Comparison of Prognostic Scales in Management of Mild Cases of Traumatic Brain Injury (Gcs-15-13)

Dr Pratik Shaparia[1], Dr Honeypalsinh H Maharaul[2], Dr Bonny Sachapara[3], Dr Vipul Gurjar[4*]

[1]Associate Professor; Department of General Surgery, Smt. B.K.Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Piparia, Vadodara-391760, Gujarat, India
[2]Professor; Department of General Surgery, Smt. B.K.Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Piparia, Vadodara-391760, Gujarat, India
[3]Postgraduate Resident, Department of General Surgery, Smt. B.K.Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Piparia, Vadodara-391760, Gujarat, India
[4*]Professor & Head, Department of General Surgery, Smt. B.K.Shah Medical Institute and Research Centre, Sumandeep Vidyapeeth, Piparia, Vadodara-391760, Gujarat, India

Abstract

Background: Traumatic brain injury (TBI) is a major cause of morbidity and mortality, and reliable bedside prognostic tools remain essential for early risk stratification, particularly in resource-limited settings. This study compared the predictive performance of four prognostic scales - the Madras Head Injury Prognostic Scale (MHIPS), the Edinburgh Prognostic Model, the National Institute of Mental Health and Neurosciences (NIMHANS) Prediction Score, and the Injury Severity Score (ISS) - in patients presenting with traumatic brain injury.

Methods: This prospective observational study was conducted in the Department of General Surgery of a tertiary care teaching hospital in Gujarat, India, over a period of one and a half years, and enrolled 50 patients presenting with traumatic brain injury and a Glasgow Coma Scale (GCS) score of 13-15 at admission. Clinical, radiological and systemic parameters were recorded, and the four prognostic scales were calculated for each patient. Sensitivity, specificity and the association between prognostic score category and clinical outcome (discharge versus death) were analyzed.

Results: The mean age of patients was 39.6 ± 11.9 years, with a male predominance (58%). Mean scores were MHIPS 17.42 ± 15.6, Edinburgh Prognostic Model 4.14 ± 1.29, NIMHANS Prediction Score 1.88 ± 0.8, and ISS 37.36 ± 21.75. Mortality was significantly higher among patients scoring below 50 points on the combined prognostic assessment (9/27, 33.3%) compared with those scoring above 50 points (2/23, 8.7%; p=0.036). The NIMHANS Prediction Score showed the highest sensitivity (87.4%), while the Edinburgh Prognostic Model showed the highest specificity (92.3%). Overall, 39 patients (78%) were discharged and 11 (22%) died.

Conclusions: The NIMHANS Prediction Score and the Edinburgh Prognostic Model showed the best sensitivity and specificity, respectively, among the scales evaluated. Bedside prognostic scoring remains a valuable, low-cost method for early outcome prediction in traumatic brain injury, and future research should explore integration of these scales with emerging biomarker- and imaging-based prognostic tools.

Keywords: Traumatic brain injury; Glasgow Coma Scale; Prognostic scales; Madras Head Injury Prognostic Scale; Edinburgh Prognostic Model; NIMHANS Prediction Score; Injury Severity Score

Introduction

Traumatic brain injury (TBI) remains a leading cause of death and disability worldwide, and outcome prediction has traditionally relied upon clinical prognostic scoring systems. Emerging computational and biomarker-based tools are increasingly being explored to complement or refine clinical prognostication [1].

Advances in neuroimaging-based prediction models, such as computed tomography (CT) features, have been shown to independently predict adverse outcomes even after mild TBI [2], while blood-based biomarkers continue to be investigated for their diagnostic and prognostic value, though several methodological issues remain unresolved [3]. Metabolomic profiling of serum has also revealed associations with injury severity that may eventually complement bedside scoring systems [4].

