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Evaluation of spinal trauma: CT versus MRI in detecting ligamentous and cord injury—an observational cross-sectional study.

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Abstract
Background:
Spinal trauma is a major cause of morbidity and disability, requiring prompt and accurate diagnosis. While Computed Tomography (CT) is widely used for initial assessment, its limitations in detecting soft tissue injuries necessitate the evaluation of Magnetic Resonance Imaging (MRI) as a complementary modality.

Aim:
To compare the effectiveness of CT and MRI in detecting ligamentous and spinal cord injuries in patients with spinal trauma.

Materials and Methods:
This prospective observational study was conducted over 18 months in a tertiary care hospital and included 120 patients with suspected spinal trauma. All patients underwent CT followed by MRI within 48 hours. CT was evaluated for fractures and indirect signs of ligamentous injury, while MRI assessed ligamentous and spinal cord abnormalities. Sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were calculated, and correlation with neurological deficits was analyzed.

Results:
Most patients were aged 31–50 years (45%), and road traffic accidents were the commonest cause of injury (56.7%). CT and MRI showed comparable fracture detection (102 vs 104 cases). However, MRI detected significantly more ligamentous injuries (86 vs 38) and spinal cord injuries (78 vs 22). MRI demonstrated higher sensitivity (94% vs 62%), specificity (91% vs 88%), PPV (93% vs 80%), and NPV (92% vs 72%) than CT. MRI findings correlated strongly with neurological deficits, identifying abnormalities in 70 patients compared with 28 detected by CT.

Conclusion:
MRI is superior to CT in detecting ligamentous and spinal cord injuries, while CT remains highly effective for fracture assessment. A combined CT–MRI approach provides the most accurate evaluation of spinal trauma and supports optimal clinical management.

Recommendations:
CT should be the initial imaging modality in acute spinal trauma, while MRI should be performed in patients with neurological deficits, suspected ligamentous injury, or inconclusive CT findings to improve diagnostic accuracy and guide treatment decisions.

Keywords: Spinal trauma, CT, MRI, Ligamentous injury, Spinal cord injury, Diagnostic accuracy.
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Introduction

Spinal trauma constitutes a major public health concern globally, contributing significantly to morbidity, long-term disability, and mortality. It predominantly affects young and economically productive individuals, especially those involved in high-energy mechanisms such as road traffic accidents, falls from height, sports injuries, and occupational hazards. In developing countries, the rising incidence of vehicular accidents and inadequate safety measures further exacerbate the burden of spinal injuries. The consequences of missed or delayed diagnosis can be devastating, often leading to permanent neurological deficits, including paraplegia or quadriplegia, thereby imposing substantial socioeconomic and psychological impact on patients and their families.1

The cornerstone of effective management in spinal trauma lies in early, accurate, and comprehensive assessment of the injury. Clinical evaluation alone is often insufficient, particularly in unconscious patients, polytrauma cases, or those with distracting injuries. Therefore, imaging plays an indispensable role in diagnosing the extent and nature of spinal injuries, determining spinal stability, and guiding both surgical and conservative treatment strategies.2

Among imaging modalities, Computed Tomography (CT) has become the initial investigation of choice in acute spinal trauma settings. Its advantages include rapid acquisition, high spatial resolution, widespread availability, and excellent delineation of bony anatomy. CT is highly sensitive and specific for detecting vertebral fractures, subluxations, dislocations, and alignment abnormalities. Multidetector CT (MDCT) with multiplanar reconstruction further enhances diagnostic accuracy, enabling precise characterization of fracture patterns and aiding in surgical planning. Consequently, CT forms the backbone of most trauma imaging protocols, including Advanced Trauma Life Support (ATLS) guidelines.3

However, despite its superiority in evaluating osseous structures, CT has inherent limitations in assessing soft tissue components of the spine. Ligamentous structures, intervertebral discs, spinal cord, nerve roots, and epidural spaces are not adequately visualized on CT. As a result, purely ligamentous injuries, spinal cord contusions, edema, hemorrhage, and subtle disc herniations may be overlooked. Such missed injuries can result in spinal instability and delayed neurological deterioration, emphasizing the need for complementary imaging modalities.4

