Section: Radiology

Original Research Article

COMPUTED TOMOGRAPHY IMAGING FEATURES IN MODERATE TO SEVERE TRAUMATIC BRAIN INJURY AND ITS CORRELATION WITH CLINICAL OUTCOME IN TERTIARY CARE HOSPITAL

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Received *: 16/02/2026*
Received in revised form *: 26/03/2026*
Accepted *: 14/04/2026*

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DOI: 10.70034/ijmedph.2026.2.194

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (2); 1149-1152

ABSTRACT

Background: Traumatic brain injury (TBI) is a leading cause of death and disability worldwide. Early CT imaging can identify lesions that not only guide acute management but also predict patient outcomes. Data from Indian populations with moderate to severe TBI remain limited. The aim is to evaluate the prognostic value of initial CT features in predicting mortality among patients with moderate to severe TBI.

Materials and Methods: This prospective cohort study included 85 consecutive patients (GCS ≤12) with neuroparenchymal abnormalities on initial non-contrast head CT. CT features recorded included extradural hematoma, subdural hematoma, traumatic subarachnoid hemorrhage, intraventricular hemorrhage, hemorrhagic contusions, diffuse axonal injury, basal cistern status, midline shift, and herniation. Mortality and functional outcomes at discharge were assessed using the Glasgow Outcome Scale. Statistical analysis comprised chi-square/Fisher's exact tests and multivariate logistic regression.

Results: Overall mortality was 22.4%. Independent predictors of death were intraventricular hemorrhage (p=0.017), basal cistern effacement (p=0.042), midline shift >10 mm (p=0.036), diffuse axonal injury grade 3 (p=0.040), and herniation (p=0.080, borderline significance). Subdural hematoma, extradural hematoma, contusions, and traumatic subarachnoid hemorrhage were not significantly associated with mortality. Good recovery (GOS 1) occurred in 56.5% of patients.

Conclusion: Baseline CT features such as intraventricular hemorrhage, basal cistern effacement, marked midline shift, high-grade diffuse axonal injury, and herniation are strong predictors of mortality in moderate to severe TBI.

Keywords: Traumatic Brain Injury (TBI), Glasgow Coma Scale (GCS), Intracranial Hemorrhage, Cerebral Edema, Moderate to Severe Head Injury.

INTRODUCTION

Traumatic brain injury (TBI) is a major cause of mortality, morbidity, and long-term disability worldwide, particularly among young and economically active populations. The burden is disproportionately high in low- and middle-income countries, where rapid urbanization and increased motor vehicle usage contribute to rising incidence rates. In India, road traffic accidents remain a leading cause, alongside falls, assaults, and sports-related trauma. [1-5]

Computed tomography (CT) is the primary imaging modality in acute TBI assessment owing to its widespread availability, rapid acquisition time, and ability to detect life-threatening lesions requiring urgent intervention. Beyond diagnosis, early CT findings have the potential to provide valuable

prognostic information, guiding both surgical decision-making and family counselling. While magnetic resonance imaging (MRI) offers superior sensitivity for subtle parenchymal lesions such as diffuse axonal injury (DAI), its use is often limited in unstable patients due to longer scan times, higher cost, and restricted accessibility. [6-8]

Multiple classification systems, including the Marshall classification and the Rotterdam CT score, have been proposed to standardize radiological assessment and predict clinical outcomes. These systems emphasize features such as midline shift, basal cistern compression, mass lesions, and subarachnoid hemorrhage. However, there remains variability in prognostic accuracy across populations, and limited data exist from Indian cohorts with moderate to severe TBI. [9,10]

This study prospectively evaluates specific CT features obtained at presentation in patients with moderate to severe TBI, aiming to determine their independent association with in-hospital mortality and functional outcome.

Aim and Objectives of the Study

1. To assess the imaging characteristic of primary brain injury on the first CT scan.
2. Predicting the clinical outcome based on individual imaging features on the basis of conservative management.

MATERIALS AND METHODS

Study Design, Duration & setting: A prospective cohort study was conducted at the Department of Radiodiagnosis, Rangaraya Medical College, between August 2024 – July 2025 (12 months). The institutional ethics committee approved the study protocol, and informed consent was obtained from patients' attendants.

