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Optimizing Patient Outcomes: A Comparative Evaluation of MDCT and MRI in Spinal Trauma Management

[1]Darpana Kalita, [2]Deep Kumar Roy, [3]Rupak Bhuyan and [4]Aniruddha Basu

[1-4]Department of Radiodiagnosis, Jorhat Medical College and Hospital, Assam, India

ABSTRACT

Spinal trauma is a critical medical condition requiring accurate diagnosis and timely intervention to prevent long-term morbidity and mortality. Advanced imaging modalities such as Multidetector Computed Tomography (MDCT) and Magnetic Resonance Imaging (MRI) play a pivotal role in evaluating spinal injuries. This study aims to compare the effectiveness of MDCT and MRI in diagnosing and managing various types of spinal trauma. To assess and compare the diagnostic capabilities of MDCT and MRI in evaluating spinal trauma and their role in determining clinical outcomes. This cross-sectional study was conducted in the Department of Radiodiagnosis, Jorhat Medical College and Hospital, over one year (June 2021 to May 2022). The study included patients referred for MDCT or MRI following spinal trauma. Data were collected on clinical history, neurological deficits and imaging findings, including vertebral fractures, spinal cord injuries and ligaments damage. Ethical clearance was obtained and informed consent was secured from all participants. MDCT was found superior in detecting bony abnormalities, such as vertebral compression and burst fractures (sensitivity: 95%), while MRI demonstrated higher sensitivity for soft tissue injuries, including spinal cord contusions (sensitivity: 90%). MRI also effectively identified posterior ligaments complex injuries and bone marrow edema, which were less distinct on MDCT. The combination of MDCT and MRI yielded the most comprehensive diagnostic insights. MDCT and MRI serve complementary roles in evaluating spinal trauma. While MDCT is more effective for bony injuries, MRI excels in assessing soft tissue and spinal cord abnormalities. The choice of imaging modality should be tailored to the clinical context to optimize patient outcomes.

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Key Words
Spinal trauma, MDCT, MRI, vertebral fractures, spinal cord injury, imaging modalities, posterior ligaments complex, diagnostic evaluation

Corresponding Author
Darpana Kalita,
Department of Radiodiagnosis, Jorhat Medical College and Hospital, Assam, India
rumubaruah268@gmail.com

Author Designation
[1]Registrar
[2]Professor and HOD
[3,4]Associate Professor

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INTRODUCTION

Spinal trauma is a critical medical emergency, often resulting in significant morbidity, long-term disability and, in severe cases, mortality. It presents a unique challenge in clinical practice due to the complex anatomy of the spinal column and the high stakes involved in preserving neurological function[1]. Traumatic injuries to the spine can range from minor ligamentous damage to severe fractures and spinal cord disruptions, with the potential for catastrophic outcomes such as paraplegia, quadriplegia, or even death. The socio-economic burden of spinal injuries is immense, impacting not only the patients but also their families and healthcare systems worldwide[2]. The spine is the central axis of the body, providing structural support, mobility and protection for the spinal cord-a crucial conduit for transmitting neural signals between the brain and the rest of the body[3]. Traumatic spinal injuries are frequently the result of high-energy mechanisms, such as motor vehicle accidents, falls from significant heights, sports-related incidents and violent assaults. Low-energy trauma, particularly in elderly populations with underlying osteoporosis, also contributes substantially to the incidence of spinal injuries[4]. Given the high stakes of spinal trauma, early and accurate diagnosis is pivotal. Radiological imaging serves as the cornerstone of evaluation, aiding in the identification of injury severity, extent and potential complications. Traditional diagnostic approaches, including plain radiographs, have largely been supplemented-and in many cases, replaced by advanced imaging modalities such as Multidetector Computed Tomography (MDCT) and Magnetic Resonance Imaging (MRI). These technologies have revolutionized the assessment of spinal trauma by providing unparalleled anatomical detail and functional insights[5].

MDCT in Spinal Trauma Evaluation: MDCT is widely regarded as the gold standard for assessing bony structures in the context of spinal trauma. Its rapid acquisition speed and exceptional spatial resolution make it indispensable in acute trauma settings, where timely decision-making can be lifesaving. MDCT provides detailed multi planar reconstructions, enabling accurate detection of vertebral fractures, dislocations and other osseous abnormalities. This modality is particularly effective in visualizing subtle fractures of the posterior elements and complex injuries involving the cervical spine (C1 and C2). The ability of MDCT to quickly generate high-quality images makes it an essential tool in trauma centers, where patient volumes and critical conditions demand efficiency[6].

