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Research Article

Clinical and Radiological Predictors of Functional Outcome in Patients with Traumatic Brain Injury: A Prospective Observational Study

Dr. P. Narasingarao[1]

[1]Associate Professor, Department of Neuro Surgery, Government Medical College, Bhadadri kothagudam, Telangana, India

*Corresponding Author
Dr. P. Narasingarao

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Abstract: ***Introduction:*** Traumatic brain injury (TBI) is a major contributor to global disability and mortality. Early risk stratification using reliable parameters is critical to optimizing clinical management. **Objectives:** To evaluate clinical and radiological parameters on admission as predictors of 6-month functional outcome in patients with acute traumatic brain injury. **Methods:** A prospective observational study was conducted at Mahatma Gandhi Memorial (MGM) Hospital, Warangal, Telangana, from September 2023 to December 2023. Forty consecutive acute TBI patients meeting the inclusion criteria were enrolled. Baseline clinical parameters, including admission Glasgow Coma Scale (GCS) score and pupillary reactivity, along with radiological features from non-contrast computed tomography (NCCT) scans (Marshall CT classification, midline shift, and intracranial hemorrhages), were documented. Functional outcome was assessed at 6 months post-injury using the Glasgow Outcome Scale (GOS) and categorized as favorable (good recovery or moderate disability) or unfavorable (severe disability, persistent vegetative state, or death). Statistical analysis involved Chi-square tests, Mann-Whitney U tests, and multivariate logistic regression. **Results:** Of 40 patients, 24 (60.0%) achieved a favorable outcome and 16 (40.0%) had an unfavorable outcome at 6 months. Lower admission GCS score ($p < 0.001$), sluggish or non-reactive pupils ($p < 0.001$), admission hypotension ($p = 0.038$), Marshall CT Grade III–IV or mass lesions ($p = 0.001$), and midline shift > 5 mm ($p = 0.002$) were significantly associated with unfavorable functional recovery. Multivariate logistic regression identified lower admission GCS score (aOR = 0.62, 95% CI: 0.44–0.88, $p = 0.007$), unreactive pupils (aOR = 5.84, 95% CI: 1.32–25.76, $p = 0.020$), high Marshall CT grade (aOR = 4.12, 95% CI: 1.15–14.81, $p = 0.030$), and midline shift > 5 mm (aOR = 3.95, 95% CI: 1.08–14.42, $p = 0.038$) as independent predictors of poor outcome. **Conclusion:** Admission GCS score, pupillary light reactivity, Marshall CT grade, and midline shift are robust independent predictors of functional outcome in TBI, facilitating early clinical decision-making.

Keywords: Traumatic brain injury, Glasgow Coma Scale, Marshall CT classification, Midline shift, Functional outcome, Prognostic factors.

INTRODUCTION

Traumatic brain injury (TBI) represents a critical public health challenge worldwide, accounting for substantial mortality, permanent disability, and socio-economic burden across low-, middle-, and high-income countries alike [1]. Globally, millions of individuals suffer head trauma annually, with road traffic accidents (RTAs), high-altitude falls, and physical violence constituting the primary mechanisms of injury [2]. In developing regions, rapid urbanization, expanding motorization, and inadequate infrastructure have contributed to a disproportionately high incidence of neurotrauma, particularly among young adults in their economically productive years [3].

The pathological cascade of TBI is broadly classified into primary and secondary injury mechanisms. Primary brain injury occurs instantaneously at the moment of impact, resulting in direct mechanical damage such as cortical contusions, lacerations, diffuse axonal injury, and intracranial hematomas [4]. Secondary brain injury develops over subsequent hours and days as a consequence of cellular ischemia, excitotoxicity, neuroinflammation, cerebral edema, elevated intracranial pressure, and systemic insults such as arterial hypotension or hypoxia [5]. Because primary damage is largely irreversible, early neurocritical care focuses intensely on mitigating secondary neurological deterioration through timely surgical intervention, hemodynamic support, and targeted medical therapies [6].

