

COMPUTED TOMOGRAPHY FINDINGS AND THEIR CORRELATION WITH CLINICAL SEVERITY IN TRAUMATIC BRAIN INJURY: A MULTI-CENTRE STUDY FROM TERTIARY CARE HOSPITALS IN PAKISTAN

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ABSTRACT

Objective: To evaluate the spectrum of computed tomography (CT) findings in patients with traumatic brain injury (TBI) and to correlate these findings with clinical severity as assessed by the Glasgow Coma Scale (GCS).

Study Design: Cross-sectional descriptive study.

Place and Duration of Study: Departments of Neurosurgery and Radiology at three tertiary care hospitals in Pakistan, from 30th September 2025 to 30th March 2026.

Methodology: A total of 102 patients presenting with traumatic brain injury were enrolled through non-probability consecutive sampling. All patients underwent non-contrast CT of the brain within six hours of presentation. CT findings were classified according to the Marshall CT Classification. Clinical severity was graded using the GCS at admission. Correlation between CT findings and GCS severity categories (mild: 13–15, moderate: 9–12, severe: 3–8) was assessed using the chi-square test and Spearman rank correlation.

Results: CT abnormalities were identified in 91 (89.2%) patients. Subdural haematoma was the most frequent finding (24; 23.5%), followed by cerebral contusion (21; 20.6%), subarachnoid haemorrhage (19; 18.6%), epidural haematoma (18; 17.6%), and diffuse axonal injury (9; 8.8%). A significant inverse correlation was observed between GCS score and Marshall CT grade (Spearman rho = -0.74; p<0.001). CT abnormality rates increased progressively with worsening GCS: 48.5% in mild, 79.3% in moderate, and 97.5% in severe TBI. In-hospital mortality was 12.7% overall, rising to 27.5% in severe TBI.

Conclusion: CT findings correlate significantly with clinical severity in TBI. Subdural haematoma and diffuse axonal injury are associated with the most severe clinical presentations and highest mortality. Non-contrast CT within six hours of injury remains an indispensable diagnostic tool in the management of TBI at tertiary care centres in Pakistan.

KEYWORDS: Traumatic Brain Injury; Computed Tomography; Glasgow Coma Scale; Marshall Classification; Intracranial Haemorrhage; Pakistan

INTRODUCTION

Traumatic brain injury is one of those diagnoses that clinicians recognise immediately as high stakes. It is the leading cause of trauma-related morbidity and mortality worldwide, responsible for an estimated 69 million new cases annually and carrying a disproportionate burden in low- and middle-income countries where road traffic accidents — the predominant mechanism — are both more frequent and more severe [1,2]. In Pakistan specifically, rapid urbanisation, a young and largely unprotected motorcycling population, and limited pre-hospital care infrastructure combine to create conditions in which TBI presents late, presents severely, and presents often [3].

The Glasgow Coma Scale (GCS) has been the cornerstone of clinical TBI severity classification for five decades and, despite its limitations, remains the most widely used bedside tool for initial neurological assessment [4]. A GCS of 13–15 defines mild TBI, 9–12 moderate, and 3–8 severe — categories that broadly correlate with prognosis but are far from sufficient to guide clinical decision-making on their own. This is where computed tomography comes in. CT of the brain is now the imaging modality of first choice in TBI and, when performed early, provides information that no clinical examination alone can offer: the presence and extent of intracranial haemorrhage, oedema, midline shift, and herniation [5,6].

The Marshall CT Classification — originally published in 1991 as part of the landmark Traumatic Coma Data Bank study — provides a structured, reproducible framework for grading CT findings in TBI and remains one of the most widely validated prognostic tools in the field [7]. It classifies injuries from Grade I (no visible

intracranial pathology) through Grade VI (evacuated or non-evacuated mass lesions), and its grades have been shown to correlate with outcomes including in-hospital mortality, need for surgical intervention, and functional recovery [7,8]. That said, the relationship between Marshall grade and GCS severity is not always linear, and the spectrum of CT findings can vary considerably across patient populations depending on injury mechanism, patient age, and time to imaging [9].

Published data on TBI-related CT findings from Pakistan are limited, particularly multi-centre data that could account for institutional variation in patient populations and imaging practice. Most available studies are single-centre, retrospective, and report heterogeneous findings that are difficult to generalise [10,11]. Given that CT availability and neurosurgical capacity are both expanding in the country, there is a real need for contemporary multi-centre data to characterise the CT spectrum of TBI and its relationship to clinical severity in the local context.