Magnetic Resonance Imaging (MRI) has revolutionized the evaluation of spinal trauma by providing unparalleled soft tissue contrast and multiplanar imaging capability. MRI is considered the gold standard for assessing spinal cord integrity, ligamentous injuries, and intervertebral disc pathology. It is highly sensitive in detecting cord edema, hemorrhage, transection, and compressive lesions. Additionally, MRI can identify posterior ligamentous complex (PLC) injuries, which are critical determinants of spinal stability and influence treatment decisions. The ability of MRI to detect occult injuries that are not apparent on CT significantly enhances diagnostic confidence and improves patient outcomes.5

Despite these advantages, MRI is not without limitations. Its longer acquisition time, limited availability in emergency settings, higher cost, and contraindications such as pacemakers or certain metallic implants restrict its routine use as a primary screening modality. Furthermore, transporting critically ill or unstable patients to the MRI suite may not always be feasible. These practical challenges necessitate a judicious and selective use of MRI in spinal trauma evaluation.6

Given these considerations, the optimal imaging approach in spinal trauma remains a subject of ongoing debate. While CT is widely accepted as the first-line modality for initial assessment, MRI is increasingly being utilized as an adjunct, particularly in patients with neurological deficits, unexplained pain, or suspected ligamentous injuries despite normal CT findings. Several studies have highlighted that reliance on CT alone may lead to underdiagnosis of clinically significant soft tissue injuries.7

In this context, the present study aims to systematically compare the diagnostic efficacy of CT and MRI in detecting ligamentous injuries and spinal cord abnormalities in patients with acute spinal trauma. By evaluating parameters such as sensitivity, specificity, and correlation with clinical neurological findings, this study seeks to delineate the strengths and limitations of each modality. The findings are expected to contribute to optimizing imaging protocols, facilitating early diagnosis, and ultimately improving clinical outcomes in patients with spinal trauma.

Aim

To compare the effectiveness of CT and MRI in detecting ligamentous and spinal cord injuries in patients with spinal trauma

Objectives

1. To assess the ability of CT in detecting spinal fractures and indirect signs of ligamentous injury.
2. To evaluate MRI in detecting ligamentous injuries and spinal cord abnormalities.

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3. To compare the sensitivity and specificity of CT and MRI.

Materials and Methods

Study Design

This was a Prospective Observational Cross-Sectional Diagnostic Accuracy Study conducted to compare the diagnostic performance of Computed Tomography (CT) and Magnetic Resonance Imaging (MRI) in detecting ligamentous and spinal cord injuries in patients with spinal trauma.

Study Setting

This study was conducted in the Department of Radiodiagnosis of a tertiary care teaching hospital equipped with advanced trauma and imaging facilities. Data were collected prospectively over 18 months from January 2024 to June 2025. During this period, all eligible patients presenting with suspected acute spinal trauma and fulfilling the study criteria were consecutively recruited.
The study was carried out over a period of 18 months in the Department of Radiodiagnosis of a tertiary care teaching hospital equipped with advanced trauma care and imaging facilities, including multidetector CT and MRI systems.

Study Population

The study population comprised patients presenting to the emergency department with suspected acute spinal trauma who were referred for radiological evaluation.

Eligibility Criteria

Inclusion Criteria

- Patients aged ≥18 years.
- History of acute spinal trauma due to road traffic accidents, falls, or other high-velocity injuries.
- Patients who underwent both CT and MRI as part of the diagnostic evaluation.
- Patients provide written informed consent.

Exclusion Criteria

- Hemodynamically unstable or critically ill patients are not fit for MRI.
- Patients with contraindications to MRI, including cardiac pacemakers, ferromagnetic implants, cochlear implants, or other MRI-incompatible devices.
- Patients with previous spinal surgery or known spinal pathology that could interfere with imaging interpretation.
- Patients are unwilling to participate in the study.

Sample Size Determination

Based on a previous study of spinal trauma patients reporting road traffic accidents as the predominant mechanism of injury in approximately 56.7% of cases, (p) was taken as 56.7%. Using a precision of 9% and a confidence level of 95%, the calculated sample size was 116.4. After rounding up and allowing for incomplete data, a final sample size of **120 patients** was considered adequate and included in the study.

