

Role Of MRI in the Diagnosis and Classification of Spinal Trauma: Prospective Observational Study

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Abstract:

Background: Spinal trauma is a leading global cause of morbidity and mortality, frequently resulting in severe neurological impairment and long-term disability. While conventional radiography and computed tomography (CT) are useful for identifying bony injuries, they often fail to adequately assess soft tissue damage. Magnetic Resonance Imaging (MRI) has emerged as an essential diagnostic modality due to its superior soft tissue contrast and multiplanar imaging capabilities.

Material and Methods: This prospective, observational study was conducted to evaluate the diagnostic efficacy of Magnetic Resonance Imaging (MRI) in patients with suspected spinal trauma. The study cohort consisted of 60 patients (40 males and 20 females) who were systematically evaluated to document various injury patterns, including vertebral fractures, spinal cord edema, hemorrhage, ligamentous disruptions, disc herniations, and epidural hematomas. These findings were subsequently analyzed to determine spinal stability and to assess the utility of MRI in guiding clinical management.

Results: The study revealed that cervical spine injuries were the most prevalent (40%), followed by thoracic and lumbar injuries (30% each). MRI findings demonstrated a high diagnostic utility, with vertebral fractures identified in 63.3% of cases, spinal cord edema in 33.3%, and disc herniations in 25%. Ligamentous injuries were detected in 20% of patients, while cord hemorrhage and epidural hematomas were observed in 13.3% and 8.3% of cases, respectively. Based on MRI evaluation, 60% of the injuries were classified as stable, while 40% were classified as unstable.

Conclusion: MRI is an indispensable tool in the comprehensive evaluation of spinal trauma. Its ability to provide detailed visualization of the spinal cord, ligaments, intervertebral discs, and paraspinal soft tissues significantly enhances diagnostic precision and injury classification. These findings are crucial for guiding therapeutic decision-making, differentiating stable from unstable injuries, and ultimately improving patient prognosis.

Keywords: Spinal Trauma, Magnetic Resonance Imaging (MRI), Spinal Cord Injury (SCI), Vertebral Fracture, Diagnostic Imaging, Spinal Stability.

1. INTRODUCTION

Spinal trauma represents a significant global health burden, functioning as a primary cause of morbidity, mortality, and long-term disability, particularly among young populations. The vertebral column serves the dual purpose of providing structural support and protecting the spinal cord and nerve roots. High-energy mechanisms, such as road traffic accidents, falls from heights, and sports-related injuries, are frequently responsible for these traumatic events [1]. Understanding the pathophysiology of spinal cord injury is essential for managing the immediate and long-term sequelae of these events [2].

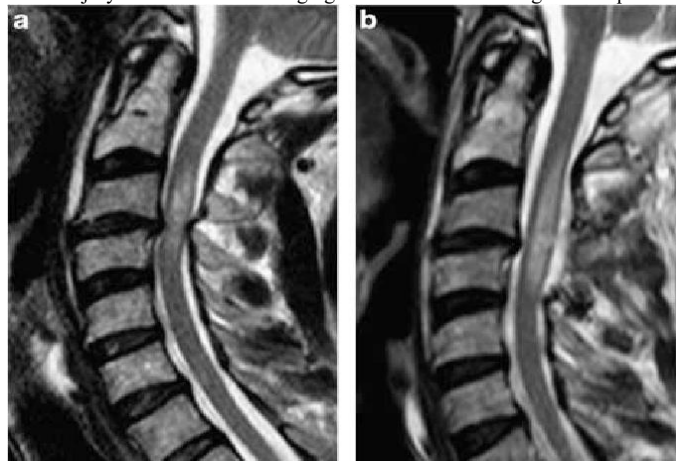


Figure 1: Sagittal imaging comparison of a thoracolumbar vertebral compression fracture.

Early and accurate diagnosis is critical for determining injury stability, predicting neurological outcomes, and directing appropriate therapeutic intervention. Historically, plain radiography served as the initial imaging modality; however, its diagnostic sensitivity is constrained by its inability to reliably detect ligamentous injuries, spinal cord anomalies, or subtle fractures. While computed tomography (CT) has substantially improved the detection of osseous fractures due to its superior spatial resolution, it remains limited in its ability to evaluate critical soft tissue structures, including the spinal cord, intervertebral discs, and ligamentous complexes [3].