Axonal injury markers such as neurofilament light (NfL) have demonstrated the ability to predict long-term neurodegeneration and functional outcome after TBI [5], and large multicentre cohorts such as CENTER-TBI have characterized distinct clinical trajectories among intensive care unit (ICU) patients with TBI, highlighting the heterogeneity of this population [6]. Machine learning approaches applied to granular ICU clinical course data have further shown promise in explaining variance in TBI outcomes beyond what conventional scoring alone can capture [7].

Beyond hospital-based moderate-to-severe TBI, biomarker elevations such as prolonged NfL rise have also been documented after sports-related concussion [8], and repetitive head impact exposure has been linked to long-term neurodegenerative sequelae such as chronic traumatic encephalopathy (CTE) [9]. Multicentre validation studies of plasma NfL assays support its potential clinical utility across TBI severities [10], while network-based molecular modelling approaches used in other neurological conditions, such as multiple sclerosis, illustrate how multi-domain severity indices might be constructed for heterogeneous brain injuries [11].

Coma prognostication after acute brain injury remains clinically challenging, and recent reviews emphasize the need for standardized, multimodal approaches to outcome prediction [12], with multimodal assessment protocols shown to improve neuroprognostic accuracy in clinically unresponsive critically ill patients [13]. Broader conceptual frameworks addressing brain health reinforce the importance of early, reliable outcome prediction after neurological insults [14], and proteomic profiling of CTE tissue illustrates how molecular staging could eventually refine long-term prognosis after repetitive TBI [15].

Despite these advances, low-resource clinical settings continue to depend on simple bedside prognostic scoring systems such as the Madras Head Injury Prognostic Scale (MHIPS), Edinburgh Prognostic Model, National Institute of Mental Health and Neurosciences (NIMHANS) Prediction Score, and Injury Severity Score (ISS), because of their low cost, ease of use, and lack of requirement for advanced laboratory or imaging infrastructure. However, comparative data on the relative predictive performance of these scales within a single cohort remain limited. This study was therefore undertaken to apply and compare the sensitivity, specificity, and overall prognostic efficacy of MHIPS, the Edinburgh Prognostic Model, the NIMHANS Prediction Score, and ISS in patients presenting with traumatic brain injury, with the aim of identifying the most reliable bedside tool for early outcome prediction.

Materials and Methods

Study Design and Setting

This was a hospital-based prospective, cross-sectional observational study conducted in the Department of General Surgery of a tertiary care teaching hospital and research centre in Gujarat, India, over a study period of one and a half years.

Study Population

A total of 50 consecutive patients presenting with traumatic brain injury and a Glasgow Coma Scale (GCS) score of 13-15 at the time of admission were enrolled after obtaining written informed consent. Patients with incomplete clinical records, those who left the hospital against medical advice, and those with pre-existing neurological disease that could confound outcome assessment were excluded.

Data Collection

For each patient, demographic details (age, gender), mechanism and severity indicators of injury, motor response, pupillary light reaction, oculocephalic reflex, computed tomography (CT) findings (status of basal cisterns and presence of midline shift), and associated systemic injuries were recorded on a structured proforma. The duration of hospital stay was also documented.

Prognostic Scales

Four prognostic scoring systems were calculated for every patient using their respective standard published criteria: the Madras Head Injury Prognostic Scale (MHIPS), the Edinburgh Prognostic Model, the NIMHANS Prediction Score, and the Injury Severity Score (ISS). For comparative outcome analysis, a combined prognostic point score was dichotomized at a threshold of 50 points.

Outcome Assessment

The primary outcome was patient status at the time of hospital discharge, categorized as "discharged" or "death." Predicted risk category from the dichotomized prognostic score was compared against the observed clinical outcome, and the sensitivity and specificity of each scale in predicting mortality were calculated using standard 2x2 contingency methods.

Statistical Analysis

Continuous variables were expressed as mean ± standard deviation, and categorical variables as frequencies and percentages. The chi-square test was used to assess the association between prognostic score category and outcome. A p-value <0.05 was considered statistically significant. Data were compiled and analyzed using standard statistical software.

