Original Research Article

ADMISSION GCS-P SCORE AND IN-HOSPITAL MORTALITY IN TRAUMATIC BRAIN INJURY

Bhatu Ashok Bhoi[1], Ramchandra Babaso Burute[2], Shreyas Ramchandra Burute[3]

[1]*Junior Resident, Department of Emergency Medicine, Government Medical College, Miraj, Maharashtra, India*
[2]*Professor and Head, Department of Emergency Medicine, Government Medical College, Miraj, Maharashtra, India*
[3]*Professor, Department of Pharmacology, GMC Sindhudurg, Maharashtra, India.*

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Corresponding Author:
Dr. Bhatu Ashok Bhoi,
Junior Resident, Department of Emergency Medicine, Room no. 310, New IHR Hostel, Government Medical College, Miraj, Maharashtra, India.
Email: bhatubhoi@gmail.com

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ABSTRACT

Background: Traumatic brain injury (TBI) is a major cause of mortality and long-term disability worldwide. Early prognostic assessment is essential for identifying high-risk patients and facilitating timely management.
Aim: To evaluate the association between admission Glasgow Coma Scale–Pupil (GCS-P) score and in-hospital mortality among adult patients with traumatic brain injury.
Materials and Methods: This prospective observational study included 75 adult patients presenting within 24 hours of traumatic brain injury to the emergency department of a tertiary-care hospital. Glasgow Coma Scale (GCS) score and pupillary reactivity were assessed at admission, and the GCS-P score was calculated. Patients were followed until discharge or death. ROC curve analysis and multivariable logistic regression were performed to evaluate the prognostic utility of GCS and GCS-P scores.
Results: Overall in-hospital mortality was 37.3%. Non-survivors had significantly lower GCS-P scores than survivors (4.6 ± 2.7 vs. 9.9 ± 3.2; $p<0.001$). Mortality increased from 10.0% in patients with mild GCS-P scores to 70.0% in those with very severe scores ($p<0.001$). Admission GCS-P score remained independently associated with mortality (adjusted OR 0.75, 95% CI: 0.57–0.98; $p=0.032$). A GCS-P score of ≤6 predicted mortality with 67.9% sensitivity and 83.0% specificity. ROC analysis demonstrated comparable predictive performance of GCS and GCS-P scores.
Conclusion: The GCS-P score is a simple bedside tool for early prognostic assessment in traumatic brain injury. Lower admission GCS-P scores were significantly associated with increased in-hospital mortality.
Keywords: Traumatic Brain Injury, Glasgow Coma Scale, Pupillary Reactivity, Mortality, Emergency Service.

INTRODUCTION

Traumatic brain injury (TBI) remains a major public health challenge worldwide and is one of the leading causes of death and long-term disability, particularly among young adults. Millions of individuals sustain traumatic brain injuries each year, resulting in substantial healthcare utilization, economic burden, and long-term functional impairment. The burden is especially high in low- and middle-income countries, where road traffic accidents, falls, and interpersonal violence account for a large proportion of cases.[1,2] TBI frequently requires intensive monitoring, specialised care, and considerable healthcare resources. Early recognition of patients at risk of clinical deterioration is therefore essential for appropriate triage, timely neurosurgical referral, and optimal utilization of critical care resources.[3,23]
The Glasgow Coma Scale (GCS), introduced by Teasdale and Jennett in 1974, remains the most widely used tool for neurological assessment in patients with traumatic brain injury.[4] It evaluates eye opening, verbal response, and motor response, providing a simple and rapid bedside assessment of consciousness. Owing to its simplicity, reproducibility, and established association with patient outcomes, the GCS has become an integral component of the initial assessment of head-injured

patients in emergency medicine, neurosurgery, and critical care practice.[5]

Despite its widespread use, the GCS has important limitations. One notable limitation is that it does not incorporate pupillary reactivity, which provides valuable information regarding brainstem function and the severity of intracranial injury.[6-9] Abnormal pupillary findings, including unilateral or bilateral non-reactive pupils, have consistently been associated with increased mortality and poor neurological outcomes following traumatic brain injury.[6-9]

To address this limitation, the Glasgow Coma Scale–Pupil (GCS-P) score was developed by incorporating pupillary reactivity into the traditional GCS score.[7,9] By combining the level of consciousness with pupillary response, the GCS-P score provides a more comprehensive neurological assessment. Previous studies have reported that GCS-P is a useful prognostic tool for predicting mortality and unfavourable outcomes following traumatic brain injury.[7-9]

