84.7%). Spinal cord edema was present in 100% of patients with complete SCI and 94.2% of those with incomplete SCI (P = 0.509). Vertebral fractures/dislocations were found in 100% of patients with complete SCI and 77.1% of those with incomplete SCI (P = 0.016). Soft-tissue injuries were found in 91.7% of patients with complete SCI and 80% of those with incomplete SCI, but this difference was not statistically significant (P = 0.287). Other MRI findings, such as cord compression (P = 0.003), canal stenosis (P = 0.008), intramedullary hemorrhage ($P \leq 0.001$), hemorrhage/hemorrhagic contusion ($P \leq 0.001$), anterior ligament damage (P = 0.04), and posterior ligament damage (P = 0.01), were significantly more common in patients with complete SCI. There was no significant difference between complete and incomplete SCI in terms of disc herniation, epidural bleeding, and transection. Transection was the least common MRI finding, occurring in three patients with complete SCI and one patient with incomplete SCI. No statistically significant differences were observed between patients with and without improvement in terms of MRI findings or quantitative measures, except for spinal cord edema and transection, which were not analyzed statistically due to their exclusive occurrence patterns. Quantitative MRI measurements were conducted in 56 patients (excluding those with complete transection where measurements could not be obtained). The results showed that MCC (P = 0.006) and lesion length (P = 0.008) were higher in patients with complete SCI. No significant differences were found for other measures.

Treatments

Surgical treatment was administered to 52 patients, steroid treatment to 32 patients, and three patients were managed with other treatment modalities. The median time from admission to surgery for patients who underwent surgery was 1320 min (IQR: 376–3015 min),

Table 1: Trauma mechanisms, accompanying injuries, and outcomes of patients

	Total (n=59), n (%)	Complete	Incomplete				
		ASIA A (n=24), n (%)	ASIA B (n=8), n (%)	ASIA C (n=9), n (%)	ASIA D (n=8), n (%)	ASIA E (n=10), n (%)	Total (n=35) n (%)
Trauma mechanism							
Dived into shallow water	18 (30.5)	9 (37.5)	2 (25.0)	1 (11.1)	4 (50.0)	2 (20.0)	9 (25.7)
Fell from height	15 (25.4)	4 (16.7)	3 (37.5)	3 (33.3)	1 (12.5)	4 (40.0)	11 (31.4)
Traffic road accident	17 (28.8)	9 (37.5)	2 (25)	3 (33.3)	2 (25)	1 (10.0)	8 (22.8)
Fall from the same level	7 (11.9)	2 (8.3)	1 (12.5)	2 (22.2)	-	2 (20.0)	5 (14.3)
Assault	1 (1.7)	-	-	-	1 (12.5)	-	1 (2.6)
Be under a dent	1 (1.7)	-	-	-	-	1 (10.0)	1 (2.6)
Accompanying injury							
Thorax	14 (23.7)	5 (20.8)	3 (37.5)	2 (22.2)	-	4 (40.0)	9 (25.7)
Extremity	9 (15.3)	4 (16.7)	1 (12.5)	3 (33.3)	-	1 (10.0)	5 (14.3)
Head	8 (13.6)	2 (8.3)	1 (12.5)	2 (22.2)	3 (37.5)	-	6 (17.1)
Pelvis	2 (3.4)	-	1 (12.5)	1 (11.1)	-	-	2 (5.7)
Abdomen	1 (1.7)	-	1 (12.5)	-	-	-	1 (2.6)
Outcomes of patients							
Discharge	32 (54.2)	7 (29.2)	2 (25.0)	5 (55.6)	8 (100)	10 (100)	25 (71.3)
Admission to the service	22 (37.2)	14 (58.3)	5 (62.5)	3 (33.3)	-	-	8 (22.9)
Admission to the ICU	3 (5)	2 (8.3)	1 (12.5)	-	-	-	1 (2.6)
Death	2 (3.4)	1 (4.2)	-	1 (11.1)	-	-	1 (2.6)

ASIA: American Spinal Injury Association Scale, ICU: Intensive care unit and the median time for initiating steroid treatment was 202 min (IQR: 90–307 min).