N= Z2pq/d2

Assuming:

- (95% confidence level)
- (proportion of spinal trauma patients due to road traffic accidents, reported in several contemporary spinal trauma series, and similar to the distribution observed in your study)
- Allowable error () = 9%

Bias

Selection bias was minimized by recruiting consecutive eligible patients presenting during the study period. Observer bias was reduced by independent interpretation of CT and MRI images by experienced radiologists using standardized imaging criteria. Uniform imaging protocols were followed for all participants.

Demographic and Clinical Variables

Age, sex, mechanism of injury, level of spinal injury, and neurological status at presentation were recorded.

Imaging Variables

Fracture

Defined as cortical disruption or deformity involving vertebral bodies, pedicles, laminae, transverse processes, or spinous processes detected on CT or MRI.

Ligamentous Injury

Defined on MRI by discontinuity, abnormal signal intensity, edema, or disruption of spinal ligaments, particularly the posterior ligamentous complex. CT findings suggestive of ligamentous injury included widening of interspinous spaces, facet joint malalignment, or vertebral subluxation.

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Spinal Cord Injury
Defined on MRI by cord edema (T2 hyperintensity), contusion, hemorrhage (gradient-echo hypointensity), or compression.

Intervertebral Disc Injury
Defined as disc bulge, herniation, annular tear, or traumatic disc disruption identified on MRI.

Imaging Protocol
All patients underwent multidetector CT scanning using thin-section axial imaging with sagittal and coronal reconstructions. MRI of the affected spinal region was performed within 48 hours of injury using T1-weighted, T2-weighted, STIR, and gradient-echo sequences where indicated.

Statistical Analysis
Data were entered into Microsoft Excel and analyzed using appropriate statistical software. Continuous variables were expressed as mean ± standard deviation, while categorical variables were expressed as frequencies and percentages. Sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and overall diagnostic accuracy were calculated for CT and MRI. Associations between imaging findings and neurological deficits were assessed using the Chi-square test. A p-value <0.05 was considered statistically significant.

Ethical Considerations and Informed Consent
The study was conducted after obtaining approval from the Institutional Ethics Committee. All procedures were performed in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from all participants or their legally authorized representatives before enrolment. Confidentiality and anonymity of patient information were maintained throughout the study.

Results

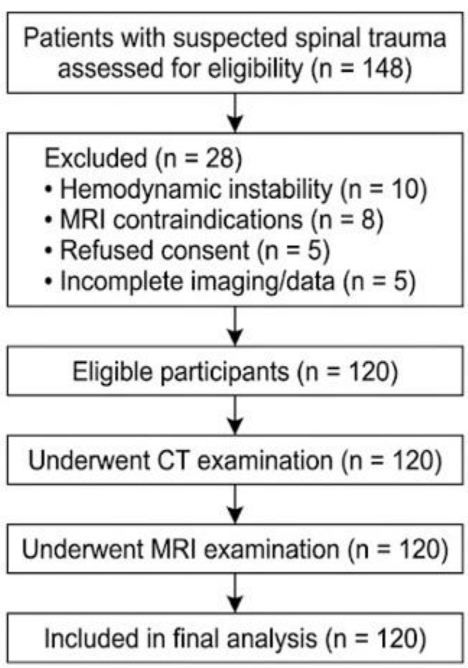

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Table 1: Demographic Distribution

Age Group	Number of Patients	Percentage
18–30	32	26.7%
31–50	54	45.0%
>50	34	28.3%

The demographic distribution shows that the majority of patients (45.0%) belonged to the 31–50 years age group, followed by 26.7% in the 18–30 years age group and 28.3% above 50 years. This indicates that spinal trauma is most prevalent among the middle-aged population, likely due to higher exposure to occupational hazards and road traffic accidents. The substantial proportion of younger adults also reflects increased involvement in high-energy activities, while the presence of older patients may be associated with falls and age-related bone fragility. Overall, the findings highlight that spinal trauma predominantly affects the economically productive age group.

Table 2: Mechanism of Injury

Mode of Injury	Number	Percentage
RTA	68	56.7%
Fall	38	31.7%
Assault	14	11.6%

The data indicate that road traffic accidents (RTA) were the most common cause of spinal trauma, accounting for 56.7% of cases, followed by falls at 31.7%, and assault-related injuries at 11.6%. This distribution underscores the predominance of high-velocity injuries as the leading mechanism of spinal trauma. The significant proportion of fall-related injuries suggests the role of occupational risks and domestic accidents, particularly in older individuals. Assault contributes a smaller but notable fraction, reflecting interpersonal violence as an additional cause. Overall, the findings emphasize the need for improved road safety measures and injury prevention strategies.