Recent studies from neurocritical care units, paediatric trauma populations, and Indian tertiary-care institutions have also demonstrated the prognostic value of the GCS-P score.[7,8,13,17] Furthermore, widely used prognostic models such as IMPACT and CRASH have emphasized the importance of neurological examination findings, particularly pupillary reactivity, in predicting outcomes following traumatic brain injury.[10-12,19]

Although the prognostic value of GCS-P has been demonstrated in several studies, evidence from Indian emergency department settings remains limited. Variations in injury patterns, prehospital management, healthcare delivery systems, and resource availability may influence the performance of prognostic tools across different clinical environments. Validation of simple bedside scoring systems in local settings is therefore important. In many emergency departments, particularly those with limited resources, decisions regarding referral, intensive care admission, and monitoring often need to be made rapidly using information available at presentation. A practical and easily applicable prognostic tool may assist clinicians in identifying high-risk patients and prioritizing management appropriately.21

The present study was undertaken to evaluate the association between admission GCS-P score and in-hospital mortality among adult patients with traumatic brain injury presenting to a tertiary-care emergency department. The study also aimed to assess the usefulness of GCS-P for early risk stratification in a real-world Indian emergency department setting and to provide local evidence supporting its routine clinical application.

MATERIALS AND METHODS

This prospective observational study was conducted in the Emergency Department of Government Medical College and Hospital, Miraj, Maharashtra, India, from August 2025 to January 2026. The department is a tertiary-care referral centre that manages a large volume of trauma patients from Miraj and the surrounding regions.

The study was approved by the Institutional Ethics Committee of Government Medical College and Hospital, Miraj (Reference No. GMCM/IEC/C/198/2025 dated 29/07/2025). Written informed consent was obtained from all participants or their legally authorised representatives. The study adhered to the ethical principles outlined in the Declaration of Helsinki.

The study cohort comprised adult patients presenting within 24 hours of traumatic head injury who fulfilled the predefined eligibility criteria. This was a duration-based prospective observational study. All eligible patients presenting to the emergency department during the study period who fulfilled the inclusion criteria were consecutively enrolled until completion of the study period.

Patients aged 18 years or older with a clinical diagnosis of traumatic brain injury were eligible for inclusion. Exclusion criteria included age below 18 years, pregnancy, death on arrival, and significant polytrauma likely to interfere with neurological assessment. Patients with alcohol or drug intoxication, hypoglycaemia (blood glucose <70 mg/dL), and those who had undergone endotracheal intubation before arrival were also excluded.

Information regarding age, sex, and mechanism of injury was collected at presentation. Vital parameters, including heart rate, respiratory rate, systolic blood pressure, oxygen saturation, and random blood glucose level, were documented. A comprehensive neurological examination was performed in all patients at the time of presentation.

The Glasgow Coma Scale (GCS) score was determined using its three components: eye opening, verbal response, and motor response. Pupillary reactivity was assessed using a handheld penlight and categorised as both pupils reactive, one pupil non-reactive, or both pupils non-reactive. Based on pupillary findings, a Pupillary Reactivity Score (PRS) of 0, 1, or 2 was assigned. The Glasgow Coma Scale–Pupil (GCS-P) score was calculated as follows:

GCS-P = GCS − PRS

As part of routine trauma assessment, all patients underwent computed tomography (CT) of the brain. CT findings, including extradural haematoma, acute subdural haematoma, cerebral contusions, diffuse cerebral oedema, traumatic subarachnoid haemorrhage, and other intracranial lesions, were recorded. The requirement for neurosurgical intervention was also documented.

The primary outcome was in-hospital mortality, defined as death occurring during the same hospital admission before discharge. All patients were followed prospectively from admission until discharge or death.

Statistical Analysis

Data were analysed using Jamovi statistical software (version 2.7.31.0; The Jamovi Project, Sydney, Australia). Continuous variables were expressed as mean ± standard deviation (SD), whereas categorical variables were presented as frequencies and percentages. Comparisons between survivors and non-survivors were performed using the independent samples t-test for continuous variables and the chi-square test for categorical variables.

Receiver operating characteristic (ROC) curve analysis was performed to evaluate the ability of the Glasgow Coma Scale (GCS) and Glasgow Coma Scale–Pupil (GCS-P) scores to predict in-hospital mortality. Discriminatory performance was assessed using the area under the ROC curve (AUC) with corresponding 95% confidence intervals (CIs). The optimal GCS-P threshold for predicting mortality was identified using the Youden index, and the corresponding sensitivity and specificity were calculated.

Multivariable logistic regression analysis was performed to examine the association between admission GCS-P score and in-hospital mortality after adjustment for age and neurosurgical intervention. Adjusted odds ratios (aORs) with 95% confidence intervals (CIs) were calculated.