Outcomes

No patients in the ASIA A group with complete SCI showed improvement, and one patient died by the 28th day. Functional improvement was observed in 11 (31.4%) patients in the ASIA B, C, and D groups with incomplete SCI within the first 28 days. Most patients with complete SCI (*n* = 14, 58.3%) were hospitalized in the ward, while the majority of patients with incomplete SCI (*n* = 25, 71.3%) were discharged. One patient from each group died [Figure 2]. As ASIA E represents complete neurological recovery, patients in this group were excluded from the short-term improvement evaluation. Among patients with complete SCI (*n* = 24) and those with incomplete SCI in the ASIA B, C, and D groups (*n* = 25), none of the patients with complete SCI showed improvement, whereas 11 patients with incomplete SCI (44%) demonstrated improvement. The median age for patients with and without improvement was 41 years (IQR: 26–66) and 36 years (IQR: 29–49), respectively. No significant differences were observed in gender ($P = 0.117$), comorbidities ($P > 0.05$), trauma mechanisms ($P = 0.076$), concomitant injuries ($P > 0.05$), hemogram findings ($P > 0.05$), and vital signs ($P > 0.05$). No significant differences were found between the improvement and nonimprovement groups regarding the use of steroids and surgical treatment [$P = 0.164$ and $P = 1.000$, respectively, Table 2]. When comparing ASIA A, B, C, and D groups within themselves, the median time to start steroid treatment was 180 min (IQR: 90–282), and the median time to surgery was 1320 min (IQR: 330–2760). In the improvement group, the median time for trauma dose steroid treatment was 135 min (IQR: 88–231), and the median surgery time was 2970 min (IQR: 388–10,005). Comparing MRI findings between improvement and nonimprovement groups, none of the findings or quantitative measures were statistically significant [Table 3].

Discussion

The incidence of (SCIs was reported to be between 8 and 21 per million in a study conducted in Turkey in 2005 by Gur *et al*.[9] Our study, however, found an incidence of 98.7 per million, which is significantly higher than previously reported figures. This elevated incidence may be attributed to several factors, including the hospital's proximity to a major highway leading to popular tourist destinations, which increases traffic accidents, and a higher proportion of elderly individuals with mobility limitations. In addition, the prevalence of coastal cliffs in our city may contribute to the increased incidence of traumatic SCIs.

Taşoğlu *et al*. (2018) reported that SCIs in Turkey are most frequently observed in individuals in their 30s, which is consistent with our findings.[10] The higher incidence of SCIs in this age group can be attributed

