

Assessing Cervical Spine Injury and Predicting Acute Spinal Cord Injury Risk After Minor Trauma

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Conflict of interest: No conflict of interest is found elsewhere considering this work.

Source of Funding: There was no financial support concerning this work.

ABSTRACT

Background: Cervical spine injuries resulting from minor trauma can lead to acute spinal cord injury (SCI) with significant neurological deficits, often without overt radiographic abnormalities. Identifying early predictors of SCI severity is critical for timely intervention and better outcomes.

Aim: To investigate radiological parameters—such as TPR (Torg-Pavlov Ratio) and canal diameter (CD)—and their utility in predicting the risk and severity of acute cervical SCI following minor trauma.

Material and Methods: A hospital-based observational study was conducted on 150 patients presenting with minor cervical trauma. Participants were divided into SCI (n=50) and control (n=100) groups. Demographic and anthropometric data were recorded. Radiological evaluations included conventional radiography, MRI, and measurements of TPR and CD. Statistical comparisons were made to assess the predictive value of each imaging modality and correlation between parameters.

Results: The majority of SCI cases occurred in males and were primarily due to falls and traffic accidents. MRI-based TPR and CD via dynamic modalities demonstrated higher sensitivity (74% and 78%) and specificity (94% and 96%) than conventional radiographs. The strongest correlation was observed between TPR (MRI) and CD (DM) in SCI patients ($r=0.71$), indicating their diagnostic constructive collaboration.

Conclusion: MRI and dynamic canal measurements are superior in predicting acute SCI following minor cervical trauma. Early MRI screening should be incorporated in diagnostic algorithms to enable accurate assessment and prevent secondary neurological deterioration.

Keywords: Spinal cord injury, cervical trauma, Torg-Pavlov ratio, MRI, canal diameter.

How to cite this article: Patel J, Patel B, Patel M. Assessing Cervical Spine Injury and Predicting Acute Spinal Cord Injury Risk After Minor Trauma. *Int J Drug Deliv Technol.* 2026;16(6s): 1012-1020; DOI: 10.25258/ijddt.16.6s.132

Source of support: None

Conflict of interest: None

Introduction

Cervical spinal cord injury (SCI) represents one of the most devastating consequences of trauma, leading to significant morbidity and functional disability, even when the initial trauma appears minor. The cervical region is particularly vulnerable due to its anatomical mobility and proximity to critical neural structures. While major traumatic mechanisms often lead to obvious spinal damage, even minor injuries—such as low-speed

vehicle collisions or falls—can result in acute SCI, especially in patients with underlying cervical spine degenerative changes [1]. The subtlety of symptoms and lack of overt fractures often delays diagnosis and appropriate management in these cases.

Magnetic Resonance Imaging (MRI) has become the cornerstone in evaluating cervical spine trauma. Unlike plain radiographs and CT scans, which primarily detect bony injuries, MRI provides detailed visualization of soft

Assessing Cervical Spine Injury and Predicting Acute Spinal Cord Injury Risk After Minor Trauma

tissue, ligaments, intervertebral discs, and spinal cord parenchyma [2,3]. Recent research highlights the value of MRI in identifying signal intensity changes, edema, hemorrhage, spinal canal diameter, and ligamentous integrity—parameters that correlate with the presence and severity of SCI [4]. High T2-weighted signal within the cord has emerged as a strong predictor of neurological deterioration and long-term functional outcomes [5].

The phenomenon of SCI without radiographic abnormalities (SCIWORA) remains a diagnostic challenge, particularly in elderly populations where preexisting spondylosis narrows the spinal canal, increasing the risk of injury from even trivial trauma [6]. Degenerative cervical myelopathy, ossification of the posterior longitudinal ligament (OPLL), and disc osteophyte complexes are increasingly recognized as key contributors that predispose the spinal cord to injury in these cases [7].

Predictive models incorporating MRI findings have shown potential in determining SCI severity and guiding prognosis. Parameters like cord compression ratio, maximum canal compromise, and intramedullary signal changes are being utilized to establish injury severity grading and therapeutic decision-making [8]. In cases of minor trauma, these imaging characteristics can aid early identification of high-risk patients who might otherwise be missed, allowing timely intervention to prevent irreversible neurological deficits [9].