A two-tailed p-value of less than 0.05 was considered indicative of statistical significance.

RESULTS

A total of 75 adult patients with traumatic brain injury presenting to the emergency department were included in the study. Of these, 47 patients survived and 28 died during hospital admission, resulting in an overall in-hospital mortality of 37.3%.

Admission Neurological Scores

Admission neurological status differed significantly between survivors and non-survivors (Table 1). Patients who died had significantly lower mean GCS scores than survivors (5.4 ± 2.6 vs. 10.5 ± 3.1; $p<0.001$). Non-survivors also had higher Pupillary Reactivity Scores (PRS) (1.5 ± 0.7 vs. 0.5 ± 0.6; $p<0.001$). Consequently, the mean GCS-P score was significantly lower among non-survivors than survivors (4.6 ± 2.7 vs. 9.9 ± 3.2; $p<0.001$).

Table 1: Comparison of admission neurological scores between survivors and non-survivors

Variable	All patients (n=75)	Survivors (n=47)	Non-survivors (n=28)	p value
GCS	8.5 ± 3.7	10.5 ± 3.1	5.4 ± 2.6	<0.001
Pupillary Reactivity Score (PRS)	0.9 ± 0.9	0.5 ± 0.6	1.5 ± 0.7	<0.001
GCS-P	7.9 ± 3.9	9.9 ± 3.2	4.6 ± 2.7	<0.001

Values are expressed as mean ± standard deviation (SD). Comparisons were performed using the independent samples t-test. GCS = Glasgow Coma Scale; PRS = Pupillary Reactivity Score; GCS-P = Glasgow Coma Scale–Pupil Score.

Mortality Across GCS-P Severity Categories

Mortality varied across different GCS-P severity categories (Table 2). The highest mortality was observed among patients with very severe GCS-P scores (70.0%), while the lowest mortality was observed among those with mild GCS-P scores (10.0%). Mortality increased progressively with worsening neurological impairment, and the association between GCS-P category and in-hospital mortality was statistically significant ($p<0.001$).

Table 2: In-hospital mortality according to GCS-P severity categories

Category	Total Patients	Deaths	Mortality Rate (%)
Mild	10	1	10.0%
Moderate	20	4	20.0%
Severe	35	16	45.7%
Very Severe	10	7	70.0%

Values are presented as frequencies and percentages. Association assessed using the chi-square test ($p < 0.001$).

ROC Analysis for Prediction of In-Hospital Mortality

Receiver operating characteristic (ROC) curve analysis demonstrated good discriminative ability for both GCS and GCS-P scores in predicting in-hospital mortality (Table 3 and Figure 1). The area under the ROC curve (AUC) was 0.793 (95% CI: 0.685–0.902) for GCS and 0.788 (95% CI: 0.677–0.899) for GCS-P, indicating comparable predictive performance. The optimal cut-off value for GCS-P was ≤6, which predicted in-hospital mortality with a sensitivity of 67.9% and a specificity of 83.0%.

Table 3: Receiver operating characteristic (ROC) analysis of GCS and GCS-P scores for prediction of in-hospital mortality

Score	AUC	95% CI	p value
GCS	0.793	0.685–0.902	<0.001
GCS-P	0.788	0.677–0.899	<0.001

AUC = Area under the curve; CI = Confidence interval.

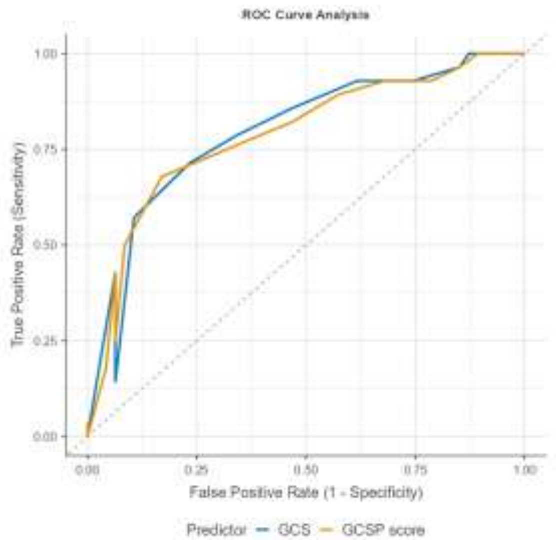

Figure 1: Receiver operating characteristic (ROC) curves of Glasgow Coma Scale (GCS) and Glasgow Coma Scale–Pupil (GCS-P) scores for prediction of in-hospital mortality

AUC = area under the curve; ROC = receiver operating characteristic.