Study population: Eighty-five consecutive patients aged ≥16 years presenting with moderate to severe head injury were enrolled. Severity was classified according to the Glasgow Coma Scale (GCS): moderate (GCS 9–12) and severe (GCS ≤8). All participants had positive neuroparenchymal findings on the initial non-contrast CT scan. Patients with polytrauma, mild TBI (GCS >12), or inadequate follow-up were excluded.

Inclusion criteria

Head injury patients with positive neuro parenchymal findings in CT scan with GCS less than 12.

Exclusion criteria

1. Poly trauma,
2. GCS more than 12
3. Surgical management

Imaging protocol: All CT examinations were performed using a Siemens Somatom Definition Edge scanner. Non-contrast helical acquisitions were obtained from the C2 vertebral level to the vertex in a caudo-cranial direction (100–120 kVp, 300–320 mAs, scan time 5–6 seconds). Images were reconstructed in axial, coronal, and sagittal planes with standard brain window settings.

Variables Recorded: Demographic data (age, sex), clinical parameters (GCS at presentation), and CT features were documented. The following radiological variables were assessed: extradural hematoma (EDH), subdural hematoma (SDH), traumatic subarachnoid hemorrhage (tSAH), intraventricular hemorrhage (IVH), hemorrhagic contusions, diffuse axonal injury (graded I–III), midline shift (none, 1–5 mm, 5–10 mm, >10 mm), basal cistern status (normal, compressed, effaced), and brain herniation (subfalcine, uncal, or other).

Outcome Assessment: Clinical outcome was evaluated using the Glasgow Outcome Scale (GOS) at hospital discharge, categorized as: Grade 1 – Good recovery; Grade 2 – Moderate disability; Grade 3 – Severe disability; Grade 4 – Persistent vegetative state; Grade 5 – Death.

Statistical Analysis: Categorical variables were compared using Pearson's Chi-square or Fisher's exact test. Multivariate logistic regression was performed to identify independent CT predictors of mortality, with $p<0.05$ considered statistically significant.

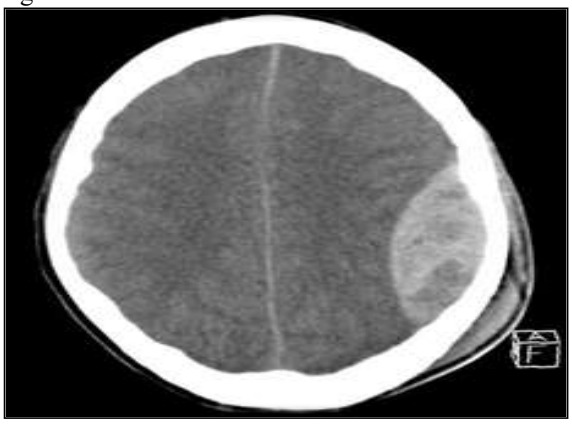


Figure 1: Axial CT brain showing a biconvex (lentiform) hyperdense extra-axial collection in the temporoparietal region (arrow), consistent with extradural hematoma. No significant association with mortality was observed in our study

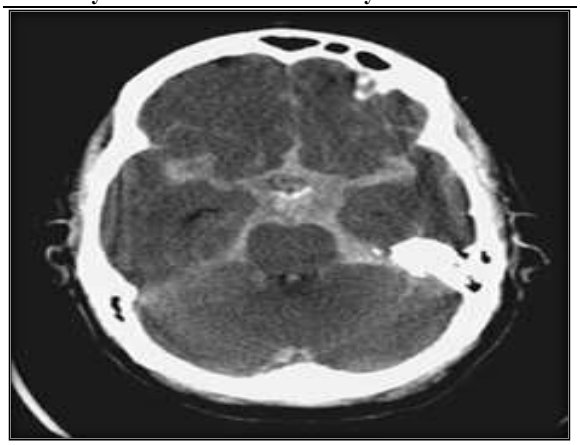


Figure 2: Axial non-contrast CT brain demonstrating hyperdense blood within the basal cisterns and bilateral Sylvian fissures, producing the characteristic "star sign" (arrow), consistent with subarachnoid hemorrhage.