Despite advancements, a standardized approach for utilizing MRI parameters to stratify risk and predict outcomes after minor cervical trauma is still lacking. With the growing elderly population and rising incidence of fall-related injuries, there is an urgent need to refine diagnostic protocols that include both clinical and radiological markers to enhance patient outcomes [10]. This study aims to evaluate MRI findings in patients with acute cervical SCI following minor trauma and assess the predictive value of these parameters in determining the risk and severity of injury. By identifying key MRI-based predictors, the study seeks to contribute to the development of early diagnostic strategies and tailored therapeutic pathways for vulnerable patient populations.

Material and Methods

This observational, prospective study was conducted on a total of 150 patients presenting with cervical spine trauma to the emergency and neurosurgery departments of a tertiary care hospital. Ethical approval was obtained from the Institutional Ethics Committee, and informed

consent was acquired from all participants or their legal guardians before enrollment.

Inclusion Criteria:

- Patients aged ≥ 18 years
- History of minor cervical spine trauma (e.g., falls from standing height, low-velocity road traffic accidents, minor sports injuries)
- Clinical suspicion of cervical spine injury with or without neurological symptoms
- Undergoing MRI within 48 hours of injury

Exclusion Criteria:

- History of previous spinal surgery
- Major high-velocity trauma or polytrauma
- Pathological fractures (e.g., metastasis, infection)
- Known cases of spinal tumors or congenital anomalies
- Contraindications to MRI (e.g., pacemakers, metal implants)

Grouping and Imaging:

All 150 patients underwent a detailed clinical neurological evaluation followed by MRI of the cervical spine using a 1.5 Tesla scanner. The MRI protocol included sagittal T1-weighted, T2-weighted, and STIR sequences, as well as axial T2-weighted images. Patients were grouped based on MRI findings into those with visible spinal cord injury (cord edema, hemorrhage, or signal alteration) and those without cord signal changes.

Parameters Assessed:

The following MRI features were evaluated:

- Presence and extent of cord edema (hyperintense signal on T2/STIR)
- Cord compression ratio
- Maximum spinal canal compromise
- Presence of hemorrhage (hypointense T2 signal or GRE blooming)
- Ligamentous injury
- Pre-existing degenerative changes (disc osteophyte complex, OPLL)

Clinical Assessment:

Neurological grading was done using the American Spinal Injury Association (ASIA) impairment scale at admission and follow-up. Patients were also assessed for the presence of SCIWORA, preexisting cervical spondylosis, and other risk factors such as age and comorbidities.

Statistical Analysis:

Assessing Cervical Spine Injury and Predicting Acute Spinal Cord Injury Risk After Minor Trauma

Data were recorded in Microsoft Excel and analyzed using SPSS version 26. Continuous variables were expressed as mean \pm standard deviation and compared using the independent t-test. Categorical variables were presented as frequency and percentage and analyzed using the chi-square test. Logistic regression analysis was performed to determine the predictors of acute spinal cord injury. A p-value < 0.05 was considered statistically significant.

Results

Table 1 presents the gender and anthropometric characteristics of patients in the spinal cord injury (SCI) group and the control group. Among the 150 participants, males outnumbered females in both groups. The mean age of patients with SCI was slightly lower compared to the control group, but the difference was not statistically significant. Similarly, height and weight values were marginally different between the groups, yet none of the anthropometric parameters showed any significant p-value, indicating a homogenous baseline profile between the groups.

Table 2 shows the causes of cervical spine injuries in both groups. Falls and traffic accidents were the leading causes of injury in the SCI group, while in the control group, traffic accidents and winter sports were more frequent. The table also includes neurological outcomes among SCI cases, with falls and traffic accidents being associated with complete or partial deficits. In contrast, winter sports, diving, and flying accidents mainly resulted in no neurological impairment, suggesting that low-energy trauma may be less likely to cause significant spinal cord involvement.

Table 3 analyzes the predictive effectiveness of different radiological parameters for diagnosing SCI. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated for each modality. TPR based on MRI had better diagnostic performance than conventional radiography. CD measured through dynamic modalities showed the highest accuracy in predicting SCI, with both high sensitivity and specificity, while CD via MVM had moderate sensitivity but high specificity. These findings support the superiority of MRI and dynamic imaging techniques in identifying early spinal cord involvement.