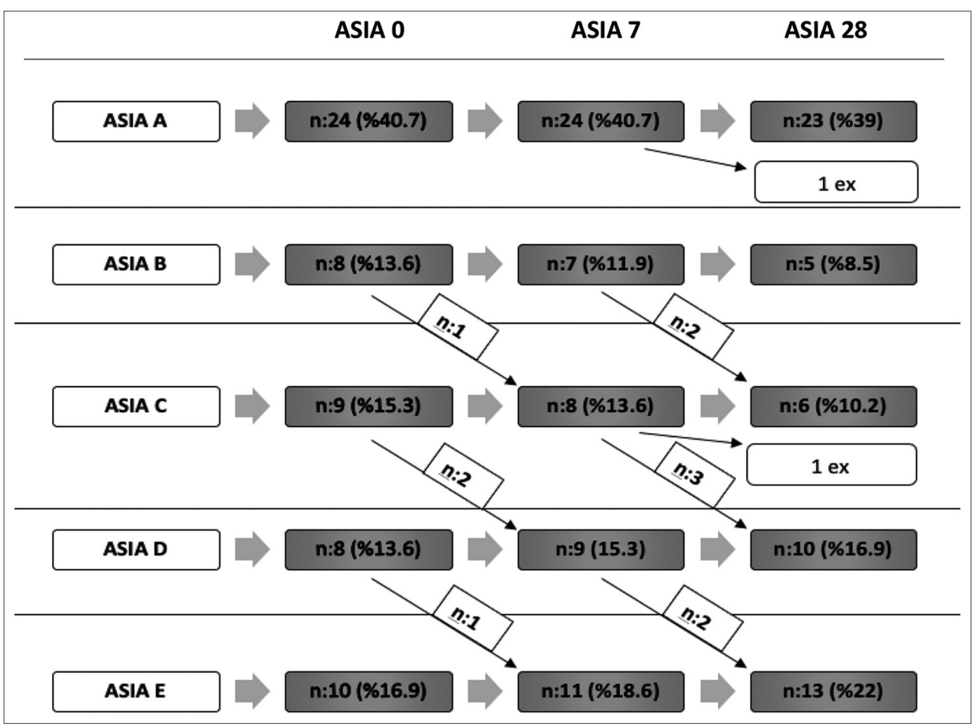

Figure 2: Patient outcomes according to American Spinal Injury Association Scale scores (ASIA: American Spinal Injury Association Scale, ASIA 0: Admission ASIA score, ASIA 7: 7th-day ASIA score, ASIA 28: 28th-day ASIA score)

Table 2: Magnetic resonance imaging findings according to American Spinal Injury Association Scale groups

MRI findings	Total	Complete	Incomplete				
	n=59	ASIA A *n*=24	ASIA B *n*=8	ASIA C *n*=9	ASIA D *n*=8	ASIA E *n*=10	Total *n*=35
	n (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)	*n* (%)
Cord edema (*P*=0.509)	57 (96.6%)	24 (100%)	8 (100%)	9 (100%)	8 (100%)	8 (80.0%)	33 (94.3%)
Vertebral Fracture/Dislocation (*P*=0.016)	51 (86.4%)	24 (100%)	8 (100%)	6 (66.7%)	5 (62.5%)	8 (80.0%)	27 (77.1%)
Soft Tissue Injury (*P*=0.287)	50 (84.7%)	22 (91.7%)	8 (100%)	7 (77.8%)	7 (87.5%)	6 (60.0%)	28 (80.0%)
Cord Compression (*P*=0.003)	35 (59.3%)	20 (83.3%)	7 (87.5%)	5 (55.6%)	2 (25.0%)	1 (10.0%)	15 (42.9%)
Canal Stenosis (*P*=0.008)	32 (54.2%)	18 (75%)	8 (100%)	3 (33.3%)	2 (25.0%)	1 (10.0%)	14 (40.0%)
Intramedullary Bleeding (*P*=<0.001)	27 (45.8%)	18 (75%)	5 (62.5%)	1 (11.1%)	2 (25.0%)	1 (10.0%)	9 (25.7%)
Hemorrhage/Hemorrhagic Contusion (*P*=<0.001)	27 (45.8%)	18 (75%)	5 (62.5%)	1 (11.1%)	2 (25.0%)	1 (10.0%)	9 (25.7%)
Anterior Ligament Injury (*P*=0.04)	25 (42.4%)	14 (58.3%)	6 (75.0%)	3 (33.3%)	1 (12.5%)	1 (10.0%)	11 (31.4%)
Disc Herniation (*P*=0.77)	16 (27.1%)	7 (29.2%)	-	4 (44.4%)	5 (62.5%)	-	9 (25.7%)
Posterior Ligament Injury (*P*=0.01)	12 (20.3%)	9 (37.5%)	2 (25.0%)	1 (11.1%)	-	-	3 (8.6%)
Epidural Hemorrhage (*P*=1.000)	8 (13.6%)	3 (12.5%)	2 (25.0%)	1 (11.1%)	2 (25.0%)	-	5 (14.3%)
Transection (*P*=0.294)	4 (6.8%)	3 (12.5%)	1 (12.5%)	-	-	-	1 (2.6%)
Quantitative MRI findings, mm	**mean±sd (min-max)**	**mean±sd (min-max)**	**mean±sd (min-max)**				
Da (*P*=0.238)	11.5±1.5 (8.1-15.2)	11,8±1,4 (8.8-14.0)	11,3±1,6 (8.1-15.2)				
Di (*P*=0.056)	7.7±2.2 (1.4-13.4)	7.0±2.4 (1.4-11.5)	8.1±2.0 (3.5-13.4)				
Db (*P*=0.202)	11.7±1.7 (7.7-15.5)	12.0±1.6 (8.0-14.8)	11.4±1.7 (7.7-15.5)				
Da (*P*=0.099)	6,3±1,2 (3,5-8,8)	6.6±1,2 (3.5-8.5)	6.0±1,1 (4.1-8.8)				
Di (*P*=0.281)	5,7±1,5 (1.2-8,7)	5,4±1.7 (1.2-8.7)	5,9±1.3 (3.0-8.4)				
Db (*P*=0.892)	5,8±0.7 (3.7-7.4)	5.9±0.7 (3.7-7.0)	5.8±0.7 (4.2-7.4)				
MCC (*P*=0,006)	33,9%±18.0 (0.7-86,1)	41.9%±18.7 (11.9-86.1)	28.7%±15.7 (0.7-66.8)				
MSCC (*P*=0.088)	5.4%±23.3 (-58,2-78.0)	12.1%±28,1 (-58.2-78.0)	1,1%±18,9 (-27.5-53.8)				
Lesion length (*P*=0.008)	31.8±17.6 (6-66)	49.4±15.6 (16-66)	26.8±17.3 (6.0-65.0)				

