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Original Research Article

COMPARATIVE EVALUATION OF NON-CONTRAST COMPUTED TOMOGRAPHY AND MAGNETIC RESONANCE IMAGING IN TRAUMATIC BRAIN INJURY: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Traumatic brain injury (TBI) requires accurate imaging for detection and characterization of intracranial lesions. Although non-contrast computed tomography (NCCT) is the primary imaging modality in acute trauma, MRI may detect subtle and microstructural injuries not adequately visualized on CT. The objective is to compare NCCT and MRI findings in patients with post-traumatic brain injury and assess their correlation in detecting traumatic lesions and complications. **Materials and Methods:** This cross-sectional study included 96 patients with TBI who underwent both NCCT and 3-T MRI brain. CT and MRI findings were compared according to lesion type, location, extent, and associated complications. The detection and agreement between the two modalities were assessed. **Result:** The mean age was 47.8 ± 18.2 years, with males comprising 54.2% of participants. On NCCT, cerebral contusion (57.3%), mass effect (56.3%), and subdural hematoma (54.2%) were frequent findings. MRI demonstrated higher detection of diffuse axonal injury (70.8%), intracerebral hemorrhage (60.4%), and subdural hematoma (57.3%). MRI detected DAI in 36 patients with negative CT findings. CT–MRI agreement was highest for epidural hematoma (91.7%) and lowest for DAI (51.0%). **Conclusion:** MRI provides substantial additional information over NCCT, particularly for DAI and subtle parenchymal injuries, while NCCT remains essential for rapid assessment of acute traumatic abnormalities.

INTRODUCTION

Traumatic brain injury (TBI) is a major cause of morbidity and mortality worldwide and represents an important clinical and public health problem, particularly among young and economically productive individuals.[1,2] Road traffic accidents, falls, assaults, and sports-related injuries are among the common causes of head trauma.[3] The clinical spectrum of TBI ranges from mild and transient neurological dysfunction to severe intracranial injury with permanent disability or death.[4] Early and accurate identification of intracranial abnormalities is therefore essential for appropriate management, prognostication, and prevention of secondary neurological deterioration.[1,5]

Neuroimaging plays a central role in the evaluation of patients with traumatic brain injury. Non-contrast computed tomography (NCCT) is widely regarded as the initial imaging modality in acute head trauma because it is rapid, readily available, relatively inexpensive, and highly sensitive for clinically significant acute intracranial hemorrhage, skull fractures, mass effect, cerebral edema, and herniation.[6,7] CT is particularly valuable in the emergency setting where rapid identification of lesions requiring immediate neurosurgical intervention is critical. However, despite its advantages, CT may have limited sensitivity for certain traumatic lesions, especially small contusions, non-hemorrhagic injuries, diffuse axonal injury, brainstem lesions, and subtle abnormalities that may be occult or poorly delineated on initial examination.[8,9]

Magnetic resonance imaging (MRI): provides superior soft-tissue contrast and offers greater sensitivity for several forms of traumatic brain injury that may not be adequately characterized on NCCT. Conventional T1- and T2-weighted sequences, fluid-attenuated inversion recovery (FLAIR), diffusion-weighted imaging (DWI), susceptibility-weighted imaging (SWI), and other advanced sequences can provide complementary information regarding parenchymal injury, diffuse axonal injury, microhemorrhages, edema, and evolving traumatic lesions.[10,11] MRI may therefore demonstrate additional abnormalities in patients with persistent

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neurological symptoms despite an apparently normal or inconclusive CT examination.[3,4,12]

Although NCCT and MRI have distinct strengths, they should be considered complementary rather than competing imaging modalities.[7,13] Correlation of findings obtained from both techniques can improve characterization of traumatic intracranial lesions and provide a more comprehensive assessment of the extent and nature of brain injury. Identification of lesions detected exclusively or more clearly on MRI may be particularly relevant in patients whose CT findings do not fully explain their clinical presentation.[12-16]

Despite the established roles of CT and MRI in neurotrauma, differences in their diagnostic contribution across various traumatic brain lesions warrant further evaluation in different clinical settings. The present study was therefore undertaken to correlate NCCT and MRI findings in patients with post-traumatic brain injury and to assess the additional information provided by MRI in the detection and characterization of traumatic brain lesions and their complications.