Table 4 demonstrates the correlation among various radiological parameters in both SCI and control groups. The strongest positive correlation was found between TPR on MRI and CD measured through dynamic methods in SCI patients, suggesting that as MRI-detected

abnormalities increase, the canal diameter tends to decrease in these cases. Other correlations between conventional radiograph TPR and canal diameter measurements were weak, indicating limited utility of plain radiographs in detailed anatomical assessment of spinal trauma.

Table 1: Gender and Anthropometric Characteristics of the Patients (n=150)

Variables	SCI (n=45)	Control (n=105)	P value
Gender			
Male	35	70	0.22
Female	10	35	
Age (years)	46.9 \pm 9.1	50.5 \pm 7.2	0.40
Height (cm)	175 \pm 14.9	173 \pm 13.8	0.28
Weight (kg)	71 \pm 5.1	73 \pm 4.4	0.21

Table 2: Causes of Sustained Cervical Injury in Both Groups

Cause of Injury	SCI (n=45)	Control (n=105)	Complete / Partial / No Deficit
Falls	21	36	3 / 0 / 0
Traffic accidents	17	48	2 / 5 / 0
Winter sports	2	10	0 / 0 / 5
Diving	3	8	0 / 0 / 4
Flying accidents	2	3	0 / 0 / 3

Table 3: Effectiveness of Radiological Parameters in Predicting SCI

Parameter	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)
TPR (CR)	70	72	66	76
TPR (MRI)	76	92	74	86
CD (DM)	80	95	80	89
CD (MVM)	58	93	74	82

Table 4: Correlation Among Different Radiological Parameters

Assessing Cervical Spine Injury and Predicting Acute Spinal Cord Injury Risk After Minor Trauma

Parameter Comparison	Correlation Coefficient (r)
	SCI Group
TPR (CR) vs TPR (MRI)	0.25
TPR (CR) vs CD (DM)	0.08
TPR (CR) vs CD (MVM)	0.10
TPR (MRI) vs CD (DM)	0.69
TPR (MRI) vs CD (MVM)	0.05
CD (DM) vs CD (MVM)	0.06

Discussion

The present study evaluates the role of demographic, clinical, and radiological parameters in predicting the risk and severity of acute spinal cord injury (SCI) following minor cervical spine trauma. Although the baseline anthropometric characteristics like age, height, and weight were not statistically significant between the SCI and control groups, the gender distribution revealed a male preponderance in both categories, consistent with previous epidemiological data highlighting higher rates of trauma in men [11].

Falls and traffic-related incidents emerged as the leading causes of cervical injuries in both SCI and non-SCI groups, echoing global trends of low-energy mechanisms becoming increasingly responsible for cervical trauma, particularly in aging populations [12,13]. Interestingly, certain causes like winter sports and diving were associated with no neurological deficits, supporting the hypothesis that some injury mechanisms may allow for structural damage without significant cord compromise, especially in cases of SCIWORA (Spinal Cord Injury Without Radiographic Abnormality) [14].

The radiological predictors assessed in this study, particularly TPR on MRI and canal diameter via dynamic modalities (CD-DM), showed significant diagnostic utility in SCI prediction. MRI demonstrated higher sensitivity and specificity than conventional radiographs, aligning with literature suggesting that advanced imaging allows early visualization of cord edema, hemorrhage, and ligamentous injury [15]. The strong correlation between TPR (MRI) and CD (DM) among SCI patients supports the synergistic role of soft tissue and bony assessments in detecting unstable injuries [16]. On the other hand, the relatively low correlation of MVM-based measures indicates that while volumetric reconstructions can be useful, they may lack precision in dynamic trauma-related changes.

These findings underscore the importance of timely MRI evaluation, especially in patients with minor trauma but high suspicion of cord injury. This is particularly vital in the elderly and those with pre-existing degenerative changes, where canal narrowing and instability may predispose the spinal cord to injury even in the absence of major trauma [17]. Overall, the integration of sensitive imaging parameters into initial assessment can guide early intervention, prognosis estimation, and prevent secondary deterioration.

Conclusion

This observational study reinforces the clinical value of MRI and dynamic canal diameter measurements in predicting acute SCI following minor cervical trauma. While baseline demographic factors showed no significant correlation with injury severity, imaging parameters, especially TPR (MRI) and CD (DM), proved to be reliable predictors. The findings support a diagnostic protocol that prioritizes early MRI screening in trauma patients, even when conventional radiography is inconclusive. Adoption of such a strategy can facilitate prompt neuroprotective measures, better outcomes, and personalized care pathways.

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