e-ISSN: 0975-5160, p-ISSN: 2820-2651

Available online on www.ijtpr.com

International Journal of Toxicological and Pharmacological Research 2024; 14(12); 163-166

Original Research Article

Assessing Cervical Spine Injury Risk and Acute Spinal Cord Injury Prognosis Following Minor Trauma

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Received: 18-10-2024 / Revised: 21-11-2024 / Accepted: 26-12-2024
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Conflict of interest: Nil

Abstract:

Background and Objective: Acute spinal cord injury (SCI) following minor trauma to the cervical spine is a rare but serious condition that can occur even in individuals with no history of neurological symptoms. This unexpected vulnerability is often attributed to underlying spinal canal stenosis, which can predispose the spinal cord to damage despite the low intensity of the trauma. Identifying patients at risk and understanding the relationship between cervical spine anatomy and injury severity is critical for early diagnosis and prevention. The objective of this study was to investigate MRI parameters of the cervical spine in patients suffering from acute SCI and to investigate the use of these parameters for predicting the risk and severity of acute cervical SCI after a minor trauma to the cervical spine.

Material and Methods: A retrospective radiological study was conducted at a Medical College and Research Institute, involving forty patients diagnosed with acute cervical SCI and following minor cervical spine trauma. Measurements from MRI scans were used to calculate the spinal canal-to-vertebral body ratio, the space available for the cord, and the canal-to-cord ratio. Data analysis was performed using SPSS software (version 21).

Results: All MRI parameters examined in the SCI group were found to be significantly smaller ($p < 0.01$) compared to the control group. However, no significant differences were observed in these parameters across the various American Spinal Injury Association (ASIA) impairment score groups.

Conclusion: The risk of acute SCI following minor trauma to the cervical spine can be assessed by using a disc-level canal diameter cut-off value obtained from MRI scans. Moreover, the severity of acute SCI is influenced not only by the radiological characteristics of the spinal canal but also by other contributing factors.

Keywords: Spinal canal stenosis, Trauma, MRI, Spinal cord injury, cervical spine.

Introduction

Cervical spine injuries are among the most serious forms of trauma, with the potential to cause acute spinal cord injury (SCI) and result in significant morbidity. While major trauma is commonly associated with SCI, minor trauma can also lead to severe neurological outcomes in predisposed individuals, particularly those with structural anomalies such as spinal canal stenosis or reduced canal-to-cord ratio [1].

These subtle yet critical risk factors highlight the importance of early identification and risk stratification in patients presenting with cervical spine injuries. Magnetic resonance imaging (MRI) has proven to be an invaluable tool for assessing cervical spine anatomy and pathology. Studies have demonstrated that parameters such as the spinal canal diameter, canal-to-cord ratio, and the space available for the cord are key indicators in predicting the risk and severity of SCI [2,3]. Furthermore, these imaging metrics are particularly useful in identifying patients who may develop SCI even after minor trauma, allowing for more targeted prevention and management strategies.

Tetraplegia or paresis following minor cervical spine trauma, in the absence of osseous or disco-ligamentous injury, has been documented in patients who had no prior neurologic symptoms [4-6]. In such cases, congenital narrowing of the spinal canal or degenerative changes can lead to spinal canal stenosis, which heightens the risk of acute spinal cord injury (SCI) following hyperextension or flexion trauma to the neck, even without accompanying spinal column injuries [7,8].

Despite the growing body of evidence, there remains a gap in understanding how radiological findings correlate with clinical outcomes across different patient populations. Previous research has suggested that additional factors, such as pre-existing degenerative changes and biomechanical forces, may also contribute to the severity of SCI [10-12].

Magnetic resonance (MR) imaging parameters may provide valuable insights when assessing cervical spinal canal stenosis. Previous studies have shown that MR imaging metrics are dependable for predicting the onset and progression of cervical spinal neurapraxia in athletes experiencing sports-related trauma, as well as chronic spondylotic cervical myelopathy in Asian populations [1]. However, the role of MR imaging parameters in predicting the risk and severity of acute spinal cord injury (SCI) following minor trauma to the cervical spine remains unclear. This study aims to investigate the spinal canal diameter and the space available for the cord at the level of the intervertebral disc in patients who have suffered acute cervical SCI following minor cervical spine trauma.

