

Retrospective Evaluation of Integrated Glasgow Coma Scale and CT Scan Results for Predicting Traumatic Brain Injury Outcomes in An Indian Tertiary Care Hospital



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Abstract

Background: Traumatic Brain Injury (TBI) is an important global health issue, especially in developing countries like India. Accurate prediction of TBI is crucial for guiding treatment choices. The Glasgow Coma Scale (GCS), and brain Computed Tomography (CT) scores have been associated with clinical outcomes in TBI patients. However, no study has used the combination of GCS score and CT scan results to predict the outcomes of TBI in Indian patients. Therefore, we aimed to investigate the association of GCS score and CT results with TBI outcomes when used in combination and alone.

Methods: This study retrospectively analyzed data of one hundred twenty TBI patients of SMS Hospital, Jaipur. The GCS deficit score was computed by subtracting the GCS score from fifteen. The midline shift, basal cistern compression and lateral ventricular compression presence were scored as 1 to calculate the mass effect CT score. The sum of mass effect CT score and Subarachnoid Hemorrhage (SAH) presence, valued as 2, determined the prognostic CT score. The CT-GCS deficit score was the sum of the GCS deficit and prognostic CT score.

Results: Higher CT-GCS deficit score (13.5 ± 3.2) was observed in-hospital mortality patients compared to survivors (8.9 ± 3.4 ; Cohen $d=1.3$). Surgical decompression was more frequent with a higher mass effect score (2.8 ± 0.5 ; Cohen $d=1.4$). The inability to follow commands at hospital discharge was associated with higher CT-GCS deficit scores (13.3 ± 3.2 ; Cohen $d=1.06$). At three months, patients not following commands had significantly higher CT-GCS deficit scores (13.6 ± 3.1 ; Cohen $d=0.94$). Logistic regression confirmed the CT-GCS deficit score as a strong predictor for all outcomes except for surgical decompression.

Conclusion: The CT-GCS deficit score is associated with in-hospital mortality and the inability to follow commands at discharge and post-discharge, indicating its potential to enhance prognostic accuracy and guide treatment decisions, particularly in resource-limited settings like India. Further prospective studies with larger sample sizes are recommended for validation and applicability.

Keywords: Computed Tomography; CT; Glasgow Coma Scale; GCS; Hospital Mortality; India; Subarachnoid Hemorrhage; TBI

Abbreviations: TBI: Traumatic Brain Injury; GCS: Glasgow Coma Scale; SAH: Subarachnoid Hemorrhage; ICP: Intracranial Pressure; EDH: Epidural Hematoma; SDH: Subdural Hematoma

Introduction

Traumatic Brain Injury (TBI) is an important global health issue, especially in developing countries like India, where incidents are due to accidents (69.52%), falls (22.77%) and violence (4.46%), with a much higher prevalence seen in young adult males [1,2]. The World Health Organization (WHO) predicts that by 2030, road injuries, which are the main cause of TBI, will become the third leading cause of death and disability in the world, mainly in low- and middle-income countries [3]. In India, the

high number of TBI cases, along with varying levels of healthcare infrastructure, poses significant challenges in effectively managing these patients and anticipating their outcomes accurately [2]. Accurate prediction of TBI is crucial for guiding treatment choices, optimising resource distribution, and informing patients and their families about potential outcomes. The Glasgow Coma Scale (GCS) is a tool which has been widely used to assess the severity of TBI upon admission to the hospital by measuring the patient's level

of consciousness [4]. Studies demonstrated that the initial GCS score had a significant association in predicting patient outcomes, such as mortality and long-term functional recovery [2,5]. The GCS score is easy and fast to assess but alone may not provide a complete picture of the patient's prognosis, as it does not give information on potential intracranial lesions seen in imaging studies [6].

Computed Tomography (CT) scanning is another important diagnostic tool for TBI, providing important information on cranial pathologies such as hemorrhage, brain tumor, and stroke. CT findings have been shown to correlate with the severity of TBI and patient outcomes, aiding in the identification of patients at higher risk of mortality [7]. Specific findings on CT scans, like midline shift or Subarachnoid Hemorrhage (SAH), are strong indicators of a poor prognosis [8]. Several CT-based scoring systems, such as the Rotterdam and Marshall scores, are used to better predict outcomes. Moreover, higher CT scores assessed using the Rotterdam and Marshall scoring systems have shown a significant association with hospital mortality in the Indian population [9]. These scoring systems have demonstrated their utility in predicting outcome [10,11]. Furthermore, numerous studies indicate that early CT scores correlate with GOS outcomes following hospital discharge [8]. However, it has been shown that CT scan can be insignificant for the prediction of functional recovery in TBI since the absence of abnormalities on CT at admission did not exclude the occurrence of raised Intracranial Pressure (ICP), except in cases of major new lesions in 40% of patients [12].