Table 3: Types of treatment and time to start treatment of the patient groups with and without improvement

	Total (*n*=49)	Improvement (+) (*n*=11)	Improvement (–) (*n*=38)	*P*
Surgery, *n* (%)	45 (91.8)	10 (90.9)	35 (92.1)	1.000*
Median application time (min), median (IQR)	1320 (330–2760)	2970 (388–1005)	1200 (300–2450)	0.101†
Steroid at trauma dose, *n* (%)	31 (63.3)	5 (45.5)	26 (68.4)	0.164‡
Median application time (min), median (IQR)	180 (90–282)	135 (88–231)	228 (90–324)	0.485†

*Fisher's exact test, †Mann–Whitney *U*-test, ‡Chi-square test. Ten patients with an ASIA score of E were excluded. ASIA: American Spinal Injury Association Scale, IQR: Inter quartile range

to the active lifestyle of younger individuals, their propensity for engaging in high-risk activities, exposure to traffic accidents, occupational hazards, and general self-confidence. While motor vehicle accidents have traditionally been identified as the leading cause of SCI globally, falls from heights have become more prevalent than traffic accidents in recent years, likely due to the aging population.[6] In line with this, a study conducted in Turkey found that falls, particularly among the elderly, accounted for 32.8% of SCI cases.[7] In our study, falls were categorized into falling from a height (25.4%) and falling from the same level (11.9%), with falls being the most common cause, as corroborated by existing literature. The incidence of shallow water diving injuries shows regional variation, with reported rates ranging from 1.2% to 21%.[11] However, our study identified a higher rate of 30.5%. Previous studies in Turkey have primarily identified falls and motor vehicle accidents as the most common causes of SCI.[6] In contrast, our research, conducted in a seaside location, found that falls and shallow-water diving were the leading causes of SCI. Public awareness campaigns regarding the dangers of diving into unknown or shallow waters, the installation of warning signs at popular swimming areas, and educating children and adolescents about safe diving practices are essential preventive measures. Furthermore, promoting the use of designated diving areas with known safe depths could help mitigate these risks.