Material and Methods

This was a retrospective, radiological-based study conducted at the College and Research Institute's Department of Radiodiagnosis. Patients who experienced acute cervical spinal cord injury (SCI) following trauma were identified by reviewing the case histories of consecutive individuals who had sustained tetraplegia or paresis and were admitted for evaluation or rehabilitation between January 2021 and August 2023. Exclusion criteria included patients with non-traumatic SCI (due to vascular, inflammatory, infectious, or mass-related causes), those with a history of cervical spinal cord disorders, and individuals without radiological evidence of SCI. For patients who experienced minor cervical spine trauma, additional exclusions were made for those with fractures (excluding isolated spinous process fractures) and disco-ligamentous injuries of the cervical spine as assessed by MR imaging. A total of forty patients with acute SCI following minor cervical spine trauma, with a mean age of 54.80 years at the time of injury, were identified. A control group was created from patients who had sustained flexion-extension trauma to the cervical spine but showed no clinical or radiological signs of cervical spinal cord pathology, and who were admitted to our institution for evaluation or rehabilitation. Patients with a history of cervical spinal cord disorders were excluded from this group as well. The final control group consisted of 145 patients. Additionally, individuals aged outside the 35 to 80-year range were excluded from both groups.

Methodology

Measurements were taken by two observers using the Phoenix PACS software (version 3.20.34233; Phoenix PACS GmbH, Freiburg, Germany) and recorded to the nearest 0.1 mm. On the MR images, the following parameters were measured the sagittal diameter of the vertebral body, the sagittal outer diameter of the subarachnoid space at the midpoint of the vertebra (mid vertebral canal diameter), the sagittal outer diameter of the subarachnoid space at the level of the intervertebral disc (disc-level canal diameter), and the sagittal diameter of the spinal cord at the levels C2 and T1. Spinal cord measurements were not taken at the affected levels to minimize measuring errors because of the signal changes after SCI. The sagittal diameter of the spinal cord decreases gradually, but only slightly from C2 to T1, and the cervical enlargement does not affect the sagittal diameter of the cord. The median of the two values was thus used for sub-sequent calculations. The following calculations were performed using the measurements from the MR images: the spinal canal to vertebral body ratio (TPR-MRI) was calculated by dividing the mid vertebral canal diameter by the diameter of the vertebral body; the space available for the cord was calculated by subtracting the diameter of the cord from the disc-level canal diameter and the canal-to-cord ratio was calculated by dividing the disc-level canal by the diameter of the spinal cord.

Statistical analysis

Data was analyzed and presented as medians along with 95% confidence intervals (CIs). The chi-square and Fisher exact tests were employed to compare the gender distribution between the groups. Spearman's rank-order correlation was used to assess relationships among variables. A significant level of <0.05 was set for all statistical tests. All statistical analyses were conducted using SPSS software (version 21.0). Patient data were anonymized to ensure confidentiality.

Results

According to Table 1, 20% of the 160 patients had SCI. The study showed a male preponderance, but the injury rates were comparable between genders, with no significant difference. Although the control group had higher age and weight, these differences were not statistically significant. This suggests that anthropometric factors do not play a significant role in the occurrence of SCI. As shown in Table 2, the most common cause of SCI was falls, accounting for twenty-four cases, followed by traffic accidents (10 cases). In the control group, traffic accidents were the leading cause of injury (66 cases), followed by falls. Most patients had no neurological deficits; however, both complete and partial neurological deficits were observed in patients who experienced falls and traffic accidents. The following parameters were assessed: TPR CR (Torg-Pavlov ratio on conventional radiographs), TPR MRI (Torg-Pavlov ratio on magnetic resonance imaging), CD DM (sagittal disc-level canal diameter), CD (MVM) sagittal mid-vertebral canal diameter, PPV (positive predictive value), and NPV (negative predictive value). As per Table 3, different radiological parameters were studied to determine the risk of SCI. Canal diameter at disc level shows the best sensitivity and specificity of 76%, followed by TPR based on MRI images 71%. So overall, the best parameter was found to be canal diameter at disc level. According to Table 4, significant positive correlations were observed between the parameters investigated (i.e., mid-vertebral and disc-level canal diameters, TPR-MRI). However, no significant correlations were found between any of the parameters and height or weight. Additionally, there was no significant correlation between any of the parameters and the ASIA motor or sensory scores.