The objectives of the study were to perform NCCT and MRI in patients with post-traumatic brain injury and to correlate the imaging findings obtained by both modalities, including the associated intracranial complications.

MATERIALS AND METHODS

Study Design and Setting: This hospital-based cross-sectional observational study was conducted in the Department of Radiodiagnosis, National Institute of Medical Sciences & Research, Jaipur, Rajasthan, over a period of 18 months. Patients of all age groups and both sexes presenting with post-traumatic brain injury and undergoing both NCCT and MRI brain were included.

Sample Size and Sampling: The sample size was calculated using the formula:

$$n = \frac{Z_{\alpha/2}^2 p(1-p)}{d^2}$$

Considering an expected MRI accuracy of 90%, 95% confidence level, and 6% allowable error, the calculated sample size was 96 patients. Patients were recruited using convenience sampling.

Inclusion and Exclusion Criteria

Patients with a history of traumatic brain injury who consented to participate were included. Patients with MRI-incompatible implants or significant claustrophobia preventing MRI examination were excluded.

Imaging Protocol: NCCT brain was performed using a multidetector CT scanner with axial and multiplanar reformatted images. CT was assessed for hemorrhage, contusions, fractures, mass effect, edema, and other traumatic abnormalities.

MRI was performed on a 3-T Siemens Magnetom Vida system using T1-weighted, T2-weighted, FLAIR, DWI with ADC, and GRE/SWI sequences. Post-contrast imaging was performed when clinically indicated.

Image Evaluation: NCCT and MRI findings were compared with respect to the presence, type, location, and extent of traumatic lesions, including contusions, diffuse axonal injury, intracerebral hemorrhage, subarachnoid hemorrhage, subdural hematoma, epidural hematoma, cerebral edema, herniation, and hydrocephalus.

Statistical Analysis: Data were recorded in a structured proforma and analyzed using appropriate statistical methods. Frequencies and percentages were used for categorical variables, while continuous variables were summarized using appropriate descriptive statistics. CT and MRI findings were compared to assess lesion detection and agreement between the modalities. A p-value <0.05 was considered statistically significant.

RESULTS

Demographic and Clinical Characteristics:

[Table 1] summarizes the demographic and clinical characteristics of the 96 study participants. The mean age was 47.8 ± 18.2 years, with a slight male predominance. Road traffic accidents were the most common mechanism of injury, and severe traumatic brain injury constituted the largest GCS category. Loss of consciousness and focal neurological deficits were observed in a substantial proportion of patients.

CT and MRI Findings

[Table 2] presents the NCCT findings, with cerebral contusion, mass effect, subdural hematoma, intracerebral hemorrhage, and subarachnoid hemorrhage being the predominant abnormalities. Table 3 summarizes MRI findings, demonstrating a higher detection of several intracranial abnormalities, particularly diffuse axonal injury, intracerebral hemorrhage, subdural hematoma, and subtle parenchymal injuries.

[Figure 1] illustrates the comparative detection of major traumatic lesions by NCCT and MRI. MRI demonstrated greater detection across most lesion categories, with the most prominent difference observed for diffuse axonal injury.

Complications and CT–MRI Correlation

[Table 4] shows the major MRI-detected complications and clinical outcomes. Hydrocephalus, infarction, and brain herniation were the principal complications, while persistent neurological deficits and seizure disorders represented the major clinical sequelae.

[Table 5] demonstrates the CT–MRI correlation for major traumatic lesions. Agreement was highest for epidural hematoma and lowest for diffuse axonal injury, indicating substantial additional detection of DAI by MRI.

[Figure 2] demonstrates the incremental detection of traumatic lesions by MRI among patients in whom NCCT was negative, with the greatest additional detection observed for diffuse axonal injury.

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[Figure 3] depicts the degree of agreement between NCCT and MRI across the major traumatic lesions, showing relatively high agreement for extra-axial hemorrhages and comparatively lower agreement for DAI.

[Figure 4] demonstrates the discordant findings between the two modalities, highlighting the greater proportion of MRI-positive/CT-negative cases, particularly for diffuse axonal injury and intracerebral hemorrhage.