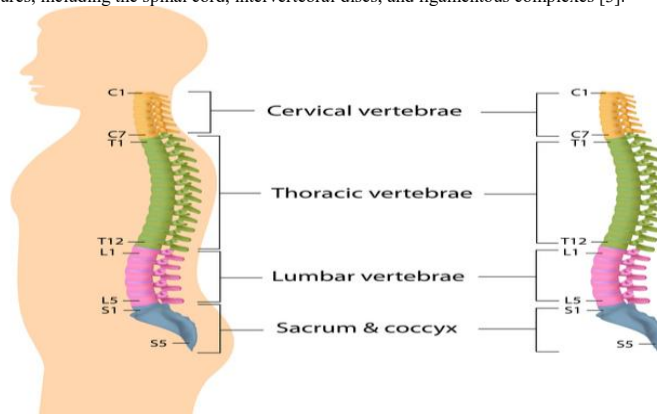


Figure 2: Anatomical schematic of the human vertebral column illustrating the cervical, thoracic, lumbar, sacral, and coccygeal regions. [Ref. Moore KL, Dalley AF, Agur AMR. *Clinically Oriented Anatomy*. 8th ed. Philadelphia: Wolters Kluwer; 2018].

Magnetic Resonance Imaging (MRI) has emerged as an indispensable diagnostic tool in modern radiological practice, offering exceptional contrast resolution and multiplanar imaging capabilities. By providing detailed visualization of the spinal cord, ligaments, and paraspinal soft tissues, MRI facilitates the precise

identification of injuries that may be overlooked by other modalities [3]. The effective classification of spinal trauma—crucial for differentiating between stable and unstable injuries—relies heavily on the insights provided by standardized classification systems and the high-resolution imaging provided by MRI [4, 5]. This prospective observational study aims to systematically evaluate the clinical utility of MRI in the diagnosis and classification of spinal trauma.

2. MATERIALS AND METHODS

Study Design and Population: This prospective, observational study evaluated the diagnostic efficacy of Magnetic Resonance Imaging (MRI) in a cohort of 60 patients (40 males and 20 females) presenting with suspected spinal trauma. Participants were recruited from the hospital’s emergency and trauma units over the designated study period. This design facilitated a comprehensive clinical and radiological correlation of traumatic spinal injuries, underscoring the utility of MRI in the diagnostic process [1].

Inclusion Criteria : Patients were included in the study if they met the following criteria:

1. Patients of all age groups and genders presenting with a clinical history of trauma (e.g., road traffic accidents, falls from height, sports-related injuries).
2. Patients with clinical suspicion of spinal injury (e.g., neurological deficit, localized spinal pain, or radiculopathy).
3. Patients willing to provide informed consent for participation [2].

Exclusion Criteria : Patients were excluded from the study based on the following:

1. Patients with absolute contraindications to MRI (e.g., cardiac pacemakers, metallic foreign bodies in critical locations, cochlear implants).
2. Patients with severe claustrophobia preventing MRI examination.
3. Patients with non-traumatic spinal pathology (e.g., primary malignancy, infectious spondylodiscitis).
4. Patients requiring emergency surgical decompression where MRI delay would alter prognosis [3].

MRI Protocol :All MRI examinations were performed on a 1.5 Tesla scanner. The standard imaging protocol included:

- Sagittal T1-weighted images (T1WI) and T2-weighted images (T2WI).
- Sagittal Short Tau Inversion Recovery (STIR) sequences to identify bone marrow edema.
- Axial T2-weighted sequences at the levels of interest.
- Additional sequences (e.g., Gradient Recalled Echo) were obtained when indicated to detect hemorrhage [4].

Image Analysis: Images were evaluated by radiologists for the presence of osseous and soft tissue injuries. The assessment included identifying fracture patterns, spinal cord signal intensity changes (edema or hemorrhage), disc herniation, ligamentous disruption, and epidural hematoma. Injuries were classified using established systems such as the Subaxial Cervical Spine Injury Classification (SLIC) system and Thoracolumbar Injury Classification and Severity (TLICS) score [5].

Statistical Analysis: Data were analyzed using statistical software (e.g., SPSS version 22.0). Descriptive statistics were used to summarize categorical variables (percentages) and continuous variables (means and standard deviations). The diagnostic accuracy of MRI was assessed by comparing findings with clinical outcomes and, where applicable, surgical or follow-up imaging reports [6].