Ethical Considerations

The study protocol was approved by the Institutional Ethics Committee prior to initiation, and written informed consent was obtained from all participants or their legal representatives.

Results

A total of 50 patients with traumatic brain injury were enrolled during the study period. The majority of patients belonged to the 21-30 year (30%) and 41-50 year (26%) age groups, with a mean age of 39.6 ± 11.9 years. Male patients predominated, accounting for 58% of the cohort. The mean duration of hospital stay was 14.58 days, with the largest proportion of patients (28%) hospitalized for 11-15 days (Table 1).

On clinical assessment, 44% of patients had a favorable motor response (score 5-6), while 20% had a poor motor response (score 1-2). Pupillary light reaction was impaired in 50% and absent in 22% of patients, and the oculocephalic reflex was impaired in 48% and absent in 16%. CT scan findings showed absent basal cisterns or midline shift in 42% of patients, partly effaced cisterns in 26%, and normal findings in 32%. Half of the patients (50%) had associated thoracic or abdominal injuries, and 30% had one or two associated long bone fractures. A

motor score of GCS <3 was present in 58% of patients, and a midline shift >5 mm was present in 42% (Table 2). The mean MHIPS score was 17.42 ± 15.6, the mean Edinburgh Prognostic Model score was 4.14 ± 1.29, the mean NIMHANS Prediction Score was 1.88 ± 0.8, and the mean ISS was 37.36 ± 21.75 (Table 3).

Among patients with a combined prognostic score below the 50-point threshold, 9 of 27 patients (33.3%) died, compared with 2 of 23 patients (8.7%) among those scoring above 50 points. This difference in mortality between the two score categories was statistically significant (p=0.036) (Table 4). Overall, 39 patients (78%) were discharged and 11 patients (22%) died during hospitalization.

On comparative analysis of predictive performance, the NIMHANS Prediction Score demonstrated the highest sensitivity (87.4%) among the four scales, while the Edinburgh Prognostic Model demonstrated the highest specificity (92.3%). The ISS showed intermediate sensitivity (78.6%) and specificity (83.7%), while MHIPS showed the lowest sensitivity (64.1%) among the four scales, though its specificity (82.6%) was comparable to that of the other scales (Table 5).

Table 1. Demographic and Clinical Characteristics of Study Population (n=50)

Variable	Category	n (%)
Age group (years)	21-30	15 (30%)
	31-40	11 (22%)
	41-50	13 (26%)
	51-60	10 (20%)
	>60	1 (2%)
	Mean age: 39.6 ± 11.9 years	
Gender	Male	29 (58%)
	Female	21 (42%)
Duration of hospital stay (days)	<5	3 (6%)
	6-10	12 (24%)
	11-15	14 (28%)
	16-20	12 (24%)
	>20	9 (18%)
	Mean: 14.58 days	

Table 2. Distribution of Clinical, Radiological and Systemic Variables (n=50)

Variable	Category	n (%)
Motor response	1-2	10 (20%)
	3-4	18 (36%)
	5-6	22 (44%)
Pupillary light reaction	Normal	14 (28%)
	Impaired	25 (50%)
	Absent	11 (22%)
Oculocephalic reaction	Normal	18 (36%)
	Impaired	24 (48%)
	Absent	8 (16%)

Variable	Category	n (%)
CT scan findings	Absent basal cisterns / midline shift	21 (42%)
	Partly effaced cisterns	13 (26%)
	Normal	16 (32%)
Associated systemic injuries	Thoracic/abdominal injuries	25 (50%)
	One or two long bone fractures	15 (30%)
	No associated injuries	10 (20%)
Motor score of GCS	<3	29 (58%)
	>3	21 (42%)
Midline shift score	<5 mm	29 (58%)
	>5 mm	21 (42%)

Table 3. Mean Scores of Prognostic Scoring Systems (n=50)