The objective of this study was to evaluate the spectrum of CT findings in patients with traumatic brain injury and to correlate these findings with clinical severity as assessed by the Glasgow Coma Scale at admission.

MATERIAL AND METHODS

Study Design and Setting

This cross-sectional descriptive study was conducted at the Departments of Neurosurgery and Radiology at three tertiary care hospitals in Pakistan from 30th September 2025 to 30th March 2026.

Sample Size:

A total of 102 patients were enrolled. Sample size was calculated based on an estimated CT abnormality rate of 75% in TBI patients presenting to tertiary care centres, with a 95% confidence interval and a margin of error of 8%, yielding a minimum requirement of 97 patients; 102 were enrolled to allow for attrition.

Sampling Technique

Non-probability consecutive sampling.

Ethical Approval

This study was conducted in accordance with the ethical principles of the Declaration of Helsinki (2013). Institutional ethical approval was obtained from the Research and Ethics Committees of all three participating hospitals prior to commencement of data collection. Written informed consent was obtained from patients or their legally authorised representatives where the patient was unable to provide consent. All patient data were fully anonymised and handled in accordance with institutional confidentiality protocols.

Inclusion Criteria

- Patients aged 14 years and above presenting with a history of head trauma within 24 hours of injury.
- Patients who underwent non-contrast CT of the brain within six hours of presentation.
- Patients presenting to the emergency department with a documented GCS score at admission.

Exclusion Criteria

- Patients with a known pre-existing intracranial pathology (tumour, prior stroke, previous neurosurgical intervention).
- Patients who presented more than 24 hours after the index injury.
- Patients with poor-quality CT images precluding reliable interpretation.
- Patients in whom GCS assessment was confounded by sedation, alcohol intoxication, or metabolic encephalopathy at the time of presentation.

Data Collection

A structured proforma was used to record demographic data (age, gender), mechanism of injury, GCS score at admission, pupillary response, presence of skull fracture on plain radiograph or CT bone window, need for surgical intervention, and in-hospital outcome. All CT scans were performed on multi-slice CT scanners and reviewed by a consultant radiologist blinded to the GCS score. CT findings were recorded and classified according to the Marshall CT Classification System (Grade I–VI). Specific intracranial pathologies documented included epidural haematoma (EDH), subdural haematoma (SDH), subarachnoid haemorrhage (SAH), intracerebral/cerebral contusion, diffuse axonal injury (DAI), intraventricular haemorrhage, and midline shift. Patients were classified by TBI severity using admission GCS: mild (13–15), moderate (9–12), and severe (3–8).

Statistical Analysis

Data were analysed using SPSS version 26.0 (IBM Corp., Armonk, NY). Categorical variables were expressed as frequencies and percentages and compared using the chi-square test or Fisher's exact test as appropriate. Continuous variables were expressed as mean $\pm$ standard deviation (SD). Spearman rank correlation was used

to assess the relationship between GCS score at admission and Marshall CT grade. A p-value of <0.05 was considered statistically significant.

RESULTS

A total of 102 patients with traumatic brain injury were enrolled across three tertiary care centres. The cohort was predominantly male (81.4%) with a mean age of 34.1 ± 14.2 years (range 14–72 years). Road traffic accidents were the mechanism of injury in 71.6% of cases, followed by falls from height (18.6%) and assault (9.8%). On the basis of admission GCS, 33 patients (32.4%) were classified as mild TBI, 29 (28.4%) as moderate TBI, and 40 (39.2%) as severe TBI (Table I).

CT abnormalities were detected in 91 of 102 patients (89.2%). Subdural haematoma was the most frequently identified pathology (24 patients; 23.5%), followed by cerebral contusion (21; 20.6%), subarachnoid haemorrhage (19; 18.6%), epidural haematoma (18; 17.6%), and diffuse axonal injury (9; 8.8%). Eleven patients (10.8%) had a normal CT scan despite a clinical diagnosis of TBI. The mean GCS in patients with diffuse axonal injury was 4.9 ± 2.1 — the lowest among all CT categories — while epidural haematoma patients had a comparatively higher mean GCS of 11.4 ± 3.2 (Table II, Figure 1).

A significant inverse correlation was found between GCS score at admission and Marshall CT grade (Spearman $\rho = -0.74$; $p < 0.001$). CT abnormality rates increased progressively and significantly with worsening GCS category: 48.5% in mild TBI, 79.3% in moderate TBI, and 97.5% in severe TBI ($p < 0.001$). Pupillary abnormalities were present in 6.1%, 27.6%, and 55.0% of mild, moderate, and severe TBI patients respectively ($p < 0.001$). Surgical intervention was required in 9.1% of mild, 31.0% of moderate, and 60.0% of severe TBI cases. In-hospital mortality was 0%, 6.9%, and 27.5% in mild, moderate, and severe TBI groups respectively, giving an overall in-hospital mortality of 12.7%.