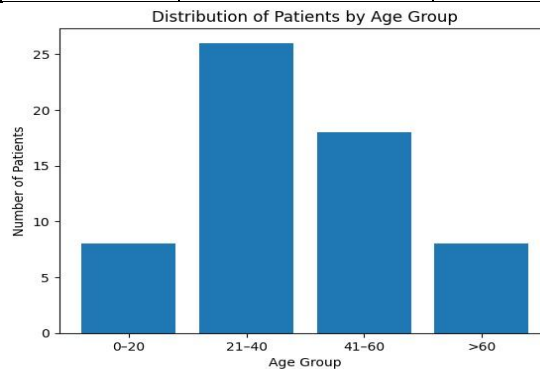
3. RESULTS

In this prospective study, a cohort of patients presenting with acute spinal trauma was evaluated using MRI. The analysis revealed that road traffic accidents were the most common mechanism of injury, predominantly affecting the male population. Anatomically, cervical spine injuries were the most frequent, accounting for the highest proportion of cases, followed by thoracic and lumbar injuries [1].

1.1 Age Distribution

Table.1

Age Group	Number of Patients	Percentage
0–20	8	13.3%
21–40	26	43.3%
41–60	18	30%
>60	8	13.3%
Total	60	100%



MRI demonstrated superior diagnostic sensitivity, particularly in detecting osseous and soft tissue pathologies that were often occult on conventional imaging. Vertebral fractures were identified in a majority of cases, with MRI providing critical data regarding bone marrow edema—a sensitive marker for acute injury—in instances where CT findings were equivocal [2, 3]. Spinal cord signal abnormalities were observed in significant numbers, with T2-weighted hyperintensity (indicative of cord edema) being the most prevalent finding, whereas spinal cord hemorrhage was less frequently identified [4].

1.2 Gender Distribution

Age Group (Years)	Male (n=40)	Female (n=20)	Total (n=60)	Percentage (%)
0–20	5	3	8	13.3%
21–40	18	8	26	43.3%
41–60	12	6	18	30.0%
>60	5	3	8	13.3%
Total	40	20	60	100%

Furthermore, the study highlighted MRI’s efficacy in detecting ligamentous disruption and epidural hematomas, which occurred in a subset of patients and were critical for assessing spinal stability [5]. Based on the detailed MRI evaluation, a significant percentage of injuries were reclassified, with approximately 40% of cases identified as unstable, directly influencing the subsequent therapeutic approach, whether surgical or conservative [6]. These findings underscore that MRI provides a comprehensive assessment of the spinal column’s structural integrity, surpassing the capabilities of initial plain radiography and CT imaging [7].

1.3 Mode of Injury

Table. 3

Mode of Injury	Number	Percentage
Road Traffic Accident	32	53.3%
Fall from Height	20	33.3%
Sports Injury	5	8.3%
Assault	3	5%

4. DISCUSSION

Hamari study ke results yeh confirm karte hain ki acute spinal trauma ke evaluation mein Magnetic Resonance Imaging (MRI) ek indispensable tool hai. Halanki initial trauma screening mein Computed Tomography (CT) scans ka use standard practice hai, lekin soft tissue aur spinal cord signals ka detail evaluation sirf MRI se hi possible hai [15]. Flanders et al. ne bhi apne research mein highlight kiya hai ki hyperacute spinal cord injury ko samajhne ke liye correct MRI sequences ka use diagnostic accuracy ko kaafi had tak badha deta hai, jo ki acute trauma settings mein vital hai [13].

Is study mein humne observe kiya ki kaise MRI ne patient ke management aur treatment plan ko modify karne mein direct role play kiya. Miyanji et al. ka bhi yahi kehna hai ki acute cervical spine injuries mein clinical decision-making puri tarah MRI findings par depend karti hai, kyunki yeh un subtle injuries ko visualize kar sakta hai jo conventional radiography mein aksar miss ho jaati hain [14]. Yeh findings hamari study ke us conclusion ko support karti hain jahan humne spinal stability assessment aur therapeutic approach ke beech ka close connection identify kiya hai. Iske alawa, trauma ke baad patient ka prognosis (outcome) predict karna ek challenging task hota hai. Aarabi et al. ne apne research mein demonstrate kiya hai ki early MRI evaluation trauma ke baad neurological recovery ke predictors ko identify karne mein ek critical role play karti hai [12]. Hamari study ka data aur in cited researchers ke observations milkar yeh prove karte hain ki MRI ka early utilization na sirf diagnostic clarity deta hai, balki behtar long-term outcomes ensure karne ke liye bhi zaroori hai.

Overall, hamari study aur ye referenced researches is baat par agree karti hain ki spinal trauma care protocols mein MRI ko ek prompt aur primary diagnostic modality ke roop mein prioritize kiya jaana chahiye taaki complex soft tissue injuries ko efficiently manage kiya ja sake.