Table 1: Demographic and Clinical Characteristics of the Study Participants

Variable	n (%) / Mean ± SD
Age (years)	47.8 ± 18.2
Sex	
Male	52 (54.2)
Female	44 (45.8)
Mode of injury	
Road traffic accident	34 (35.4)
Fall	30 (31.3)
Assault	20 (20.8)
Other causes	12 (12.5)
Time since injury (hours)	22.6 ± 16.3
GCS severity	
Mild (13–15)	26 (27.1)
Moderate (9–12)	34 (35.4)
Severe (≤8)	36 (37.5)
Loss of consciousness	60 (62.5)
No loss of consciousness	36 (37.5)
Pupillary reaction	
Dilated	39 (40.6)
Unequal	32 (33.3)
Normal	25 (26.0)
Focal neurological deficit	51 (53.1)
No focal deficit	45 (46.9)

Table 2: Traumatic Brain Injury Findings Detected on NCCT

CT finding	Present, n (%)	Absent, n (%)
Epidural hematoma	39 (40.6)	57 (59.4)
Subdural hematoma	52 (54.2)	44 (45.8)
Subarachnoid hemorrhage	49 (51.0)	47 (49.0)
Intracerebral hemorrhage	50 (52.1)	46 (47.9)
Intraventricular hemorrhage	38 (39.6)	58 (60.4)
Cerebral contusion	55 (57.3)	41 (42.7)
Cerebral edema	44 (45.8)	52 (54.2)
Diffuse axonal injury	43 (44.8)	53 (55.2)
Mass effect	54 (56.3)	42 (43.7)
Skull fracture	47 (49.0)	49 (51.0)
Hydrocephalus	32 (33.3)	64 (66.7)
Midline shift (mm)	5.4 ± 3.2	—

Table 3: Traumatic Brain Injury Findings Detected on MRI

MRI finding	n (%)
Epidural hematoma	41 (42.7)
Subdural hematoma	55 (57.3)
Subarachnoid hemorrhage	51 (53.1)
Intracerebral hemorrhage	58 (60.4)
Intraventricular hemorrhage	44 (45.8)
Diffuse axonal injury	68 (70.8)
Hydrocephalus*	36 (37.5)
White matter injury	52 (54.2)
Microbleeds	49 (51.0)
Non-hemorrhagic contusion	45 (46.9)
Infarction	38 (39.6)

Table 4: MRI-Detected Complications and Clinical Outcomes

Variable	n (%)
Complications	
Hydrocephalus	39 (40.6)
Infarction	36 (37.5)
Brain herniation	34 (35.4)
Clinical outcomes	
Persistent neurological deficit	46 (47.9)
Seizure disorder	42 (43.8)

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Table 5: CT–MRI Correlation for Detection of Major Traumatic Lesions

Lesion	CT+/MRI+	CT+/MRI−	CT−/MRI+	CT−/MRI−	Agreement (%)
EDH	36	3	5	52	91.7
SDH	48	4	7	37	88.5
SAH	44	5	7	40	87.5
ICH	46	4	12	34	83.3
IVH	34	4	10	48	85.4
DAI	32	11	36	17	51.0

CT+/MRI+ = lesion detected by both modalities; CT+/MRI− = detected on CT only; CT−/MRI+ = detected on MRI only; CT−/MRI− = detected by neither modality.