The cervical spine is most commonly affected in SCIs, with C5 and C4 being the most frequently injured levels in developed countries.[12] In developing countries, including Turkey, studies have reported lumbar and thoracic regions as the most affected.[13] In our study, which aligns with data from developed countries, the cervical region was the most frequently affected, with an incidence rate of 57.6%. Among cervical injuries, C4 was the most frequently affected level at 18.6%, followed by C5 at 16.9%. The higher prevalence of cervical injuries in our study may be attributed to the increased occurrence of diving accidents in a seaside setting.

At the time of admission, the ASIA classification of patients most commonly indicated ASIA A, followed by ASIA D.[8,13] Most patients in the literature have incomplete injuries. In our study, 40.7% of patients were classified as ASIA A, while 59.3% had incomplete SCIs. Interestingly, ASIA E was the second-most common classification in our study, with a rate of 16.9%, which deviates from the literature.

A prospective study by Gupta *et al*., which included 50 patients, identified cord edema as the most common MRI finding in SCI (26%), followed by contusion (24%) and hemorrhage (16%). Transection (4%) and compression (6%) were the least common findings.[14] Rutges *et al*. reviewed MRI scans taken within the first 48 h and found spinal cord edema in all ASIA A and B patients and 50% of ASIA C patients.[15] In our study, all MRI scans were performed within the first 48 h of emergency department admission, and cord edema was the most common finding at 96.6%. All patients across ASIA A, B, C, and D classifications exhibited spinal cord edema. Other common findings included vertebral fractures and dislocations (86.4%) and soft-tissue injuries (84.7%). Transection was the least common finding (6.8%), consistent with existing literature. A prospective study in 2014 found that intramedullary hemorrhage, cord edema, cord swelling, canal stenosis, and soft-tissue injury were significantly more common in patients with complete SCI, whereas disc herniation showed no significant difference.[16] In our study, vertebral fracture and dislocation, spinal cord compression, canal stenosis, intramedullary hemorrhage, hemorrhage, and hemorrhagic contusion on MRI were statistically significantly higher in patients with complete SCI. The relationship between spinal cord edema and neurological outcomes has been debated, with some studies finding no association[17] and others linking spinal cord edema to poorer neurological outcomes.[18] Aarabi *et al*. reported a significant association between spinal cord edema and poor neurological outcome,[18] while Selden *et al*. did not.[19] In our study, no significant difference in spinal cord edema was observed between complete and incomplete SCI cases.

A review of the literature on the relationship between intramedullary hematomas and neurological outcomes reveals conflicting results. Two studies found no association between the presence of intramedullary hematomas and neurological outcomes, while three other studies reported that hematomas were associated with poorer neurological outcomes.[20] Another study identified the presence of hematomas as a poor prognostic factor for neurological recovery, with detection rates ranging from 50 to 100% in ASIA A patients and 14%–72% in ASIA B patients.[21] Selden *et al*. reported that all ASIA A patients had intra-axial hematomas and none showed functional improvement. Furthermore, the presence of larger intramedullary hematomas has been linked to worse neurological outcomes.[19] In our study, while intramedullary hematomas were more prevalent in patients with complete SCI, there was no significant difference in neurological improvement between those with and without hematomas.

A review of quantitative MRI measurements in SCIs indicates considerable variability across studies. For example, Boldin *et al*.[21] reported a mean lesion length of 10.5 mm for complete SCI and 4.0 mm for incomplete SCI, whereas our study measured lesion lengths of 49.4 ± 15.6 mm and 26.8 ± 17.3 mm, respectively, which are notably higher. MCC values of 41.9% and 28.7% for complete and incomplete SCI, and MSCC values of 12.1% and 1.1% for complete and incomplete SCI, respectively, partially align with existing literature but diverge in incomplete SCI MSCC measurements.