The integration of GCS scores with CT scan results can provide a superior prediction of in-hospital mortality and post-hospital adverse outcomes than the independent use of GCS subscores or CT findings [11]. Dunham et al. [13] conducted a recent retrospective study employing GCS scores and prognostic CT scores to predict hospital mortality and the patient's capacity to follow commands at discharge and three months thereafter. The findings indicated that this combined approach produced more precise predictions than either method independently. To our knowledge, there is no Indian study which had used this combined approach to predict the outcomes of TBI. Nonetheless, most of these studies have been done in wealthier and developed countries, and it is unclear if these combined scoring methods would work as well in India, where access to advanced neuroimaging and trauma care may vary [14,15]. To fill this gap, this retrospective study aimed to assess the predictive ability of GCS score, CT score and CT-GCS deficit scores for hospital mortality, surgical compression and the inability to follow commands at discharge and three months post-discharge in patients at a tertiary care hospital in Jaipur, India. This research seeks to improve TBI care in resource-limited settings like India, offering a more accurate way to predict outcomes and manage care for patients with brain injuries [8,16].

Methods

Study design

The study was conducted at the SMS Medical College and attached hospitals in Jaipur, India. This retrospective cohort study analyzed data of adult patients with TBI admitted to the hospital during the study period from January 2018 to December 2023. Since the research involved only minimal risk only oral consent was obtained from all participants after providing a detailed explanation of $\left[I_p - \frac{r_{C_{\text{def}}} \times (V_p - V_r)}{1 - r_{C_{\text{def}}}} \right]$ objectives and procedures. The study protocol was approved by the Ethics Committee of SMS Medical College, Jaipur. The primary objective was to investigate the prediction of TBI outcomes using CT-GCS deficit score.

Samples Size and Participants

The sample size for this retrospective analysis was analyzed at 80% study power, 95% confidence level, significance level (α) of 0.05 and assuming a moderate effect size (Cohen's $d = 0.3$) of associations between the CT-GCS deficit score and patient outcomes between based on previous studies [8,13], which recommended 87 patients. Thus, the data of 120 consecutive patients meeting the inclusion criteria was identified from the trauma registry data and thereby retrospectively reviewed for this study.

Inclusion Criteria

- Age > 18
- Diagnosis of blunt head trauma with evidence of intracranial injury.
- GCS score between 3 and 12 upon admission.
- Requirement of mechanical ventilation for at least 5 days.
- Patients who underwent a CT scan within 24 hours of admission.

Exclusion Criteria

- Penetrating trauma
- GCS score of 13-15.
- Patients who died within the first 24 hours of admission.
- Mechanical ventilation for less than 5 days.
- Lack of complete medical records or inability to follow up for three months post-discharge
- Patients with concomitant fatal injuries or comorbidities

Data collection

Demographic information, clinical data and radiological imaging were gathered from the hospital trauma registry. GCS

value of admission was recorded. The GCS deficit was calculated as 15 (normal GCS) minus the admission GCS value (study range, 3-12), where a higher GCS deficit indicated a more severe impairment. CT scans of all patients were reviewed by a neuro-radiologist blinded to the study's objectives to ensure consistency in interpretation. CT hemorrhage distribution included Epidural Hematoma (EDH), Subdural Hematoma (SDH), cerebral hematoma, brain contusion and Subarachnoid Hemorrhage (SAH). The CT scan was also assessed for the presence of midline shift, basal cistern compression, and lateral ventricle compression to calculate the mass effect score (theoretical range 0-3). Each of the three was scored as 0 if absent and 1 if present. SAH was scored as 0 if absent and 2 if present and was added to the mass effect score to create the prognostic CT score with a theoretical range from 0-5 [13]. The CT-GCS deficit score was then calculated by the sum of the prognostic CT score and the GCS deficit (theoretical study range, 3-17). The outcome variables included in-hospital mortality, surgical decompression and ability to follow commands at hospital discharge and at three months post-discharge. These were collected from the data registry, and when necessary, follow-up calls were made to assess functional status three months post-discharge.

Statistical analysis

The data were initially recorded in Microsoft Excel (Microsoft Corporation, Redmond, WA, USA) and subsequently imported into IBM SPSS version 23.0.0 (IBM, New York, USA) for formal statistical analysis. Continuous variables such as GCS score, GCS deficit, and CT-GCS deficit score were summarized using mean $\pm$ standard deviation. Categorical variables such as mortality and surgical intervention were expressed as frequencies and percentages. Since the assumption of normality of data tested using Shapiro Wilk test was violated, Wilcoxon signed rank test was used to compare the two groups. Further, a paired t-test was also employed to determine difference in the groups. Cohen's d was computed to determine the effect size of differences between groups, with values of 0.20, 0.50, and 0.80 representing small, medium, and large effect sizes, respectively [17]. The Pearson Chi-square test was utilized to determine the differences in proportions. Binary logistic regression (Method=Forward: LR) was conducted to identify independent factors that predicted outcomes (Yes or No). Additionally, a Receiver Operating Characteristic (ROC) curve was generated, and the area under the ROC curve (AUC) was calculated to quantify the model's discriminative power. The level of significance was kept at $\alpha=0.05$ for all analyses.

Results

Table 1: Distribution of GCS, GCS deficit and CT-GCS deficit score.