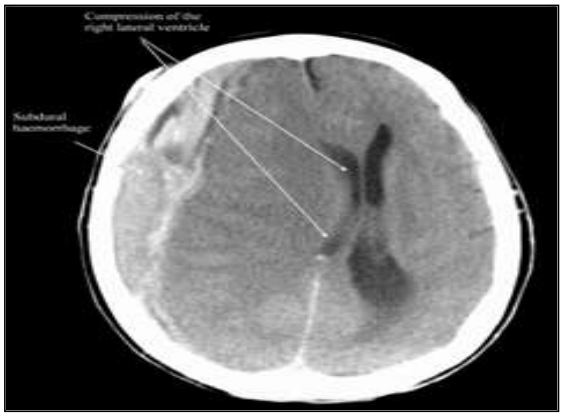


Figure 3: Axial CT scan demonstrating a crescent-shaped hyperdense extra-axial collection along the cerebral convexity (arrow), suggestive of subdural hematoma with midline shift towards left and compression of ipsilateral lateral ventricle.

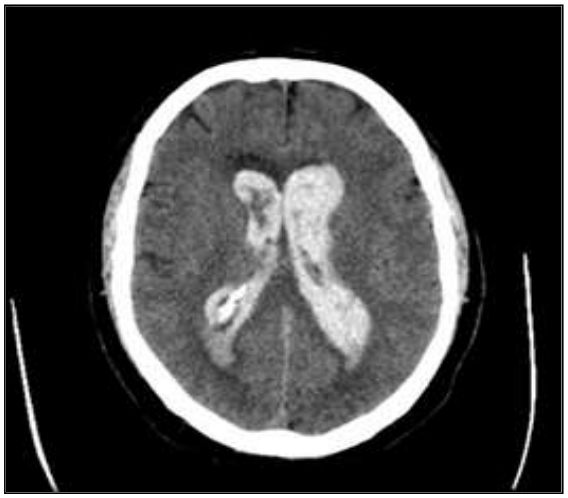


Figure 4: Axial CT brain showing hyperdense blood within the lateral ventricles (arrow), consistent with intraventricular hemorrhage, which was significantly associated with mortality in our study (p=0.017)

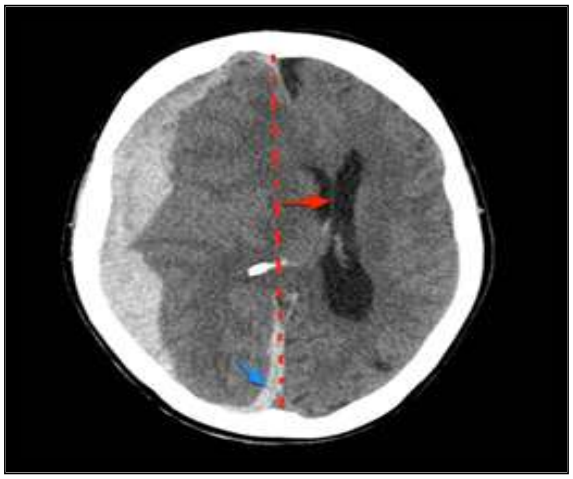


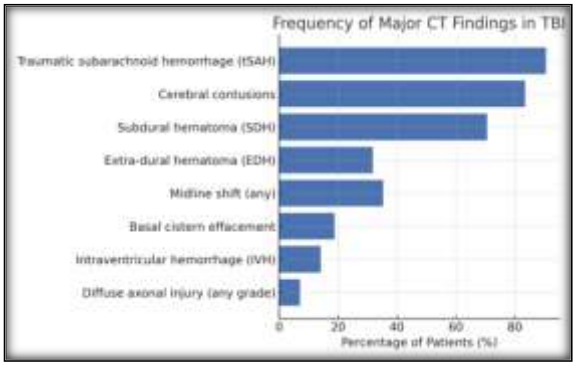
Figure 5: Axial CT brain demonstrating significant midline shift with displacement of the septum pellucidum (arrow) along with features of herniation, including effacement of basal cisterns and medial displacement of temporal lobe structures (arrowhead). These findings indicate severe mass effect and were associated with increased mortality in our study.