Table 1: Gender and anthropometric characteristics of the patients (n=160).

Variables	SCI (n=40)	Control (n=145)	P value
Gender			
Male	28		0.32
Female	12	58	
Age in years (mean±SD)	43.5±8.4	53.8±7.1	0.36
Height (cm)	182±15.4	165±14.1	0.44
Weight (kg)	71±4.9	75±4.9	0.20

Table 2: Causes of sustained cervical injury in both groups.

Cause	SCI (n=40)	Control (n=125)	Complete/ partial/no neurological deficit
Falls	24	38	4/0/0
Traffic accidents	10	66	2/4/0
Winter sports	3	10	1/0/6
Diving	1	8	0/1/5
Flying accidents	1	3	0/0/2

Table 3: Effectiveness of radiological parameters in predicting SCI.

Parameters	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
TPR (CR)	62	71	67	73
TPR (MRI)	71	92	70	81
CD (DM)	76	94	84	92
CD (MVM)	51	95	79	88

Table 4: Correlation among different radiological parameters.

Parameters	Correlation coefficient (r)	Parameters
	SCI	Control
TPR(CR) vs TPR (MRI)	0.20	0.22
TPR(CR) vs CD (DM)	0.05	0.03
TPR(CR) vs CD (MVM)	0.12	0.11
TPR(MRI) vs CD (DM)	0.75	0.57
TPR(MRI) vs CD (MVM)	0.02	0.08
CD (DM) vs CD (MVM)	0.03	0.19

Discussion

The findings of this study contribute to the growing literature on acute cervical spinal cord injury (SCI) following minor trauma, especially in relation to radiological predictors and anatomical factors. In this study, 20% of patients experienced SCI, with falls being the most common cause. Significant correlations were found between mid-vertebral and disc-level canal diameters and the Torg-Pavlov ratio on MRI, which can serve as predictors of SCI risk. However, no significant correlations were observed between these parameters and clinical outcomes, such as ASIA motor or sensory scores [10].

These results align with studies like those of Choi et al. (2019) [11], which also found the Torg-Pavlov ratio to be a reliable predictor of SCI severity in cervical spondylosis. Similarly, Eismont et al. (1984) [12] reported that smaller sagittal canal diameters increase SCI risk, supporting the role of anatomical factors in injury severity.

However, other studies, such as Lee et al. (2018) [3], emphasized that biomechanical forces and degenerative changes also contribute significantly to SCI risk. This aligns with the current study's finding that, while imaging parameters predict SCI risk, they do not directly predict clinical outcomes like ASIA scores, suggesting the importance of a broader assessment that includes clinical and biomechanical factors.

A notable difference between this study and others, such as Smith et al. (2015) [2], is the exclusion of patients with pre-existing cervical spinal cord disorders. Smith's study found that degenerative conditions, like cervical spondylosis, complicate SCI predictions, as these conditions can cause spinal canal stenosis and increase SCI susceptibility. The current study, by excluding such patients, limits its ability to capture the full range of risk factors. The results reinforce the findings of Johnson & Patel (2017) [9], who concluded that MRI could help predict anatomical risks, but clinical outcomes are influenced by other factors. This suggests that while MRI is valuable in predicting SCI risk, it may not be sufficient on its own to predict the severity or recovery from SCI.

Conclusion

In conclusion, the study highlights the importance of anatomical imaging in predicting SCI after minor trauma, but it also shows that other factors, such as pre-existing conditions and biomechanical forces, need to be considered. Future research should integrate radiological, clinical, and biomechanical factors to improve SCI prediction and management strategies. Additional factors beyond the radiological characteristics of the cervical spinal canal influence the severity of acute SCI following minor trauma to the cervical spine.

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