Figure 1: Comparative CT–MRI Detection of Major Traumatic Lesions

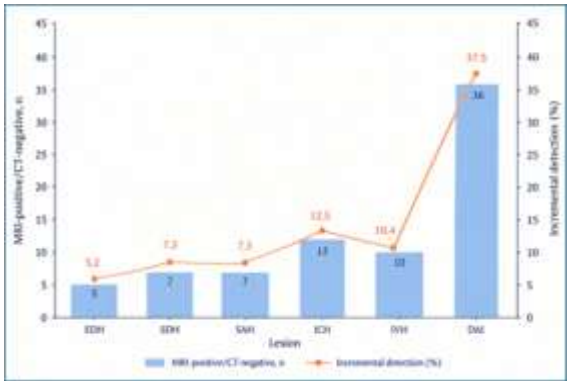

Figure 2: MRI Incremental Detection Over NCCT

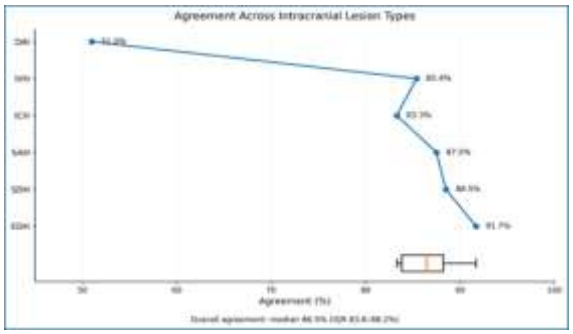

Figure 3: CT–MRI Agreement Across Major Lesion

Figure 4: CT–MRI Discordance Pattern

DISCUSSION

Traumatic brain injury remains a heterogeneous neurological condition in which the extent of structural damage may not be completely characterized by a single imaging modality. In the present study of 96 patients, the mean age was 47.8 ± 18.2 years, with a slight male predominance, and road traffic accidents constituted the most common mechanism of injury. A considerable proportion of patients had moderate-to-severe injury, loss of consciousness, and focal neurological deficits, reflecting a clinically significant trauma population. These findings provide an appropriate clinical context for evaluating the complementary roles of NCCT and MRI in traumatic brain injury.

In the present study, NCCT demonstrated cerebral contusion as the most frequent abnormality (57.3%), followed by mass effect (56.3%) and subdural hematoma (54.2%). Intracerebral hemorrhage and subarachnoid hemorrhage were also frequently identified. These findings are consistent with the established role of CT as the primary imaging modality for rapid assessment of acute traumatic intracranial abnormalities. Vande Vyvere et al. emphasized the broad spectrum of traumatic abnormalities identifiable on admission CT, including extra-axial hemorrhage, contusions, edema, mass effect, and other acute structural injuries in the CENTER-TBI cohort.[12] Similarly, Diouf et al. highlighted that conventional CT remains particularly valuable in the acute trauma setting because of its rapid acquisition and ability to identify hemorrhage, mass effect, and surgically relevant lesions.[10]

MRI demonstrated a greater overall detection of several traumatic abnormalities in the present study. Most notably, DAI was identified in 68 patients (70.8%) on MRI compared with 43 patients (44.8%) on CT. The CT–MRI correlation further demonstrated that 36 patients had MRI-positive/CT-negative DAI, representing the largest modality-specific discordance in the study. This finding is clinically important because DAI represents a predominantly microscopic and multifocal injury pattern that can be occult on conventional CT. Graham et al. demonstrated the importance of DAI as a clinically relevant marker of subsequent neurodegeneration following moderate-to-severe TBI, emphasizing that axonal injury represents more than an incidental radiological finding.[1] Bourke et

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al. similarly demonstrated that diffusion-based and volumetric MRI measures can provide information regarding traumatic brain injury beyond conventional structural assessment.[8]

The substantially greater detection of DAI by MRI in our cohort is also supported by the literature concerning advanced MRI techniques. Grant et al. described DWI and DTI as increasingly important techniques for characterizing microstructural brain injury and improving prognostic assessment following TBI.[11] Palacios et al. further reported that diffusion abnormalities in white matter were independently associated with long-term outcome after mild TBI, supporting the concept that MRI-derived microstructural abnormalities may contain clinically relevant information not captured by conventional CT.[9] Thus, the marked CT–MRI discrepancy for DAI observed in the present study is biologically plausible and reinforces the complementary role of MRI when CT findings do not adequately explain the severity or neurological manifestations of injury.

MRI also demonstrated higher detection rates for intracerebral hemorrhage, intraventricular hemorrhage, and subdural hematoma than NCCT in the present study. The difference was particularly evident for intracerebral hemorrhage, detected in 60.4% on MRI compared with 52.1% on CT. The CT–MRI correlation showed 12 patients with ICH detected on MRI despite negative CT findings. Leary et al. demonstrated that quantitative assessment of traumatic intracranial hemorrhage on CT is associated with functional outcome and mortality, highlighting the prognostic importance of accurately characterizing traumatic hemorrhagic burden.[3] Meanwhile, Turtzo et al. showed that cytotoxic edema associated with hemorrhage is associated with poor outcome after TBI, indicating that traumatic hemorrhage and its accompanying tissue response may have important prognostic implications.[4]

The present study also demonstrated a high frequency of MRI-detected white matter injury and microbleeds. These findings highlight the value of susceptibility-sensitive and diffusion-sensitive sequences in identifying traumatic abnormalities that may be inconspicuous on NCCT. Környei et al. demonstrated that susceptibility-weighted MRI can identify cerebral microbleeds after TBI, although their detectability may vary according to the interval between injury and imaging.[6] Hageman et al. likewise investigated susceptibility-weighted MRI findings and microbleeds in mild TBI, supporting the relevance of susceptibility-based imaging in the characterization of traumatic microvascular injury.[7] These observations provide a plausible explanation for the additional microhemorrhagic abnormalities observed on MRI in our study.