Table I: Demographic, Clinical, and Outcome Characteristics Stratified by TBI Severity (n=102)

Variable	Mild TBI(n=33)	Moderate TBI(n=29)	Severe TBI(n=40)
Age — mean $\pm$ SD (years)	28.4 ± 11.2	34.7 ± 13.8	38.2 ± 15.4
Gender — Male n (%)	26 (78.8)	23 (79.3)	34 (85.0)
Mechanism — Road Traffic Accident n (%)	22 (66.7)	20 (69.0)	31 (77.5)
Mechanism — Fall from Height n (%)	7 (21.2)	6 (20.7)	6 (15.0)
Mechanism — Assault n (%)	4 (12.1)	3 (10.3)	3 (7.5)
GCS at Admission — mean $\pm$ SD	14.1 ± 0.8	10.4 ± 1.1	5.6 ± 1.9
Pupillary Abnormality n (%)	2 (6.1)	8 (27.6)	22 (55.0)
Skull Fracture n (%)	4 (12.1)	9 (31.0)	18 (45.0)
CT Abnormality n (%)	16 (48.5)	23 (79.3)	39 (97.5)
Surgical Intervention Required n (%)	3 (9.1)	9 (31.0)	24 (60.0)
In-hospital Mortality n (%)	0 (0.0)	2 (6.9)	11 (27.5)

Table II: CT Findings According to Marshall Classification with Corresponding GCS Data (n=102)

CT Finding	n (%)	Marshall Grade(Mean)	Associated GCS(Mean $\pm$ SD)
Epidural Haematoma	18 (17.6)	II	11.4 ± 3.2
Subdural Haematoma	24 (23.5)	III–IV	7.8 ± 3.6
Subarachnoid Haemorrhage	19 (18.6)	II–III	9.2 ± 4.1
Cerebral Contusion	21 (20.6)	II–III	9.8 ± 3.8
Diffuse Axonal Injury	9 (8.8)	V–VI	4.9 ± 2.1
Normal CT	11 (10.8)	I	13.6 ± 1.4
Total Abnormal CT	91 (89.2)	—	8.6 ± 4.2

Figure 1. CT Findings and Correlation with Clinical Severity in Traumatic Brain Injury — Multi-Centre Study, Pakistan (n=102)

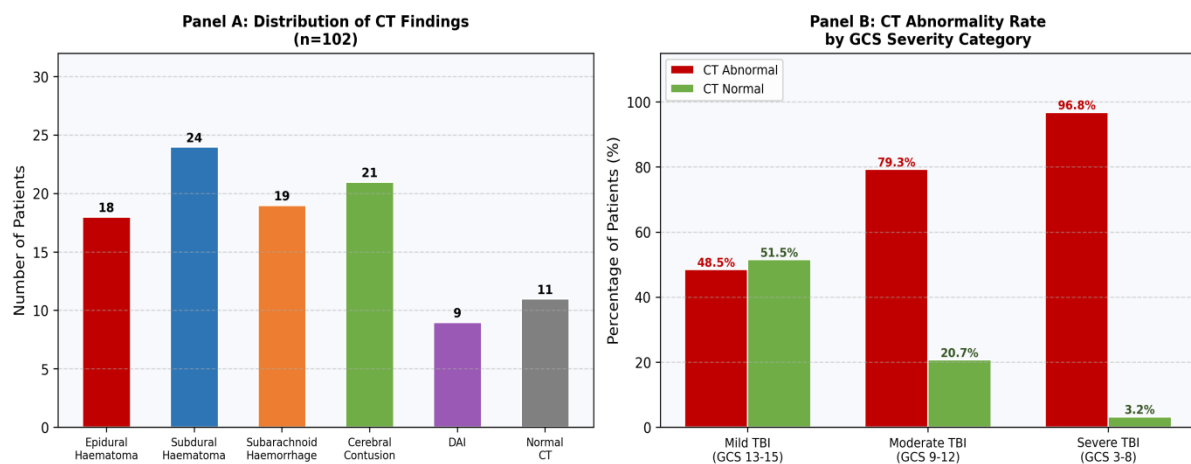


Figure 1. Panel A: Absolute number of patients by CT finding category (n=102). Panel B: CT abnormality rate (%) stratified by GCS severity category. EDH = Epidural Haematoma; SDH = Subdural Haematoma; SAH = Subarachnoid Haemorrhage; DAI = Diffuse Axonal Injury; GCS = Glasgow Coma Scale. Multi-centre study, Pakistan (n=102).