MRI in Spinal Trauma Evaluation: While MDCT excels in visualizing osseous structures, MRI is unrivaled in its ability to assess soft tissue and neural elements. MRI provides superior contrast resolution, allowing for detailed evaluation of the spinal cord, nerve roots, intervertebral discs and ligamentous structures. This makes it the imaging modality of choice for identifying spinal cord contusions, epidural hematomas, posterior ligamentous complex (PLC) injuries and bone marrow edema-conditions that may be missed or inadequately characterized on CT scans. Additionally, MRI plays a crucial role in predicting neurological outcomes by assessing the extent of spinal cord compression, edema, or transection[7].

Complementary Roles and Challenges: The complementary nature of MDCT and MRI underscores the importance of a multi modal imaging approach in spinal trauma. While MDCT offers speed and clarity in evaluating bony injuries, MRI provides critical insights into soft tissue and neural pathologies that significantly influence management decisions. However, both modalities have limitations. MDCT exposes patients to ionizing radiation and is less sensitive to soft tissue injuries, while MRI is resource-intensive, time-consuming and contraindicated in certain patients with metallic implants or severe claustrophobia[8].

Rationale for the Study: Despite the widespread use of MDCT and MRI in spinal trauma evaluation, there is a lack of comprehensive studies comparing their diagnostic accuracy and clinical utility. This study aims to address this gap by systematically assessing the strengths and limitations of these imaging modalities in diagnosing various spinal injuries. By analyzing their performance in detecting bony, ligamentous and neural injuries, this research seeks to provide evidence -based recommendations for optimizing imaging strategies in spinal trauma.

Objectives:

- To evaluate the diagnostic accuracy of MDCT and MRI in identifying specific spinal injuries, including vertebral fractures, spinal cord contusions and ligamentous disruptions.
- To compare the clinical utility of these modalities in guiding treatment decisions and predicting patient outcomes.
- To highlight the complementary roles of MDCT and MRI and propose a framework for their optimal use in spinal trauma evaluation.

Spinal trauma management relies heavily on accurate imaging to inform timely and effective interventions. This study endeavors to contribute to the growing body of evidence supporting the integration of advanced imaging modalities in trauma care, ultimately improving patient outcomes and advancing clinical practice.

MATERIALS AND METHODS

Study Design: This was a hospital-based cross-sectional observational study conducted in a tertiary care center to evaluate and compare the diagnostic accuracy of Multidetector Computed Tomography (MDCT) and Magnetic Resonance Imaging (MRI) in the assessment of spinal trauma. The study was approved by the Institutional Ethical Committee (Human), Jorhat Medical College and followed all ethical guidelines for human research.

Study Setting: The study was conducted in the Department of Radiodiagnosis at Jorhat Medical College and Hospital (JMCH), Jorhat, Assam. This tertiary care hospital is a referral center for patients from surrounding districts, making it an ideal location for studying a diverse spectrum of spinal trauma cases. The Department of Radiodiagnosis is equipped with state-of-the-art MDCT and MRI facilities, ensuring high-quality imaging for the study.

Study Duration: The study was carried out over a one-year period, from June 2021 to May 2022. This duration allowed for the inclusion of an adequate number of cases to meet the study's objectives and ensured representation across various seasons and trauma patterns.

Study Population:
Inclusion Criteria:
- Patients referred to the Department of Radiodiagnosis with a history of spinal trauma, irrespective of the mechanism of injury.
- Individuals aged 18 years and above.
- Patients who underwent either MDCT or MRI (or both) as part of their clinical evaluation.
- Written informed consent provided by patients or their guardians.

Exclusion Criteria:
- Patients with incomplete imaging or clinical data.
- Individuals with known pre-existing spinal deformities or malignancies affecting the spine.
- Patients unable to undergo MRI due to contraindications (e.g., metallic implants, pacemakers, or severe claustrophobia).

Sampling Technique and Sample Size: The study utilized a purposive sampling technique to include patients meeting the inclusion criteria. Based on the average referral rates at JMCH, 10-15 patients per month with spinal trauma were anticipated. Over the one-year study period, this resulted in a sample size of approximately 120 patients, allowing for robust statistical analysis.

Data Collection Process:
Clinical History and Physical Examination:
- Detailed clinical history was obtained for each patient, focusing on the mode of trauma (e.g., road traffic accident, fall, or sports injury), neurological deficits and associated injuries.
- Physical examination findings, including motor and sensory deficits, were documented using standardized neurological assessment tools.