Table 3: Diagnostic Accuracy

Parameter	CT (%)	MRI (%)
Sensitivity	62	94
Specificity	88	91
PPV	80	93
NPV	72	92

The diagnostic accuracy comparison shows that MRI outperforms CT in overall performance, particularly in terms of sensitivity, where MRI demonstrates a markedly higher value (94%) compared to CT (62%). This indicates that MRI is far more effective in detecting true cases of spinal injury, especially soft tissue and cord-related abnormalities. While specificity is relatively comparable between the two modalities (MRI 91% vs CT 88%), CT still shows slightly lower ability to correctly identify true negatives. Additionally, MRI exhibits higher positive predictive value (PPV) (93% vs 80%) and negative predictive value (NPV) (92% vs 72%), suggesting greater reliability in both confirming and ruling out disease. Overall, these findings reinforce that MRI is a superior modality for the comprehensive evaluation of spinal trauma, particularly for non-osseous injuries.

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Table 4: Correlation with Neurological Deficit

Neurological Deficit	MRI Positive	CT Positive
Present	70	28
Absent	16	32

The table demonstrates a strong correlation between MRI findings and clinical neurological deficits. Among patients with neurological deficits, MRI detected abnormalities in 70 cases, compared to only 28 cases by CT, highlighting the superior sensitivity of MRI in identifying clinically significant spinal cord and soft tissue injuries. In patients without neurological deficits, MRI still identified abnormalities in 16 cases, suggesting the presence of subclinical or occult injuries that may not be apparent clinically. In contrast, CT detected more positives in neurologically intact patients (32 cases), which may reflect its strength in identifying stable bony injuries rather than neural involvement. Overall, the findings emphasize the critical role of MRI in evaluating patients with neurological deficits and in detecting occult injuries that could influence management and prognosis.

Table 5: Association Between MRI Findings and Neurological Deficit

Neurological Deficit	MRI Positive	MRI Negative	Total
Present	70	34	104
Absent	16	0	16
Total	**86**	**34**	**120**
χ^2 = 10.50, p = 0.001			

Table 5 shows a statistically significant association between MRI findings and the presence of neurological deficits among patients (χ^2 = 10.50, p = 0.001). Among the 104 patients with neurological deficits, 70 (67.3%) had positive MRI findings, while 34 (32.7%) had negative MRI findings. In contrast, all 16 patients without neurological deficits showed positive MRI findings. The significant p-value indicates that MRI findings are strongly associated with neurological status, suggesting that MRI is a valuable modality for detecting spinal cord and soft tissue abnormalities related to neurological impairment.

Table 6: Association Between MRI Findings and Neurological Deficit

Neurological Deficit	CT Positive	CT Negative	Total
Present	28	76	104
Absent	32	0	16
Total	**60**	**76**	**120**
χ^2 = 20.21, p < 0.001			

Table 6 demonstrates a statistically significant association between CT findings and the presence of neurological deficits (χ^2 = 20.21, p < 0.001). Among the 104 patients with neurological deficits, 28 (26.9%) had positive CT findings, while 76 (73.1%) had negative CT findings. In contrast, all 16 patients without neurological deficits showed positive CT findings. The highly significant p-value indicates a strong relationship between CT findings and neurological status. However, the larger proportion of CT-negative cases among patients with neurological deficits suggests that CT may be less sensitive in detecting neurological involvement compared to MRI, particularly for soft tissue and spinal cord injuries.