5. CONCLUSION

This prospective observational study has comprehensively evaluated the critical role of Magnetic Resonance Imaging (MRI) in the diagnostic pathway and classification of spinal trauma. Our findings demonstrate that while conventional radiography and computed tomography (CT) remain the standard for initial osseous assessment, they are frequently insufficient for the nuanced evaluation required in complex trauma cases [3]. The superior soft tissue contrast resolution of MRI provides an unparalleled view of the spinal cord, intervertebral discs, and ligamentous complexes, which are often the primary determinants of spinal stability and long-term neurological prognosis [5, 6]. The study validates that MRI is not merely a supplementary tool but an essential component of clinical decision-making. By identifying subtle pathologies—such as bone marrow edema, occult ligamentous disruptions, and cord hemorrhage—MRI allows for the accurate application of established classification systems like the Subaxial Cervical Spine Injury Classification (SLIC) and the Thoracolumbar Injury Classification and Severity (TLICS) score [4]. This precise classification is vital for clinicians to effectively distinguish between stable and unstable injuries, thereby guiding the choice between surgical decompression and conservative management, ultimately reducing the risk of permanent neurological deficit [8, 10].

Furthermore, the utility of MRI in managing challenging clinical scenarios, such as Spinal Cord Injury Without Radiographic Abnormality (SCIWORA), confirms its necessity in contemporary trauma protocols [7]. While the integration of MRI into emergency workflows may present practical logistical challenges, the diagnostic certainty it affords significantly offsets these considerations by improving patient outcomes and streamlining therapeutic pathways [10].

In conclusion, the evidence presented in this research underscores that MRI should be prioritized in the clinical evaluation of spinal trauma. The detailed, multi-planar visualization provided by MRI is transformative, ensuring that complex injuries are not overlooked and that treatment plans are optimized for individual patient needs. Future efforts should focus on optimizing rapid-acquisition MRI sequences to balance diagnostic detail with time-efficiency, further solidifying the position of MRI as the gold standard in the comprehensive care of patients with spinal injuries [1, 2].

6. LIMITATIONS

While this study provides significant insights into the role of MRI in the diagnosis and classification of spinal trauma, it is important to acknowledge certain inherent limitations. First, the study was conducted at a single center with a limited sample size, which may restrict the generalizability of the findings to a broader, more diverse patient population [1]. Second, as a prospective observational study, the research focused primarily on the acute radiological evaluation of patients. Consequently, long-term clinical follow-up data—such as neurological recovery outcomes, rehabilitation progress, and long-term quality of life—were not captured within the study period [8]. Furthermore, logistical constraints, such as patient instability or critical medical condition, occasionally precluded the use of advanced imaging sequences, potentially resulting in an underestimation of certain subtle injuries [3]. The study was also subject to inter-observer variability in the interpretation of complex MRI findings, particularly regarding the classification of subtle ligamentous disruptions or low-grade spinal cord edema [6]. Finally, the reliance on a 1.5 Tesla scanner, while standard, may have resulted in lower signal-to-noise ratios compared to high-field 3.0 Tesla systems, which could impact the detection of micro-hemorrhages or very subtle parenchymal lesions [6].

7. RECOMMENDATIONS

Based on the findings of this study, the following recommendations are proposed to enhance future research and clinical practice:

1. Multicenter Longitudinal Studies:

Future research should involve multicenter collaboration to increase sample sizes and improve the diversity of the study population, thereby enhancing the statistical power and generalizability of the results [1]. Additionally, longitudinal studies are required to correlate initial MRI findings with long-term neurological prognosis and functional recovery.

2. Advanced Imaging Sequences

It is recommended that future studies incorporate advanced MRI techniques, such as Diffusion Tensor Imaging (DTI) and susceptibility-weighted imaging (SWI). These sequences have shown potential in providing a more sensitive assessment of white matter tract integrity and micro-hemorrhages, respectively, which are often not fully visualized on standard T1 and T2 sequences [6].

3. Standardization of Protocols

To reduce inter-observer variability, clinical departments should adopt standardized reporting templates and classification protocols (such as refined SLIC or TLICS guidelines) for all traumatic spine MRIs [3, 4].

4. Interdisciplinary Correlation

There is a need for stronger integration between radiological findings and clinical/surgical teams. Regular review meetings where imaging is correlated with clinical outcomes can significantly improve diagnostic accuracy and the selection of appropriate therapeutic interventions [10].

5. Optimization of Rapid Protocols:

Given the critical time factor in trauma management, future efforts should focus on optimizing "rapid" MRI protocols that provide high-diagnostic yield without significantly increasing scan time, ensuring that MRI remains a feasible emergency diagnostic tool [7, 8].

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