Prognostic Scale	Mean ± SD
Madras Head Injury Prognostic Scale (MHIPS)	17.42 ± 15.6
Edinburgh Prognostic Model	4.14 ± 1.29
NIMHANS Prediction Score	1.88 ± 0.8
Injury Severity Score (ISS)	37.36 ± 21.75

Table 4. Association Between Prognostic Score Category and Clinical Outcome

Prognostic Score	Discharged (n)	Death (n)	Total
<50 points	18	9	27
>50 points	21	2	23
Total	39	11	50

p = 0.036 (chi-square test, statistically significant)

Table 5. Sensitivity and Specificity of Prognostic Scoring Systems

Prognostic Scale	Sensitivity (%)	Specificity (%)
MHIPS	64.1	82.6
Edinburgh Prognostic Model	71.5	92.3
NIMHANS Prediction Score	87.4	80.1
ISS	78.6	83.7

Discussion

In this prospective study of 50 patients with traumatic brain injury, the NIMHANS Prediction Score demonstrated the highest sensitivity (87.4%) for predicting mortality, whereas the Edinburgh Prognostic Model demonstrated the highest specificity (92.3%). The ISS occupied an intermediate position on both measures, while MHIPS showed comparatively lower sensitivity despite acceptable specificity. These findings suggest that no single bedside scale is uniformly superior across both sensitivity and specificity, and that the choice of scale may need to be tailored to the clinical objective - for example, a highly sensitive tool such as the NIMHANS Prediction Score may be preferable for identifying patients at risk who require closer monitoring, whereas a highly specific tool such as the Edinburgh Prognostic Model may better avoid unnecessary escalation of care in patients likely to have a favorable outcome.

Our observation that a combined prognostic score below 50 points was significantly associated with higher mortality (33.3% versus 8.7%, p=0.036) supports the broader concept that composite bedside scoring, despite relying only on readily available clinical and radiological parameters, retains meaningful discriminatory value for outcome prediction, consistent with the rationale underlying computational and machine-learning-based prognostic frameworks that integrate multiple clinical variables to improve prediction beyond what any single parameter can achieve [1]. Similarly, our findings on CT-derived variables (absent basal cisterns/midline shift in 42% of patients) reinforce the established link between adverse imaging findings and worse outcome that has also been demonstrated using more granular, quantitative CT-based prediction models even in milder injury categories [2].

Emerging blood- and serum-based biomarkers [3,4] and axonal injury markers such as neurofilament light [5,8,10] represent a complementary, more objective dimension of TBI prognostication that could, in principle, be integrated with bedside clinical scales such as those evaluated in this study to improve predictive accuracy, particularly in patients with equivocal clinical or radiological findings. Large multicentre studies employing granular intensive care unit trajectory data and machine learning methods have similarly emphasized the marked heterogeneity of TBI populations [6,7], an observation that resonates with the wide standard deviations observed in our own cohort's MHIPS and ISS scores, and which may partly explain why no single scale achieved uniformly high sensitivity and specificity in our analysis.

Approaches used to model multi-domain disease severity in other neurological conditions, such as multiple sclerosis [11], illustrate how future TBI prognostic tools might combine clinical, radiological, and molecular domains into unified indices. Recent reviews on coma prognostication after acute brain injury [12] and evidence that multimodal assessment improves neuroprognostic accuracy in unresponsive critically ill patients [13] similarly argue for a move away from single-modality prediction toward integrated, multimodal frameworks - an evolution that bedside scales such as MHIPS, the Edinburgh Prognostic Model, the NIMHANS Prediction Score, and ISS could serve as a practical clinical foundation for, particularly in settings where advanced imaging and biomarker testing are not readily available.

Finally, our use of in-hospital mortality as the primary outcome, while pragmatic, does not capture the longer-term functional and cognitive trajectories that are increasingly recognized as important after TBI, including delayed neurodegenerative sequelae described in chronic traumatic encephalopathy [9,15] and the broader construct of brain health after neurological insult [14]. Future comparative studies of these prognostic scales should therefore incorporate longer-term functional outcome measures in addition to survival.