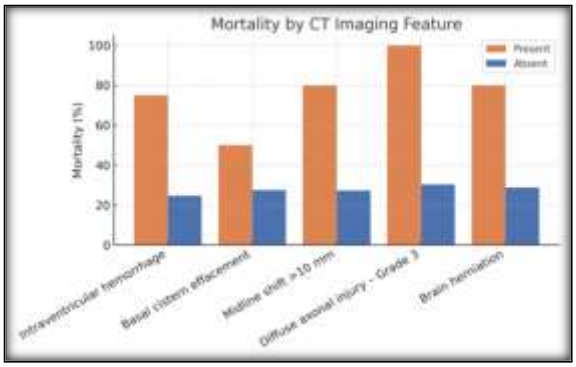
RESULTS

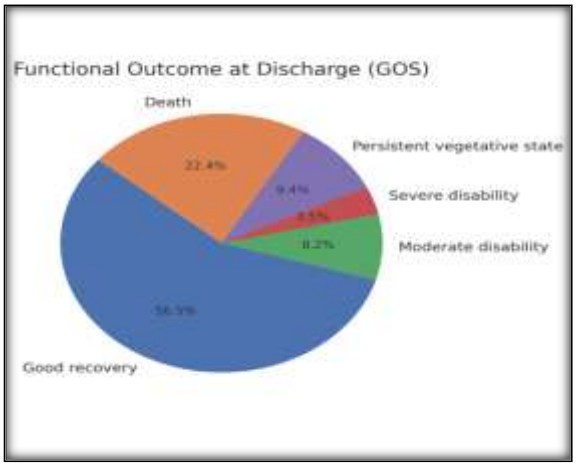
A total of 85 patients met inclusion criteria. The mean age was 36.9 years (range 16–70 years), with 57.6% aged 20–40 years. Males comprised 83.5% of the cohort. Severe TBI (GCS ≤8) was observed in 54.1%, and moderate TBI (GCS 9–12) in 45.9%.

The most frequent CT abnormality was traumatic subarachnoid hemorrhage (90.6%), followed by cerebral contusions (83.5%), subdural hematoma (70.6%), and extradural hematoma (31.8%). Intraventricular hemorrhage occurred in 14.1%, basal cistern effacement in 18.8%, midline shift in 35.3%, and diffuse axonal injury in 7.1%. Herniation was noted in 5.9%.

Overall in-hospital mortality was 22.4%. Significant predictors of mortality included intraventricular hemorrhage, basal cistern effacement, midline shift >10 mm, grade 3 diffuse axonal injury, and herniation.







DISCUSSION

This prospective study identified intraventricular hemorrhage, basal cistern effacement, midline shift >10 mm, high-grade diffuse axonal injury, and herniation as the most significant predictors of mortality in moderate to severe TBI. These findings support the prognostic relevance of early CT and align with established scoring systems like Marshall and Rotterdam.

The high mortality associated with IVH highlights its value as a prognostic marker, consistent with its inclusion in the Rotterdam score. Grade 3 DAI, even though less common, showed universally poor outcomes, emphasizing the need for meticulous CT evaluation in suspected shearing injuries.

Strengths of the study include its prospective design and focus on an underrepresented patient population. Limitations involve the modest sample size, exclusion of mild TBI, and short-term outcome measurement limited to hospital discharge.

Future studies should explore integrating CT features with clinical parameters and applying AI-based quantitative imaging to improve prognostic accuracy.

Summary

In this prospective cohort study, 85 patients with moderate to severe head injury (GCS < 12) showing neuroparenchymal abnormalities on their initial post-trauma CT scans were included.

The impact of specific imaging features on patient mortality was evaluated using statistical tests such as the chi-square test and multivariate logistic regression analysis.

The study findings indicated that certain CT features were strongly linked to higher mortality risk, including:

- Intraventricular hemorrhage
- Effacement of basal cisterns
- Midline shift greater than 10 mm
- Grade 3 diffuse axonal injury
- Evidence of brain herniation.

CONCLUSION

Baseline CT features such as intra-ventricular hemorrhage, basal cistern effacement, marked midline shift (>10mm), high-grade diffuse axonal injury, and brain herniation are strong predictors of mortality in moderate to severe TBI. Predictive mortality percentages provide valuable information for patient families, helping them understand prognosis, plan financially, and make informed decisions regarding costly therapeutic interventions.

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