DISCUSSION

An 89.2% CT abnormality rate in this cohort is a striking figure — and it reflects something important about the nature of TBI as it presents to tertiary care hospitals in Pakistan. These are not predominantly mild concussive injuries with normal scans; they are serious, often polytraumatic injuries with visible intracranial pathology in nearly nine out of ten cases. The strong inverse correlation between GCS score and Marshall CT grade (Spearman $\rho = -0.74$; $p < 0.001$) confirms what experienced neurotrauma clinicians already know in practice: the lower the GCS, the more severe and extensive the CT findings tend to be. But quantifying this relationship in a local multi-centre dataset adds something that clinical intuition cannot — a benchmark against which individual institutional practice can be assessed.

Subdural haematoma was the most common CT finding (23.5%), which aligns with data from comparable low- and middle-income country TBI series and reflects the mechanism predominance of high-velocity road traffic accidents in this cohort [1,12]. SDH is particularly concerning not just because of its frequency, but because of its association with severe clinical presentations — the mean GCS in SDH patients in this series was 7.8 ± 3.6 , firmly in the severe TBI category. By contrast, epidural haematoma, despite its dramatic radiological appearance, was associated with a relatively higher mean GCS of 11.4 ± 3.2 . This aligns well with the classical clinical description of EDH — arterial in origin, with the potential for a lucid interval before deterioration — and underscores the importance of early CT rather than sole reliance on GCS for clinical decision-making [5,13]. Diffuse axonal injury deserves particular attention. It was identified in only 9 patients (8.8%), but this figure almost certainly represents an underestimate given that DAI is notoriously difficult to detect on standard CT and is far better characterised by MRI [14]. The mean GCS of 4.9 ± 2.1 in this group — the lowest of any CT category — and the absence of evacuable lesions explain why many of these patients end up in prolonged coma without a clear surgical target. It could be argued that the outcomes of DAI patients in resource-limited settings are particularly poor precisely because MRI availability is restricted and the diagnosis is delayed, leading to missed opportunities for neuroprotective management in the acute phase.

Perhaps the most clinically instructive finding is that 11 patients (10.8%) had a normal CT scan despite meeting clinical criteria for TBI. All of these were in the mild TBI category, and none required surgical intervention. This raises a question that the neurotrauma community continues to debate: how selectively should CT be used in mild TBI? The Canadian CT Head Rule and similar decision instruments were developed precisely to reduce unnecessary CT utilisation in this group [15]. Their applicability in the Pakistani context — where a missed intracranial injury could be catastrophic given limited neurosurgical follow-up capacity — is debatable, but the 10.8% normal CT rate in this cohort does suggest that a proportion of mild TBI patients might be safely managed without imaging if validated clinical criteria were systematically applied.

The overall in-hospital mortality of 12.7%, rising to 27.5% in severe TBI, is consistent with previously published Pakistani data [10,11] and reflects both the severity of injury in this population and the challenges of intensive care management in resource-constrained tertiary centres. Pupillary abnormalities, skull fractures, and the need for surgical intervention all increased progressively and significantly across GCS severity categories, reinforcing the validity of GCS as a triage tool even where CT is not immediately available.

LIMITATIONS

Several limitations of this study merit acknowledgement. The cross-sectional design captures initial CT findings and short-term outcomes but does not allow for assessment of neurological recovery or long-term functional

outcomes, which are arguably the most meaningful endpoints in TBI research. MRI was not routinely performed, meaning that diffuse axonal injury — typically underdetected on CT — was likely underdiagnosed, and the true frequency of DAI in this cohort may be higher than reported. GCS assessment in the emergency setting can be confounded by factors such as sedation, pain, and haemodynamic compromise, and while exclusion criteria were applied to mitigate this, some misclassification cannot be excluded. Finally, the study was conducted exclusively at tertiary care centres in urban settings, which are likely to capture more severe injuries than would be seen in a community or primary care sample, potentially overestimating CT abnormality rates relative to the broader TBI population.