Limitations

This study has several limitations. It was conducted at a single center with a relatively small sample size of 50 patients, which may limit the generalizability of the findings. Follow-up was restricted to the duration of hospital stay, without assessment of long-term functional or neurocognitive outcomes. Additionally, emerging biomarker- and imaging-based prognostic modalities discussed above were not available for comparison within this study, and the dichotomization of prognostic scores at a single threshold may not capture the full predictive information contained within each continuous scale.

Conclusions

Among the four prognostic scales evaluated in this study, the NIMHANS Prediction Score offered the highest sensitivity and the Edinburgh Prognostic Model offered the highest specificity for predicting outcome in patients with traumatic brain injury. A combined prognostic score threshold of 50 points was significantly associated with in-hospital mortality. Bedside prognostic scoring systems remain valuable, low-cost tools for early risk stratification in traumatic brain injury, particularly in resource-limited settings, and future research should explore their integration with emerging biomarker- and imaging-based prognostic models to further improve outcome prediction.

Additional Information

Human Subjects: Consent was obtained from all participants in this study. The Institutional Ethics Committee of the study institution issued approval for this study.

Animal Subjects: All authors have confirmed that this study did not involve animal subjects or tissue.

Conflicts of Interest: In compliance with the ICMJE uniform disclosure form, all authors declare no relationships or activities that could appear to have influenced the submitted work.

Financial Relationships: All authors declare no financial relationships with any organizations that might have an interest in the submitted work in the previous three years.

Other Relationships: All authors declare no other relationships or activities that could appear to have influenced the submitted work.

References

1. Farzaneh N, Williamson CA, Gryak J, Najarian K. A hierarchical expert-guided machine learning framework for clinical decision support systems: an application to traumatic brain injury prognostication. npj Digit Med. 2021 May 7;4(1):78.