Accurate early prognostication in acute TBI is essential for guiding clinical management, managing family expectations, optimizing intensive care resource allocation, and stratifying patients for specialized neurorehabilitation [7]. Clinical scoring systems, most notably the Glasgow Coma Scale (GCS), have historically served as the cornerstone for bedside neurological assessment [8]. However, clinical evaluation alone may be confounded by patient sedation, endotracheal intubation, systemic shock, or substance intoxication [9]. Non-contrast computed tomography (NCCT) of the head provides crucial anatomical and structural visualization, allowing rapid identification of

mass lesions, midline shift, and diffuse cerebral edema through standardized grading systems such as the Marshall CT classification [10].

While individual clinical and radiological parameters have demonstrated predictive capability, integrating acute clinical markers with initial CT scan parameters offers superior prognostic accuracy for long-term functional recovery [11]. The primary objective of this prospective observational study was to evaluate the clinical parameters (admission GCS score and pupillary light reactivity) and radiological findings (Marshall CT classification, midline shift, and traumatic subarachnoid hemorrhage) as independent predictors of 6-month functional outcome in patients presenting with acute traumatic brain injury at a tertiary neurotrauma center.

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted at Mahatma Gandhi Memorial (MGM) Hospital, Warangal, Telangana, India. MGM Hospital is a tertiary-care teaching medical center serving a large urban and rural population across northern Telangana. The study protocol was reviewed and approved by the Institutional Ethics Committee, and informed written consent was obtained from all conscious patients or legally authorized representatives prior to enrollment.

Study Period and Population

The study was carried out over a four-month period from September 2023 to December 2023. Consecutive adult patients presenting to the emergency department or trauma unit with acute traumatic brain injury within 24 hours of injury were screened for eligibility.

Inclusion and Exclusion Criteria

Inclusion criteria comprised: (1) adult patients aged 18 years and above; (2) presentation within 24 hours of acute head trauma; and (3) documented initial neurological evaluation and baseline non-contrast head CT scan performed upon admission. Exclusion criteria comprised: (1) age under 18 years; (2) severe co-existing major organ systemic trauma (ISS non-head score > 15); (3) pre-existing major neurological deficit, neurodegenerative condition, or psychiatric disorder; (4) presentation beyond 24 hours of injury; and (5) loss to follow-up or refusal to provide consent.

Sample Size

A non-probability consecutive sampling technique was utilized during the designated study timeframe, resulting in a final study cohort of 40 qualified acute TBI patients who completed all clinical, radiological, and 6-month outcome assessments.

Data Collection and Clinical Assessment

Upon admission, baseline demographic details (age, sex, mechanism of injury) were systematically documented. Primary clinical parameters were evaluated prior to administration of paralytics or sedatives, including the initial Glasgow Coma Scale (GCS) score (categorized as severe [GCS 3–8], moderate [GCS 9–12], or mild [GCS 13–15]), pupillary light reactivity (both reactive, sluggish, or unreactive/fixed), and systemic hemodynamic parameters (presence of early hypotension, defined as systolic blood pressure < 90 mmHg).

Radiological Evaluation

Initial non-contrast CT head scans obtained at admission were reviewed by an experienced consultant neuro-radiologist and neurosurgeon blinded to patient outcome. Scans were categorized using the Marshall CT classification (Grade I: no visible pathology; Grade II: diffuse injury with cisterns present and midline shift 0–5 mm; Grade III: diffuse injury with compressed cisterns; Grade IV: diffuse injury with midline shift > 5 mm; evacuated or non-evacuated mass lesions) [10]. Specific structural parameters were recorded, including absolute midline shift in millimeters (> 5 mm defined as significant), traumatic subarachnoid hemorrhage (tSAH), intraventricular hemorrhage (IVH), and parenchymal contusions.