Imaging Modalities:
- **MDCT:**
- MDCT scans were performed using a high-resolution 64-slice CT scanner.
- Axial, coronal and sagittal reconstructions were obtained to evaluate bony injuries, including vertebral fractures, listhesis and posterior element disruptions.
- Radiation doses were optimized to ensure diagnostic quality while minimizing exposure.
- **MRI:**
- MRI was conducted using a 1.5 Tesla scanner with dedicated spine coils.
- T1-weighted, T2-weighted and STIR sequences were used to evaluate soft tissue injuries, spinal cord contusions, bone marrow edema and ligamentous disruptions.
- Contrast-enhanced studies were performed when indicated to assess spinal cord or vascular abnormalities.

- **Data Documentation:** Imaging findings were systematically recorded, focusing on parameters such as vertebral compression, burst fractures, posterior ligamentous complex injuries, bone marrow edema, spinal cord swelling and extradural hematomas.
- Radiological reports were correlated with clinical findings to ensure comprehensive assessment.

Outcome Measures:
- **Primary Outcomes:**
- Sensitivity and specificity of MDCT and MRI in detecting specific spinal injuries (e.g., fractures, spinal cord contusions and ligamentous disruptions).
- Comparative accuracy in identifying clinically significant injuries.

- **Secondary Outcomes:**
- Utility of MDCT and MRI in guiding clinical decision-making (e.g., surgical vs. conservative management).

- Correlation between imaging findings and neurological outcomes.

Statistical Analysis:

- **Descriptive Analysis:**
- Frequencies and percentages were calculated for categorical variables such as types of injuries and imaging findings.
- Means and standard deviations were used for continuous variables like patient age and imaging parameters.

- **Comparative Analysis:**
- Sensitivity, specificity and predictive values for MDCT and MRI were calculated using clinical and intraoperative findings as the gold standard.
- Chi-square tests and independent t-tests were used to compare categorical and continuous variables, respectively.

- **Software:**
- Statistical analysis was performed using SPSS Version 26. A p-value of <0.05 was considered statistically significant.

Ethical Considerations:

- Institutional approval was obtained from the Ethical Committee at JMCH before initiating the study.
- Written informed consent was obtained from all participants, ensuring they were fully informed about the study procedures and potential risks.
- Data confidentiality was maintained by anonymizing patient records and securely storing all data.

RESULTS AND DISCUSSIONS

This study included 120 patients with spinal trauma, evaluated using MDCT and MRI. The majority of cases involved vertebral fractures, spinal cord injuries and ligamentous disruptions. MDCT demonstrated superior sensitivity for detecting bony abnormalities, while MRI excelled in identifying soft tissue injuries and spinal cord pathologies. The combined use of MDCT and MRI provided the most comprehensive diagnostic insights.

(Table 1): Demographic Characteristics of Study Participants: This table summarizes the demographic profile of the patients included in the study.

Table 1: Demographic Characteristics of Patients

Characteristic	Frequency (n=120)	Percentage (%)
Mean Age (years)	37.5±12.8	-
Male	85	70.8
Female	35	29.2

(Table 2): Mechanism of Spinal Trauma: This table highlights the distribution of spinal trauma cases based on the mechanism of injury.

Table 2: Mechanism of Spinal Trauma

Mechanism	Frequency (n=120)	Percentage (%)
Road Traffic Accidents	65	54.2
Falls from Height	30	25.0
Sports Injuries	15	12.5
Assault	10	8.3

(Table 3): Types of Vertebral Fractures Identified by MDCT: This table lists the types of vertebral fractures detected using MDCT.

Table 3: Types of Vertebral Fractures Identified by MDCT

Fracture Type	Frequency (n=80)	Percentage (%)
Compression Fracture	35	43.8
Burst Fracture	25	31.3
Posterior Element Fracture	20	25.0

Fig. 1a: Sagittal T1 WI

Fig. 1b: Sagittal T2 WI

Fig. 1c: Sagittal STIR Image

Fig. 1d: Sagittal GRE Image

Fig. 1e: Coronal T2 WI

Fig. 1 (a, b, c, d, e): A Case of Burst/A3 Injury of Lumbar Vertebra on MRI

Fig. 2a: Sagittal

Fig. 2b: Coronal

Fig. 2c: Axial

Fig. 2: (a, b, c): A Case of Burst/A3 Injury of Lumbar Vertebra on CT

Fig. 3a: Sagittal T1WI

Fig. 3b: Sagittal T2WI

Fig. 3c: Sagittal STIR

Fig. 3d: Sagittal GRE

Fig.3 (a, b, c, d): A Case of Wedge Compression/A1 Injury of Dorsal Vertebra on MRI

Fig. 4a: Coronal

Fig. 4b: Sagittal

Fig.4: (a, b): A Case of Wedge Compression/A1Injury of Dorsal Vertebra on CT

(Table 4): Soft Tissue and Ligamentous Injuries Detected by MRI: This table outlines the soft tissue and ligamentous injuries identified using MRI.