Studies investigating the relationship between quantitative MRI parameters and neurological outcomes have produced mixed results. Gupta *et al*.[18] suggested a correlation between low MCC and poor neurological outcomes, while other studies found no significant association.[16] A review indicated that while variables such as MSCC, lesion length, and cord edema do not consistently predict neurological prognosis, intramedullary hemorrhage, and cord swelling demonstrate more consistent correlations with outcomes in multivariate analyses.[20] In our study, higher MCC and lesion lengths were observed in complete SCI patients, but these parameters did not reliably predict neurological outcomes or overall prognosis. This suggests that, although quantitative MRI provides valuable insights into SCI characteristics, further research is needed to elucidate their predictive value and refine treatment strategies.

The timing of surgery for SCI remains a subject of debate, with conflicting evidence regarding its impact on outcomes. Some studies advocate for early surgical intervention to improve neurological prognosis by reducing intensive care unit stays and mobilization times.[22] Conversely, other research highlights potential risks of early surgery, including increased complications and potentially worse outcomes.[23] The STASCIS trial indicated a higher recovery rate with early surgery combined with glucocorticoid therapy, although no significant differences in mortality or complications were observed.[24] Recent studies have not shown significant improvements in ASIA scores or motor outcomes between early and late surgical interventions.[25]

Regarding methylprednisolone, updated guidelines recommend against its routine use in acute SCI due to mixed evidence on efficacy. A meta-analysis suggests that while high-dose methylprednisolone may contribute to long-term motor improvement and gastrointestinal recovery, its use is not strongly endorsed due to potential risks.[26] In our study, there was no significant neurological improvement in groups receiving methylprednisolone at trauma doses, and early surgery did not demonstrate short-term functional or neurological benefits. These findings underscore the need for further research to identify optimal treatment protocols tailored to individual patient needs in acute SCI cases.

Limitations

Our study was a retrospective, single-center study with a relatively small sample size and some missing patient data. We excluded patients whose neurological assessments were confounded by additional injuries, such as head trauma, to ensure that any observed neurological dysfunction could be attributed specifically to SCIs rather than other concurrent injuries. In addition, we evaluated MRI findings during the acute phase of injury. It is important to note that in some cases of SCI, the nature, and extent of lesions may not be fully delineated by MRI at such an early stage.

Conclusion

Traumatic SCI predominantly affects young males and is commonly associated with activities such as diving into shallow water, falls from heights, and motor vehicle accidents. Clinical findings upon hospital admission alone are insufficient for predicting patients' neurological outcomes. MRI findings, including vertebral fracture/dislocation, spinal cord compression, canal stenosis, intramedullary hemorrhage, hemorrhagic contusion, and damage to anterior and posterior ligaments, are observed more frequently in cases of complete SCI compared to incomplete SCI. In addition, lesion length and MCC rate are greater in complete SCI patients. However, these MRI findings do not reliably predict short-term neurological improvement. Therefore, regardless of lesion length and canal compression, patients should undergo evaluation by a multidisciplinary team, and their treatment and follow-up should be comprehensive. The effects of treatment modalities such as surgical intervention, trauma doses of steroids, and timing of treatment on short-term neurological outcomes remain unclear.

Author contributions statement

The manuscript has been read and approved by all authors.
Conceptualization: MU, NC, SK, AB.
Data curation: MU, SK, SS.
Formal analysis: MU, NC, AB.
Investigation: MU, SK, NC.
Methodology: MU, NC, SK.
Project administration: MU, NC, AB.
Supervision: AB, NC.
Roles/Writing - original draft: MU, NC, SK.
Writing - review and editing: MU, NC, SK, SK, SS.

Conflicts of interest

None Declared.

Ethical approval

The study was started after receiving the 18.11.2019 dated and 2019/28-28 numbered approval of Dokuz Eylül University Faculty of Medicine Non-Invasive Ethics Committee.

Funding

None.

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