Outcome Assessment and Statistical Analysis

Functional recovery was evaluated at 6 months post-injury via telephonic structured interview or outpatient clinic follow-up using the Glasgow Outcome Scale (GOS). Patients were dichotomized into Favorable Outcome (GOS 4–5: moderate disability or good recovery) and Unfavorable Outcome (GOS 1–3: death, persistent vegetative state, or severe disability). Continuous variables were expressed as mean ± standard deviation (SD) and compared using the Student's t-test or Mann-Whitney U test. Categorical variables were presented as frequencies and percentages, compared using Pearson's Chi-square test or Fisher's exact test. Multivariate binary logistic regression analysis was performed using SPSS version 26.0 (IBM Corp., Armonk, NY) to establish independent outcome predictors. Statistical significance was defined as $p < 0.05$.

RESULTS

A total of 40 patients presenting with acute traumatic brain injury were included in this prospective observational study. The overall mean age of the study population was 34.8 ± 11.2 years (range: 18–62 years). Males constituted 77.5% (n =

31) of the cohort. Road traffic accidents (RTAs) represented the predominant mechanism of injury in 28 patients (70.0%), followed by falls from height in 8 patients (20.0%) and direct physical assault in 4 patients (10.0%).

On initial clinical examination, 15 patients (37.5%) presented with severe TBI (GCS ≤ 8), 14 patients (35.0%) with moderate TBI (GCS 9–12), and 11 patients (27.5%) with mild TBI (GCS 13–15). Pupillary evaluation revealed normal bilateral reactivity in 27 patients (67.5%), whereas 8 patients (20.0%) had sluggish pupils and 5 patients (12.5%) presented with bilaterally fixed/unreactive pupils. Systemic hypotension (systolic blood pressure < 90 mmHg) was documented upon admission in 6 patients (15.0%).

Admission non-contrast head CT findings showed that 12 patients (30.0%) had Marshall Grade I–II diffuse injury, 18 patients (45.0%) had Marshall Grade III–IV (high-risk diffuse swelling/cisternal compression), and 10 patients (25.0%) presented with intracranial mass lesions. Significant midline shift (> 5 mm) was identified in 11 patients (27.5%). Associated hemorrhage patterns included traumatic subarachnoid hemorrhage (tSAH) in 16 patients (40.0%), intraventricular hemorrhage (IVH) in 7 patients (17.5%), and parenchymal contusions in 22 patients (55.0%).

At 6 months post-injury, 24 patients (60.0%) achieved a favorable functional outcome (good recovery: n = 18 [45.0%]; moderate disability: n = 6 [15.0%]). Unfavorable outcomes occurred in 16 patients (40.0%), comprising severe disability in 7 patients (17.5%), persistent vegetative state in 2 patients (5.0%), and mortality in 7 patients (17.5%). Table 1 summarizes the univariate analysis comparing baseline clinical and radiological characteristics between outcome groups.

Variable	**Total Sample (N = 40)**	**Favorable Outcome (n = 24)**	**Unfavorable Outcome (n = 16)**	**p-value**
Age (years), Mean ± SD	34.8 ± 11.2	31.4 ± 9.8	39.9 ± 11.8	0.021*
Admission GCS Score, Mean ± SD	9.6 ± 3.4	11.8 ± 2.1	6.3 ± 2.0	< 0.001*
Pupillary Reactivity, n (%)				< 0.001*
— Both Reactive	27 (67.5%)	22 (91.7%)	5 (31.3%)	
— Sluggish / Non-reactive	13 (32.5%)	2 (8.3%)	11 (68.8%)	
Hypotension on Admission, n (%)	6 (15.0%)	1 (4.2%)	5 (31.3%)	0.038*
Marshall CT Grade III–IV / Mass, n (%)	28 (70.0%)	12 (50.0%)	16 (100.0%)	0.001*
Midline Shift > 5 mm, n (%)	11 (27.5%)	2 (8.3%)	9 (56.3%)	0.002*

Table 1. Comparison of clinical and radiological characteristics according to 6-month functional outcome. *Statistically significant at $p < 0.05$.