The CT–MRI agreement in the present study was highest for epidural hematoma (91.7%), followed by subdural hematoma (88.5%) and subarachnoid hemorrhage (87.5%). In contrast, agreement for DAI was considerably lower (51.0%), primarily because MRI identified substantially more CT-negative cases. This pattern illustrates an important distinction between the two modalities: NCCT and MRI demonstrate relatively comparable performance for several macroscopic hemorrhagic lesions, whereas MRI provides substantially greater sensitivity for selected parenchymal and microstructural injuries. Dabas et al., in their systematic review comparing MRI and CT in TBI, similarly concluded that MRI can provide additional diagnostic information, particularly for subtle parenchymal injuries and DAI that may not be adequately demonstrated on CT.[13]

The additional abnormalities demonstrated by MRI may have implications for prognostication and clinical management. In our cohort, hydrocephalus, infarction, and brain herniation were important complications, while persistent neurological deficits and seizures represented notable clinical sequelae. Naeimi et al. reported that both CT and MRI findings have prognostic value for predicting poor neurological outcomes and mortality following acute TBI, although the prognostic contribution varies according to the specific imaging abnormality.[14] More broadly, Patil et al. emphasized that CT and MRI provide complementary information in TBI, with CT being particularly valuable for acute structural assessment and MRI offering greater characterization of parenchymal and microstructural injury.[15]

The findings of the present study therefore support a complementary imaging strategy rather than replacement of NCCT by MRI. NCCT remains highly valuable as the initial investigation in acute trauma because it rapidly identifies hemorrhage, skull injury, mass effect, and other potentially life-threatening abnormalities. MRI, however, appears particularly valuable when neurological findings are disproportionate to CT abnormalities, when CT is negative or equivocal despite persistent symptoms, or when DAI, non-hemorrhagic contusion, white matter injury, or microhemorrhages are suspected. Diouf et al. similarly emphasized the complementary diagnostic contribution of conventional MR imaging in trauma management.[10] while Grant et al. highlighted the expanding role of diffusion-based MRI techniques in characterization and prognostication of TBI.[11]

An important strength of the present study is that each patient underwent both NCCT and MRI, permitting direct patient-level comparison between the two modalities rather than comparison of separate patient populations. The paired analysis particularly demonstrates the clinical relevance of MRI-positive/CT-negative abnormalities, with DAI showing the greatest incremental detection. This provides a more clinically meaningful assessment of the complementary value of MRI than simply comparing overall positivity rates between independent groups.

Limitations: This study has several limitations. First, it was a single-center cross-sectional study with a relatively small sample size of 96 patients, which

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may limit generalizability. Second, convenience sampling may have introduced selection bias. Third, the timing of MRI relative to injury was not uniform, which may influence the visibility of hemorrhagic and diffusion abnormalities, particularly microbleeds as noted by Környei et al.[6] Fourth, the study primarily assessed imaging detection and CT–MRI agreement and did not incorporate a uniform independent reference standard or long-term functional outcome scale for all patients. Larger multicenter prospective studies incorporating standardized MRI timing, quantitative lesion assessment, and validated long-term neurological outcomes are warranted.

CONCLUSION

In conclusion, the present study demonstrates that NCCT and MRI have complementary roles in the evaluation of traumatic brain injury. NCCT remains highly valuable for the rapid identification of acute hemorrhage, skull fractures, mass effect, and other major structural abnormalities, whereas MRI provides additional diagnostic information, particularly for diffuse axonal injury, white matter injury, microbleeds, non-hemorrhagic contusions, and other subtle parenchymal abnormalities. The substantially higher detection of DAI on MRI and the presence of MRI-positive/CT-negative lesions highlight the added value of MRI in patients with persistent or unexplained neurological findings despite NCCT. Thus, while NCCT should remain the initial imaging modality in acute TBI, MRI should be considered an important complementary investigation for comprehensive characterization of traumatic brain injury and its complications.

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