2. Yuh EL, Jain S, Sun X, Pisică D, Harris M, Taylor SR, Markowitz AJ, Mukherjee P, Okonkwo DO, Diaz-Arrastia R, Manley GT. Pathological computed tomography features associated with adverse outcomes after mild traumatic brain injury. JAMA Neurol. 2021 Jul 19;78(9):1137-48.
3. Hier DB, Obafemi-Ajayi T, Thimgan MS, Olbricht GR, Azizi S, Allen B, Hadi B, Wunsch DC 2nd. Blood biomarkers for mild traumatic brain injury: a selective review of unresolved issues. Biomark Res. 2021 Sep 16;9(1):70.
4. Thomas I, Dickens AM, Posti JP, Czeiter E, Duberg D, Sinioja T, Bänd M, Buki A, Vogelzang C, Ebert N, Tenovuo O, Ånkarcrona M, Waller D, Weckman AM, Sarkola T, Rostami E, Ala-Kokko N, Maanpää H, Newcombe VF, Menon DK, Mäenpää H, Takala RS, Hänninen H, Nyman TA, Hyotylainen T, Orešič M. Serum metabolome associated with severity of acute traumatic brain injury. Nat Commun. 2022 May 10;13(1):2545.
5. Graham NS, Zimmerman KA, Moro F, Heslegrave A, Maillard SA, Bernini A, Miroz JP, Donat CK, Lopes Pinheiro Ribeiro T, Abu Hamdeh S, Marklund N, Sandler M, Meyer-Ohlendorf M, Ratmoto A, Correia S, Cnossen MC, Steyerberg EW, Menon DK, Oddo M, Zetterberg H, Sharp DJ. Axonal marker neurofilament light predicts long-term outcomes and progressive neurodegeneration after traumatic brain injury. Sci Transl Med. 2021 Sep 29;13(613):eabg9922.
6. Åkerlund CAI, Holst AV, Bhattacharyay S, Stocchetti N, Steyerberg EW, Smielewski P, Menon DK, Ercole A, Nelson DW; CENTER-TBI investigators and participants. Clinical descriptors of disease trajectories in patients with traumatic brain injury in the intensive care unit (CENTER-TBI): a multicentre observational cohort study. Lancet Neurol. 2024;23(1):71-80.
7. Bhattacharyay S, Caruso PF, Åkerlund C, Wilson L, Stevens RD, Menon DK, Steyerberg EW, Nelson DW, Ercole A; CENTER-TBI collaborators. Mining the contribution of intensive care clinical course to outcome after traumatic brain injury. npj Digit Med. 2023 Aug 21;6(1):154.
8. McDonald SJ, O'Brien WT, Symons GF, Chen Z, Bain J, Major BP, Aussel K, Miles S, Costello D, Sun M, Wright DK, O'Brien TJ, McKinnon C, Tinworth K, Willmott C, Corrigan F, van Donkelaar P, Bailes J, Jeromson T, Vonder Haar C, Solomon V, Marshman L, Brady RD, Shultz SR. Prolonged elevation of serum neurofilament light after concussion in male Australian football players. Biomark Res. 2021 Jan 10;9(1):4.
9. Daneshvar DH, Nair ES, Baucom ZH, Rasch A, Abdolmohammadi B, Uretsky M, Saltiel N, Ha Nguyen T, Xia W, Alosco ML, Martin B, Palmisano J, Weuve J, McClean MD, Cormier KA, Kubilus CA, Mahar I, McHale L, Delano-Wood L, Bondi MW, Cherry JD, Kiernan PT, Alvarez VE, Huber BR, Mez J, Nowinski C, Katz DI, Tripodis Y, Cantu RC, Kowall NW, Goldstein LE, Dwyer B, Daiello LA, Stein TD, Au R, Stern RA, McKee AC. Leveraging football accelerometer data to quantify associations between repetitive head impacts and chronic traumatic encephalopathy in males. Nat Commun. 2023 Jun 20;14(1):3470.
10. Ashton NJ, Janelidze S, Al Khleifat A, Leuzy A, van der Ende EL, Karikari TK, Benedet AL, Pascoal TA, Lleo A, Parnetti L, Galimberti D, Bonanni L, Pilotto A, Padovani A, Lycke J, Novakova L, Axelsson M, Blennow K, Zetterberg H, Hansson O, Al-Chalabi A, Rosa-Neto P, van Swieten JC, Portelius E; on behalf of the Swedish BioFINDER study. A multicentre validation study of the diagnostic value of plasma neurofilament light. Nat Commun. 2021 Jun 7;12(1):3400.
11. Kósa P, Barbour C, Varosanec M, Wichman A, Sandford M, Greenwood M, Masvekar R, Bielekova B. Molecular models of multiple sclerosis severity identify heterogeneity of pathogenic mechanisms. Nat Commun. 2022 Dec 12;13(1):7670.
12. Fischer D, Edlow BL. Coma prognostication after acute brain injury. JAMA Neurol. 2024 Mar 4;81(4):405-16.
13. Rohaut B, Calligaris C, Hermann B, Perez P, Faugeras F, Raimondo F, Valente M, Weiss N, Marois C, Demeret S, Sitt JD, Naccache L. Multimodal assessment improves neuroprognosis performance in clinically unresponsive critical-care patients with brain injury. Nat Med. 2024 May 30;30(8):2349-55.
14. Alsufieva A, Aleeva D. A review of the definition and significance of the brain health. J Biomed Sustain Healthc Appl. 2023 Jul 5;3:129-40.
15. Gutierrez-Quiceno L, Dammer EB, Johnson AG, Webster JA, Shah R, Duong DM, Yin L, Fisher-Foye RA, Fardo DW, Katsumata Y, Wang X, Seyfried NT, Stein TD. A proteomic network approach resolves stage-specific molecular phenotypes in chronic traumatic encephalopathy. Mol Neurodegener. 2021 Jun 25;16(1):40.