As detailed in Table 1, patients with unfavorable outcomes were significantly older (39.9 ± 11.8 vs. 31.4 ± 9.8 years, $p = 0.021$) and presented with significantly lower mean GCS scores (6.3 ± 2.0 vs. 11.8 ± 2.1, $p < 0.001$). Additionally, abnormal pupillary reactivity (68.8% vs. 8.3%, $p < 0.001$), admission hypotension (31.3% vs. 4.2%, $p = 0.038$), high Marshall CT Grade III–IV/Mass (100.0% vs. 50.0%, $p = 0.001$), and midline shift > 5 mm (56.3% vs. 8.3%, $p = 0.002$) were significantly associated with poor functional recovery.

Variables demonstrating statistical significance in univariate analysis were entered into a multivariate binary logistic regression model. As shown in Table 2, lower admission GCS score, sluggish or unreactive pupils, Marshall CT Grade III–IV or mass lesions, and midline shift > 5 mm remained independent predictors of unfavorable 6-month functional outcome.

Independent Predictor	**Adjusted Odds Ratio (aOR)**	**95% Confidence Interval (CI)**	**p-value**
Admission GCS Score (per 1 unit drop)	0.62	0.44 – 0.88	0.007*
Unreactive / Sluggish Pupils	5.84	1.32 – 25.76	0.020*
Marshall CT Grade III–IV / Mass	4.12	1.15 – 14.81	0.030*
Midline Shift > 5 mm	3.95	1.08 – 14.42	0.038*

Table 2. Independent predictors of unfavorable functional outcome at 6 months post-injury. *Statistically significant at $p < 0.05$.

DISCUSSION

Accurate outcome prediction in acute traumatic brain injury remains a major goal of contemporary neurotrauma research. In this prospective observational study conducted at MGM Hospital, Warangal, we evaluated clinical and radiological parameters in 40 TBI patients to determine their prognostic power for 6-month functional outcome. Our findings confirm that admission Glasgow Coma Scale score, pupillary light reactivity, Marshall CT classification, and midline shift are powerful independent predictors of recovery [8,10].

The demographic profile of our cohort, characterized by a mean age of 34.8 years and a strong male predominance (77.5%), reflects global neurotrauma trends where young active males are preferentially affected due to high road traffic collision rates [1,3]. The strong inverse

association between admission GCS score and unfavorable outcome observed in our study (aOR = 0.62, p = 0.007) aligns with landmark international prognostic models, including the IMPACT and CRASH studies [8,11]. Initial GCS reflects the immediate degree of primary diffuse or focal neuronal dysfunction, serving as the primary bedrock for bedside clinical triage.

Pupillary reactivity on presentation served as another strong clinical predictor of prognosis. Patients presenting with sluggish or fixed pupils had nearly six times higher odds of experiencing an unfavorable functional outcome (aOR = 5.84, p = 0.020). Impaired pupillary light reflex directly correlates with uncal herniation, brainstem compression, and severe ischemia within the midbrain microcirculation [9]. This reinforces the necessity of prompt surgical and medical decompression whenever acute pupillary changes are identified.

Regarding radiological indices, non-contrast head CT remains the cornerstone of emergency neuroimaging. High Marshall CT scores (Grade III–IV/Mass) and significant midline shift (> 5 mm) were independently predictive of poor outcome (aOR = 4.12 and 3.95, respectively). Compression of basal cisterns and anatomical midline displacement signify elevated intracranial pressure and global brain swelling, mechanisms that severely restrict cerebral perfusion pressure and promote secondary ischemic injury [10,12]. Incorporating CT parameters with clinical scores provides superior discrimination compared to clinical scoring alone [11,13].