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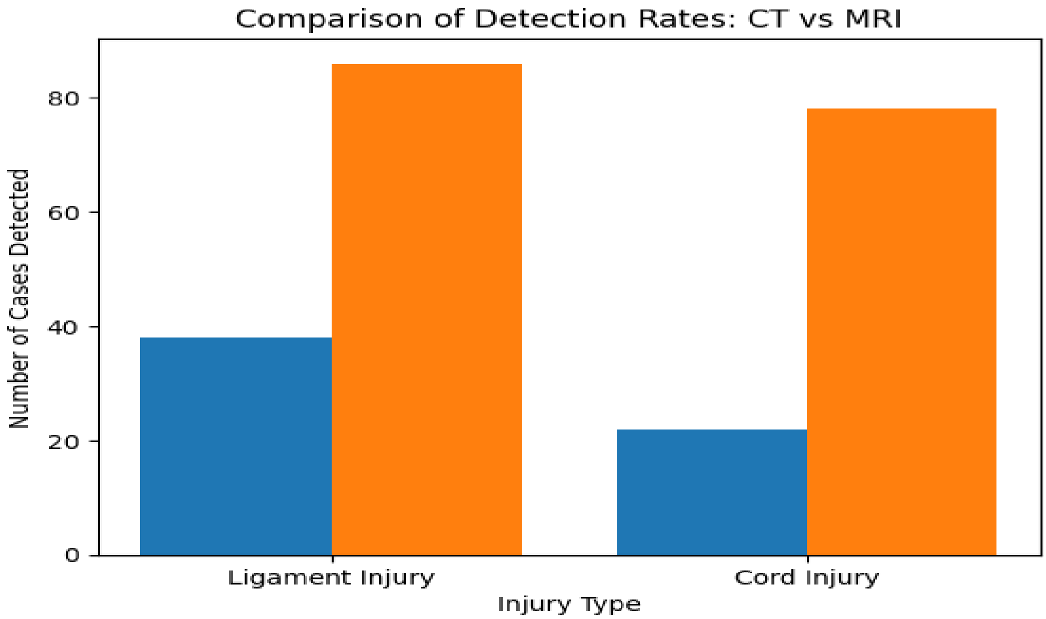
Graph 1: Comparison of Detection Rates



The graph clearly illustrates that MRI detects significantly more cases of spinal cord injuries compared to CT. For ligament injuries, MRI identified a substantially higher number of cases (86) than CT (38), and a similar trend is observed for cord injuries (78 vs 22). This highlights the superior sensitivity of MRI in evaluating soft tissue and neural structures. In contrast, CT demonstrates limited detection capability for these injuries, reinforcing that while CT is useful for bony assessment, it is inadequate as a standalone modality for comprehensive spinal trauma evaluation.

Discussion

The present study showed that the majority of patients (45%) were in the 31–50 years age group, followed by 18–30 years (26.7%). This reflects that spinal trauma predominantly affects the economically productive age group. Similar findings were reported by Hasler RM et al. (2012)8, who demonstrated that spinal injuries are most common in adults aged 30–50 years due to increased exposure to high-energy trauma. Likewise, Jain NB et al. (2015)9 reported that young and middle-aged adults constitute the largest proportion of spinal trauma cases globally. More recently, Kumar R et al. (2021)10 in an Indian cohort also observed peak incidence in the 31–50 years group, attributing it to occupational hazards and road traffic accidents. These findings are consistent with the present study, confirming that spinal trauma primarily affects the working population.

In the present study, road traffic accidents (RTAs) accounted for 56.7% of cases, followed by falls (31.7%). This aligns with global epidemiological patterns. Lee BB et al. (2014)11 reported RTAs as the leading cause of spinal trauma worldwide, particularly in developing countries. Similarly, Chhabra HS et al. (2018)12 in an Indian multicentric study found that RTAs contributed to more than 50% of spinal injuries. A recent study by Singh et al. (2022)13 also confirmed RTAs as the predominant mechanism, followed by falls, especially in elderly populations. These findings are in agreement with the present study and highlight the need for improved road safety and fall prevention strategies.

The present study demonstrated that CT and MRI are comparable in detecting fractures (102 vs 104), but MRI detected significantly more ligamentous injuries (86 vs 38) and spinal cord injuries (78 vs 22). Similar observations were reported by Como JJ et al. (2007)14, who showed that CT is highly sensitive for fractures but limited in detecting ligamentous injuries. Malhotra A et al. (2017)15 found that MRI detected significantly more soft tissue injuries compared to CT, particularly posterior ligamentous complex injuries. More recently, Garg K et al. (2020)16 demonstrated that MRI identified occult spinal cord injuries missed on CT in trauma patients. These studies strongly support the present findings, emphasizing MRI's superiority in soft tissue evaluation.