CONCLUSION

CT findings correlate significantly and inversely with GCS-based clinical severity in traumatic brain injury, with subdural haematoma and diffuse axonal injury associated with the most severe clinical presentations and poorest outcomes. The 89.2% CT abnormality rate and 12.7% overall in-hospital mortality documented in this multi-centre Pakistani series highlight the substantial burden of serious TBI at tertiary care facilities. Non-contrast CT within six hours of injury remains an indispensable diagnostic tool and should be universally accessible in all centres managing head trauma. Future prospective studies incorporating MRI, longer follow-up periods, and standardised outcome measures are needed to fully characterise the natural history and functional prognosis of TBI in Pakistan.

REFERENCES

1. Dewan MC, Rattani A, Gupta S, et al. Estimating the global incidence of traumatic brain injury. *J Neurosurg.* 2019;130(4):1080–1097. doi: 10.3171/2017.10.JNS17352
2. Maas AIR, Menon DK, Adelson PD, et al. Traumatic brain injury: integrated approaches to improve prevention, clinical care, and research. *Lancet Neurol.* 2017;16(12):987–1048. doi: 10.1016/S1474-4422(17)30371-X
3. Razzak JA, Luby S, Laflamme L, Chotani H. Injuries among children in Karachi, Pakistan — what, where and how. *Public Health.* 2004;118(2):114–120. doi: 10.1016/S0033-3506(03)00144-9
4. Teasdale G, Jennett B. Assessment of coma and impaired consciousness: a practical scale. *Lancet.* 1974;2(7872):81–84. doi: 10.1016/S0140-6736(74)91639-0
5. Lee B, Newberg A. Neuroimaging in traumatic brain injury. *NeuroRx.* 2005;2(2):372–383. doi: 10.1602/neurorx.2.2.372
6. Wintermark M, Sanelli PC, Anzai Y, Tsiouris AJ, Whitlow CT. Imaging evidence and recommendations for traumatic brain injury: conventional neuroimaging techniques. *J Am Coll Radiol.* 2015;12(2):e1–e14. doi: 10.1016/j.jacr.2014.10.014
7. Marshall LF, Marshall SB, Klauber MR, et al. The diagnosis of head injury requires a classification based on computed axial tomography. *J Neurotrauma.* 1992;9(Suppl 1):S287–S292.
8. Maas AIR, Hukkelhoven CW, Marshall LF, Steyerberg EW. Prediction of outcome in traumatic brain injury with computed tomographic characteristics: a comparison between the computed tomographic classification and combinations of computed tomographic predictors. *Neurosurgery.* 2005;57(6):1173–1182. doi: 10.1227/01.NEU.0000186013.63046.6B
9. Stein SC, Spettell C. The Head Injury Severity Scale (HISS): a practical classification of closed-head injury. *Brain Inj.* 1995;9(5):437–444. doi: 10.3109/02699059509005780
10. Khan MB, Kumar R, Irfan FB, et al. CT findings and correlation with clinical outcome in traumatic brain injury: experience from a teaching hospital in Pakistan. *J Pak Med Assoc.* 2016;66(7):808–813.
11. Qureshi JS, Ohuma EO, Achebe I, et al. Traumatic brain injury in Pakistan: a review of published data. *J Coll Physicians Surg Pak.* 2014;24(9):678–683.
12. Bruns J, Hauser WA. The epidemiology of traumatic brain injury: a review. *Epilepsia.* 2003;44(Suppl 10):2–10. doi: 10.1046/j.1528-1157.44.s10.3.x
13. Bullock MR, Chesnut R, Ghajar J, et al. Surgical management of acute epidural hematomas. *Neurosurgery.* 2006;58(3 Suppl):S7–S15. doi: 10.1227/01.NEU.0000210363.91172.A8
14. Skandsen T, Kvistad KA, Solheim O, Strand IH, Folvik M, Vik A. Prevalence and impact of diffuse axonal injury in patients with moderate and severe head injury: a cohort study of early magnetic resonance imaging findings and 1-year outcome. *J Neurosurg.* 2010;113(3):556–563. doi: 10.3171/2009.9.JNS09626
15. Stiell IG, Wells GA, Vandemheen K, et al. The Canadian CT Head Rule for patients with minor head injury. *Lancet.* 2001;357(9266):1391–1396. doi: 10.1016/S0140-6736(00)04561-X
16. Jennett B, Bond M. Assessment of outcome after severe brain damage. *Lancet.* 1975;1(7905):480–484. doi: 10.1016/S0140-6736(75)92830-5
17. Servadei F, Teasdale G, Merry G. Defining acute mild head injury in adults: a proposal based on prognostic factors, diagnosis, and management. *J Neurotrauma.* 2001;18(7):657–664. doi: 10.1089/089771501750357609