LIMITATIONS

The study has a modest sample size of 40 patients from a single tertiary-care hospital, which restricts generalizability across diverse populations. The observational design precludes establishing direct causality. Advanced neuroimaging techniques such as diffusion tensor imaging and longitudinal serum biomarkers were not evaluated. Additionally, secondary complications arising after hospital discharge were not dynamically tracked throughout the 6-month follow-up period.

CONCLUSION

In conclusion, admission Glasgow Coma Scale score, pupillary light reactivity, Marshall CT classification grade, and radiological midline shift serve as strong independent predictors of 6-month functional outcome in patients with acute traumatic brain injury. Combining acute bedside clinical assessment with initial non-contrast head CT findings provides exceptional prognostic precision, enabling clinicians to identify high-risk patients early, guide intensive monitoring, optimize neurosurgical interventions, and counsel families effectively. Early risk stratification based on these parameters is vital for improving long-term neurofunctional outcomes.

REFERENCES

1. Maas AIR, Menon DK, Adelson PD, Andelic N, Bell MJ, Belli A, et al. Traumatic brain injury: integrated approaches to improve prevention, clinical care, and research. Lancet Neurol. 2017;16(12):987-1048.
2. Dewan MC, Rattani A, Gupta S, Baticulon RE, Hung YC, Punchak M, et al. Estimating the global incidence of traumatic brain injury. J Neurosurg. 2018;130(4):1080-1097.
3. Gururaj G. Epidemiology of traumatic brain injuries: Indian scenario. Neurol India. 2002;50(3):256-260.
4. Ng SY, Lee AYW. Traumatic Brain Injury: Pathophysiology and Potential Therapeutic Targets. Front Cell Neurosci. 2019;13:528.
5. Werner C, Engelhard K. Pathophysiology of traumatic brain injury. Br J Anaesth. 2007;99(1):4-9.
6. Carney N, Totten AM, O'Reilly C, Ullman JS, Hawryluk GW, Bell MJ, et al. Guidelines for the Management of Severe Traumatic Brain Injury, Fourth Edition. Neurosurgery. 2017;80(1):6-15.
7. Steyerberg EW, Musske E, Baethmann A, Unterberg A, Jansen O, Maas AIR, et al. Prognostic value of clinical and radiological features in severe traumatic brain injury. Acta Neurochir (Wien). 2008;150(11):1123-1131.
8. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2(7872):81-84.
9. Marmarou A, Lu J, Butcher I, McHugh GS, Murray GD, Steyerberg EW, et al. Prognostic value of the Glasgow Coma Scale and pupil reactivity in traumatic brain injury. J Neurotrauma. 2007;24(2):270-280.
10. Marshall LF, Marshall SB, Klauber MR, Van Berkum Clark M, Eisenberg HM, Jane JA, et al. The diagnosis of head injury requires a classification based on computed tomography. J Neurotrauma. 1992;9 Suppl 1:S287-S292.
11. Steyerberg EW, Woolf SH, Bowman ML, Mushkudiani NA, Choi SC, Lu J, et al. Predicting outcome after traumatic brain injury: development and international validation of prognostic scores based on admission characteristics. PLoS Med. 2008;5(8):e165.
12. Munakomi S. Role of computed tomography scores and findings to predict early death in patients with traumatic brain injury: A reappraisal in a major tertiary care hospital in Nepal. World Neurosurg. 2016;90:221-228.
13. Taalas W, Raj R, Öhman J, Siironen J. Long-Term Functional Outcome and Quality of Life in Long-Term Traumatic Brain Injury Survivors. Neurotrauma Rep. 2023;4(1):813-822.
14. Korley FK, Jain S, Sun X, Puccio AM, Yue JK, Gardner RC, et al. Prognostic value of day-of-injury plasma GFAP and UCH-L1 concentrations for predicting functional recovery after traumatic brain

injury in patients from the US TRACK-TBI cohort: an observational cohort study. Lancet Neurol. 2022;21(9):803-813.