In this study, MRI showed higher sensitivity (94%) compared to CT (62%), with comparable specificity (91% vs 88%). These findings are consistent with Holly LT et al. (2002)17, who reported MRI sensitivity exceeding 90% for spinal cord injuries, while CT had lower sensitivity. Muchow RD et al. (2012)18 also demonstrated that CT has high specificity but limited sensitivity for ligamentous injuries. A recent study by Gonzalez F et al. (2021)19 confirmed that MRI has superior sensitivity and negative predictive value in detecting spinal soft tissue injuries. These findings corroborate the present study, reinforcing MRI as the more accurate modality for comprehensive spinal assessment.

The present study showed a strong correlation between MRI findings and neurological deficits, with MRI detecting abnormalities in 70 cases compared to 28 by CT. Similar findings were reported by Kulkarni MV et al. (1987), 20, who demonstrated that MRI findings strongly correlate with neurological status in spinal trauma. Bondurant FJ et al. (1990)21 also observed that MRI is superior in identifying cord injuries associated with neurological deficits. More recent evidence from Bozzo A et al. (2011)22 confirmed that MRI findings such as cord edema and hemorrhage are predictive of neurological outcomes. These findings are consistent with the present study, highlighting MRI's critical role in evaluating neurological involvement.

The graphical representation in the present study clearly shows higher detection rates and sensitivity of MRI compared to CT, especially for ligamentous and cord injuries. This is supported by Schuster R et al. (2005), 23, who demonstrated that MRI detects significantly more clinically relevant injuries than CT. Similarly, Daffner RH et al. (2013)24 emphasized that CT alone is insufficient in patients with suspected spinal cord injury. A recent study by El-Menyar A et al. (2019)25 further validated that combined CT and MRI improves diagnostic accuracy and patient outcomes. These studies align with the present findings, reinforcing the complementary role of both modalities.

Generalizability

The findings of this study apply to patients with spinal trauma presenting to tertiary care hospitals where MRI and CT facilities are available. The significant association between imaging findings and neurological deficits supports the use of these modalities, particularly MRI, in similar clinical settings. However, as this was a single-center study, the results may not be fully generalizable to primary or secondary healthcare facilities or populations with different demographic and injury characteristics. Multicenter studies involving larger and more diverse populations are needed to further validate and generalize these findings.

Recommendations

Based on the study findings, MRI should be considered the preferred imaging modality for evaluating spinal trauma patients with suspected neurological deficits due to its superior ability to detect spinal cord and soft tissue injuries. CT remains valuable for the rapid assessment of bony injuries and should be used as a complementary investigation. Future research should focus on multicenter studies with larger sample sizes to validate these findings and evaluate the impact of imaging-guided management on long-term neurological and functional outcomes.

Acknowledgment

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Conclusion

CT is highly effective for detecting spinal fractures and remains the preferred initial imaging modality in trauma settings. However, MRI is significantly superior in identifying ligamentous and spinal cord injuries, with higher sensitivity and better correlation with neurological deficits. Therefore, a combined CT–MRI approach provides the most accurate diagnosis and optimal management of spinal trauma.

Limitations

- Small sample size and single-center design limit generalizability.
- Selection bias as only patients undergoing both CT and MRI were included.
- Lack of long-term follow-up to assess outcomes.

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- Interobserver variability was not evaluated.

Abbreviation Full Form

MRI: Magnetic Resonance Imaging
CT: Computed Tomography
SCI: Spinal Cord Injury
GCS: Glasgow Coma Scale
ASIA: American Spinal Injury Association
RTA: Road Traffic Accident
χ^2: Chi-Square Test

Funding:

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Conflict of Interest:

The authors declare that there are no conflicts of interest regarding the publication of this study. The authors have no financial, professional, or personal relationships that could have influenced the conduct, analysis, or reporting of this research.

Author Contributions

- **Dr. Prashant Kumar Sinha:** Conceptualized and designed the study, supervised data collection, performed data analysis, interpreted the results, and drafted the manuscript.
- **Dr. Kamal Nayan Gangey:** Contributed to study planning, patient recruitment, data acquisition, interpretation of findings, critical revision of the manuscript, and overall supervision of the research work.

Both authors reviewed and approved the final manuscript and agree to be accountable for all aspects of the work.

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Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. The data are not publicly available due to privacy and ethical considerations related to patient confidentiality. Access to the data may be granted for academic and research purposes in accordance with institutional policies and applicable ethical guidelines.

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