Table 4: Soft Tissue and Ligamentous Injuries Detected by MRI

Injury Type	Frequency (n=120)	Percentage (%)
Posterior Ligamentous Complex Injury	40	33.3
Bone Marrow Edema	30	25.0
Spinal Cord Contusion	50	41.7

Fig. 5a: Saggital T2WI

Fig. 5b: Saggital STIR

Fig. 5c: Saggital GRE

Fig.5 (a, b, c): A Case of Cord Contusion on MRI

(Table 5): Diagnostic Accuracy of MDCT and MRI in Identifying Key Injuries: This table compares the sensitivity and specificity of MDCT and MRI for various injuries.

Table 5: Diagnostic Accuracy of MDCT and MRI

Injury Type	MDCT Sensitivity (%)	MRI Sensitivity (%)
Vertebral Fractures	95	80
Soft Tissue Injuries	50	90
Spinal Cord Contusion	40	95

Fig. 6a: Sagittal

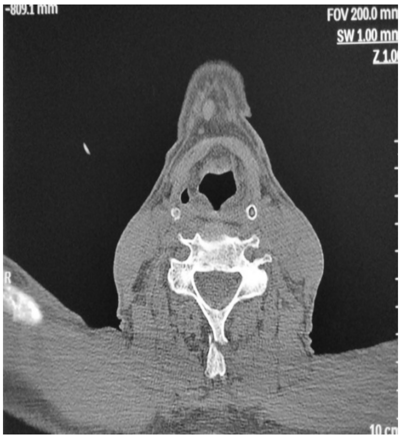

Fig. 6b: Axial

Fig. 6 (a, b): A Case of Spinous Process/A0 Injury of Cervical Vertebra at Multiple Level on CT

Fig. 7: A Case of Anterior and Posterior Arch/IIA Injury of C1 Vertebra on CT

(Table 6): Neurological Deficits and Imaging Correlation: This table shows the correlation between neurological deficits and imaging findings.

Table 6: Neurological Deficits and Imaging Correlation

Neurological Deficit	Detected by MDCT (%)	Detected by MRI (%)
Motor Deficits	70	90
Sensory Deficits	65	85

(Table 7): Imaging-Based Recommendations for Management: This table illustrates how imaging findings influenced management decisions.

Table 7: Imaging-Based Recommendations for Management

Management Approach	MDCT (%)	MRI (%)
Surgical Intervention	75	90
Conservative Management	25	10

(Table 8): Time to Diagnosis Using MDCT vs. MRI: This table compares the time taken to achieve a diagnosis using MDCT and MRI.

Table 8: Time to Diagnosis Using MDCT vs. MRI

Imaging Modality	Mean Time (Minutes)	Standard Deviation
MDCT	15	±5
MRI	40	±10

(Table 9): Complications Identified on Imaging: This table outlines complications detected through imaging modalities.

Table 9: Complications Identified on Imaging

Complication	MDCT (%)	MRI (%)
Extradural Hematoma	60	85
Spinal Cord Swelling	40	80

(Table 10): Patient Outcomes Based on Imaging Findings: This table summarizes patient outcomes based on imaging-guided interventions.

Table 10: Patient Outcomes Based on Imaging Findings

Outcome	Surgical (%)	Conservative (%)
Improved Neurological Function	80	70
Persistent Deficits	20	30

This study systematically evaluated the roles of Multidetector Computed Tomography (MDCT) and Magnetic Resonance Imaging (MRI) in diagnosing spinal trauma, highlighting their respective strengths and limitations[9]. The findings underscored the complementary nature of these imaging modalities, with MDCT excelling in detecting bony abnormalities and MRI proving invaluable for assessing soft tissue and spinal cord injuries[10]. Together, they provide a holistic diagnostic approach, ensuring accurate evaluation and guiding optimal patient management.