Multivariable Logistic Regression Analysis

Multivariable logistic regression analysis was performed to assess the association between admission GCS-P score and in-hospital mortality after adjustment for age and neurosurgical intervention (Table 4). The GCS-P score remained significantly associated with mortality (adjusted OR 0.75, 95% CI: 0.57–0.98; p=0.032). Each one-point increase in GCS-P score was associated with an approximately 25% reduction in the odds of in-hospital death. Age was not significantly associated with mortality (adjusted OR 1.00, 95% CI: 0.96–1.04; p=0.978). Neurosurgical intervention did not demonstrate an independent association with mortality after adjustment (p=0.992); however, estimation of its odds ratio was unstable because of sparse data within the regression model.

Table 4: Multivariable Logistic Regression Analysis for Prediction of In-Hospital Mortality

Variable	Adjusted OR	95% CI	p value
GCS-P score	0.75	0.57–0.98	0.032
Age	1.00	0.96–1.04	0.978
Neurosurgical intervention	NA	NA	0.992

aOR = Adjusted odds ratio; CI = Confidence interval.

OR could not be reliably estimated because of sparse data and model instability.

Pupillary Reactivity and Mortality

A significant association was observed between pupillary reactivity and in-hospital mortality. Mortality was highest among patients with bilaterally non-reactive pupils (81.3%), followed by those with one non-reactive pupil (55.6%). Patients with bilaterally reactive pupils had the lowest mortality rate (12.2%). This association was statistically significant (p<0.001).

Additional Clinical Findings

Neurosurgical intervention was required in 42 patients, among whom mortality was 52.4%. In comparison, mortality among patients managed conservatively was 18.2%. Patients with severe CT abnormalities, particularly diffuse cerebral oedema and large acute subdural haematomas, appeared to have higher mortality rates; however, formal statistical analysis of individual radiological findings was not performed.

Age and sex were not significantly associated with in-hospital mortality. Non-survivors had a significantly shorter duration of hospital stay compared with survivors (4.2 ± 2.1 days vs. 7.8 ± 3.4 days; p<0.01).

DISCUSSION

The present study evaluated the association between admission Glasgow Coma Scale–Pupil (GCS-P) score and in-hospital mortality among adult patients with traumatic brain injury presenting to a tertiary-care emergency department. Lower GCS-P scores at presentation were associated with higher in-hospital mortality. Patients who died had lower GCS and GCS-P scores and higher Pupillary Reactivity Scores (PRS) than survivors, underscoring the value of early neurological assessment in predicting outcomes after traumatic brain injury.

Traumatic brain injury remains a major cause of mortality and disability worldwide, particularly in low- and middle-income countries where road traffic accidents account for a substantial proportion of severe head injuries.[1,2] Early recognition of patients at risk of deterioration is essential for appropriate triage, timely neurosurgical referral, and effective use of critical care resources.[3] Although the Glasgow Coma Scale (GCS) remains the most widely used tool for neurological assessment, it does not incorporate pupillary reactivity, an important indicator of brainstem function and intracranial injury severity.[5,6]

Abnormal pupillary responses have long been recognised as markers of poor prognosis in traumatic brain injury. Several studies have reported higher mortality rates among patients with unilateral or bilateral non-reactive pupils.[6-9] The Glasgow Coma Scale–Pupil (GCS-P) score was developed to combine information from level of consciousness and pupillary response into a single bedside measure. Previous studies have demonstrated its prognostic utility in patients with traumatic brain injury.[7-9]

In the present study, both GCS and GCS-P were strongly associated with in-hospital mortality. Non-survivors had substantially lower scores at admission than survivors. Similar findings have been reported by Lin et al., Yao et al., Agrawal et al., and Chawnchhim et al., all of whom demonstrated the prognostic value of GCS-P in traumatic brain injury.[7,9,13,17]

Mortality increased progressively across worsening GCS-P severity categories, rising from 10.0% in the mild category to 70.0% in the very severe category. This clear gradient supports the usefulness of GCS-P as a practical tool for early risk stratification. Comparable trends have been observed in large prognostic studies, including the IMPACT and CRASH models, which identified neurological examination findings as major determinants of outcome following traumatic brain injury.[10-12,19,21]

After adjustment for age and neurosurgical intervention, admission GCS-P score remained significantly associated with in-hospital mortality (adjusted OR 0.75, 95% CI: 0.57–0.98; p=0.032). Each one-point increase in GCS-P score was associated with an approximately 25% reduction in the odds of in-hospital death. In addition, a GCS-P score of ≤6 identified patients at increased risk of mortality with a sensitivity of 67.9% and a specificity of 83.0%. This threshold may be useful in identifying patients who require closer monitoring, early neurosurgical consultation, or intensive care evaluation.

Receiver operating characteristic (ROC) analysis demonstrated good discriminative ability for both GCS and GCS-P scores. The AUC values observed in the present study were 0.793 (95% CI: 0.685–0.902) for GCS and 0.788 (95% CI: 0.677–0.899) for GCS-P, indicating comparable predictive performance. Although some previous studies have reported superior prognostic accuracy of GCS-P compared with GCS alone,[7-9,13,17] the present study did not demonstrate a meaningful improvement in discrimination with the addition of pupillary reactivity. This finding may be related to the relatively small sample size and single-centre design. In addition, the relatively small number of patients with severe pupillary abnormalities may have limited the incremental prognostic contribution of the pupillary component. Nevertheless, GCS-P remains clinically valuable because it incorporates an important neurological sign reflecting brainstem function and can be assessed rapidly at the bedside without additional investigations.

Pupillary reactivity emerged as an important predictor of mortality in the present study. Mortality increased from 12.2% among patients with bilaterally reactive pupils to 81.3% among those with bilaterally non-reactive pupils. These findings are consistent with previous evidence demonstrating that abnormal pupillary responses reflect severe intracranial injury and poor neurological prognosis.[6-9,18]

Higher mortality was also observed among patients requiring neurosurgical intervention and among those with severe CT abnormalities such as diffuse cerebral oedema and large acute subdural haematomas. Previous studies have demonstrated that radiological findings play an important role in prognostication because they reflect the extent of intracranial pathology and secondary brain injury.[15,22]

No significant relationship was observed between age, sex, and in-hospital mortality in the study population. Although age has been identified as an important predictor of outcome in larger studies, the relatively small sample size may have limited the ability to detect statistically significant demographic associations.[14]

The present study provides prospective data regarding the utility of GCS-P in an Indian tertiary-care emergency department. In resource-constrained settings, simple bedside assessment tools are particularly valuable because decisions regarding referral, intensive care admission, and monitoring often need to be made rapidly. The findings support the applicability of GCS-P as a practical risk-stratification tool in routine emergency department practice.

Several limitations should be acknowledged. First, the study was conducted at a single tertiary-care centre and included a relatively small sample size, which may limit generalizability. Second, only in-hospital mortality was assessed, and long-term neurological or functional outcomes were not evaluated. Third, although multivariable logistic regression analysis was performed, the model included a limited number of variables because of the relatively small sample size and number of outcome events. Therefore, the regression findings should be interpreted cautiously and considered exploratory. Therefore, larger multicentre studies with more comprehensive multivariable analyses and long-term follow-up are required to further validate these findings.

Despite these limitations, the findings support the clinical usefulness of the GCS-P score as a practical bedside tool for early prognostic assessment in traumatic brain injury. Incorporation of pupillary reactivity into routine neurological evaluation may assist clinicians in identifying high-risk patients who require closer monitoring, timely neurosurgical consultation, and appropriate utilization of critical care resources.

CONCLUSION

The Glasgow Coma Scale–Pupil (GCS-P) score is a simple and practical bedside tool for early prognostic assessment in patients with traumatic brain injury. Lower admission GCS-P scores were significantly associated with higher in-hospital mortality, and abnormal pupillary reactivity was strongly associated with poor outcomes. Mortality increased progressively across worsening GCS-P severity categories, supporting the usefulness of GCS-P for early risk stratification.

A GCS-P score of ≤6 identified patients at increased risk of mortality with a sensitivity of 67.9% and a specificity of 83.0% and may assist clinicians in early decision-making. In addition, admission GCS-P score remained significantly associated with mortality after adjustment for age and neurosurgical intervention. Incorporating pupillary reactivity into routine neurological assessment may complement traditional Glasgow Coma Scale evaluation and assist in early risk stratification of patients with traumatic brain injury. Because it can be assessed rapidly at the bedside without additional investigations, the GCS-P score may be particularly useful in emergency departments and resource-limited settings for identifying patients who require closer monitoring, timely neurosurgical consultation, and aggressive management.

Further multicentre studies with larger sample sizes, more comprehensive multivariable analyses, and long-term follow-up are needed to validate these findings and evaluate the role of GCS-P in predicting long-term functional outcomes.

Conflict of Interest

The authors declare that they have no conflict of interest.

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Data Availability Statement

The data supporting the findings of this study may be obtained from the corresponding author upon reasonable request.

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