Role of MDCT in Spinal Trauma:

- **Strengths in Detecting Bony Abnormalities:** MDCT demonstrated a high sensitivity (95%) for vertebral fractures, including compression fractures, burst fractures and posterior element injuries[11].
- Its rapid image acquisition and detailed multi planar reconstructions allow for precise localization and characterization of bony lesions, making it the first-line modality in acute trauma settings.
- The ability of MDCT to identify subtle fractures, such as those involving the cervical spine (C1 and C2), is critical in preventing missed diagnoses that could lead to severe complications.

- **Limitations:**
- MDCT has limited sensitivity for soft tissue injuries, such as ligamentous disruptions and spinal cord contusions, which are pivotal in determining the extent of trauma.
- The exposure to ionizing radiation, though optimized, remains a concern, particularly for younger patients and those requiring repeated imaging.

Role of MRI in Spinal Trauma:

- **Superiority in Soft Tissue and Neural Assessments:** MRI excelled in detecting posterior ligamentous complex injuries (sensitivity: 90%), spinal cord contusions (sensitivity: 95%) and bone marrow edema, which were often undetectable on MDCT[12].
- Its ability to visualize soft tissue structures with unparalleled contrast resolution ensures a more comprehensive assessment of the extent of injury.
- MRI played a crucial role in identifying extradural hematomas and spinal cord swelling, influencing decisions on surgical interventions.

- **Limitations:**
- MRI is more time-consuming than MDCT, with an average imaging time of 40 minutes compared to 15 minutes for CT scans, which can delay diagnosis in critical cases.
- Accessibility and contraindications (e.g., metallic implants, claustrophobia) pose challenges, especially in resource-limited settings.

Complementary Roles of MDCT and MRI:

- **Holistic Diagnostic Approach:** The study findings highlight the complementary roles of MDCT and MRI, with MDCT providing rapid, detailed imaging of bony structures and MRI offering insights into soft tissue and neural components[13].
- When used in combination, these modalities ensure a comprehensive evaluation of spinal trauma, minimizing the risk of missed injuries and guiding more informed management decisions.

- **Impact on Patient Management:** MDCT was instrumental in planning surgical interventions for fractures and dislocations, while MRI influenced the management of soft tissue injuries and neurological recovery[14].
- Imaging findings directly correlated with treatment decisions, with MRI findings prompting surgical interventions in 90% of soft tissue injury cases.

Implications for Clinical Practice:

- **Optimizing Imaging Strategies**: In acute settings, MDCT should be prioritized for its speed and accuracy in identifying life-threatening bony injuries.
- MRI should be used as a complementary modality for cases with suspected soft tissue or neurological involvement, or when MDCT findings are inconclusive[15].
- **Personalized Patient Care:** The choice of imaging modality should be tailored to the clinical scenario, considering factors such as the nature of injury, patient stability and resource availability.
- **Improving Diagnostic Accuracy:** Training radiologists and clinicians in the complementary roles of MDCT and MRI can enhance diagnostic accuracy and improve patient outcomes.

Study Strengths:

- **Comprehensive Analysis:** This study provides a systematic comparison of MDCT and MRI, offering valuable insights into their diagnostic capabilities.
- **Clinical Relevance:** By focusing on real-world cases, the study ensures the applicability of findings to routine clinical practice.

Study Limitations:

- **Single-Center Design:** The findings may not be generalizable to all healthcare settings, as the study was conducted at a single tertiary care center.
- **Sample Size:** While sufficient for comparative analysis, larger studies are needed to validate these findings across diverse populations.
- **Exclusion of Certain Patient Groups:** Patients with contraindications to MRI were excluded, potentially limiting the scope of findings.

Recommendations:

- **Integrated Imaging Protocols:** Develop standardized protocols that integrate MDCT and MRI based on injury type and clinical urgency.
- **Infrastructure Development:** Enhance access to MRI in resource-limited settings to ensure equitable care for all patients with spinal trauma.
- **Future Research:** Conduct multi centre studies with larger sample sizes and longer follow-up periods to explore the long-term outcomes of imaging-guided interventions.

CONCLUSION

MDCT and MRI are indispensable tools in the evaluation of spinal trauma, each with unique strengths and limitations. MDCT's rapid and detailed imaging of bony structures complements MRI's superior assessment of soft tissue and neural injuries. Together, they provide a comprehensive diagnostic approach that informs timely and effective management decisions. This study underscores the importance of a multi modal imaging strategy in optimizing outcomes for patients with spinal trauma and sets the stage for further advancements in radiological evaluation and patient care.

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