Score	Categories	Frequency (N=120)	Percent
GCS (Mean $\pm$ SD)	7.02 $\pm$ 3.09		
	03-04-	36	30
	05-08-	42	35
	09-10-	18	15
	11-12-	24	20
GCS deficit (Mean $\pm$ SD)	7.97 $\pm$ 3.09		
	12-11-	36	30
	10-07-	42	35
	06-05-	18	15
	04-Mar	24	20
CT-GCS deficit (Mean $\pm$ SD)	11.07 $\pm$ 3.99		
	04-09-	44	36.7
	10-12-	26	21.6
	13-14	17	14.2
	15-17	33	27.5

GCS - Glasgow Coma Scale, CT - Computed Tomography.

The study analysed the 120 patients of TBI, out of which 89 (74%) were males and 31 (26%) were females. The road traffic accident was the most major cause of the TBI (71%), followed by

fall (21%) and violence (5%). The mean age of patients was 39 $\pm$ 14.61 years (range: 18-68), where the majority of patients were in the young age category of 18-25 years (62 %). The mean GCS

score was 7.02 ± 3.09 . The mean GCS deficit score was 7.97 ± 3.09 . The mean CT-GCS deficit was 11.07 ± 3.99 . The distribution of GCS, GCS deficit and CT-GCS deficit scores is presented in Table 1. The CT hemorrhage distribution was as: EDH in 43 (35.8%), SDH in 56 (46.7%), SAH in 66 (55%), brain contusion in 49 (40.8%), and cerebral hematoma in 27 (22.5%) patients. The midline shift, basal cistern compression, and lateral ventricle compression were present in 78 (65%), 82 (68.3%), 80 (66.7%) patients respectively. The mean mass effect CT score was 2.0 ± 0.91 . The distribution of mass effect CT score was as: none in seven (5.8%), one in 29 (24.2%), two in 41 (34.2%), and three in 43 (35.8%) patients. The mean prognostic CT score was 3.1 ± 1.39 . The distribution of prognostic CT score was as: one in 18 (15%), two in 28 (23.3%), three in 26 (21.7%), four in 20 (16.7%) and five in 28 (23.3%) patients.

In-hospital mortality

The in-hospital mortality proportion was 29.2% (35/120). The mass effect CT score, prognostic CT score and CT-GCS deficit score were significantly higher whereas the GCS score was low in the patient who died in hospital (Table 2). CT-GCS deficit score

differentiated the in-hospital mortality with a large effect size (Cohen $d = 2.43$) compared to GCS, mass effect and prognostic CT score alone. The proportion of in-hospital mortality was similar for EDH (12/43, 27.90%) and no EDH (23/77, 29.8%), $p=0.821$, SDH (14/56, 25%) and no SDH (21/64, 32.8%), $p=0.348$, cerebral hematoma (8/27, 29.6%) and no cerebral hematoma (27/93, 29%), $p=0.952$, brain contusion (11/49, 22.4%) and no brain contusion (24/71, 33.8%), $p=0.179$. The proportion of in-hospital mortality was higher for SAH (27/66, 40.9%) compared to no SAH (8/54, 14.81%), $p=0.002$. The proportion of in-hospital mortality was significantly greater for midline shift (33/78, 42.3%) compared to no midline shift (2/42, 4.7%), $p<0.001$, lateral ventricle compression (30/80, 37.5%) compared to no lateral ventricle compression (5/40, 12.5%), $p=0.005$, basal cistern compression (31/82, 37.8%) compared to no basal cistern compression (4/38, 10.52%) $p=0.002$. Forward stepwise logistic regression showed an association of in-hospital mortality only with CT-GCS deficit score ($p<0.001$, AUC=0.957) but not for prognostic CT score ($p=0.474$), mass effect CT score ($p=0.455$), GCS score ($p=0.474$), EDH ($p=0.300$), SDH (0.857), SAH (0.755), brain contusion ($p=0.811$) and cerebral hematoma ($p=0.895$).

Table 2: Association of in-hospital mortality with predictor scores

In-hospital mortality	No (Mean $\pm$ SD)	Yes (Mean $\pm$ SD)	Wilcoxon, p-value	T-test, p-value	Cohen d
Frequency (N =120)	85 (70.8%)	35 (29.2%)			
GCS score	8.35 ± 2.67	3.8 ± 0.83	< 0.001	< 0.001	2.3
Mass effect CT score	1.71 ± 0.89	2.68 ± 0.59	< 0.001	< 0.001	1.2
Prognostic CT score	2.63 ± 1.21	4.22 ± 1.13	0.001	< 0.001	1.35
CT-GCS deficit score	9.28 ± 3.23	15.42 ± 1.52	< 0.001	< 0.001	2.43

GCS - Glasgow Coma Scale, CT - Computed Tomography.

Surgical decompression

The surgical decompression proportion was 63.3 % (76/120). The Cohen d was significantly better for mass effect CT score compared to prognostic CT and CT-GCS score. GCS score was insignificant to predict the need for surgical decompression (Table 3). The proportion of surgical decompression was not different for EDH (29/43, 67.4%) and no EDH (47/77, 61.03%), $p=0.485$, SDH (34/56, 60.7%) and no SDH (42/64, 65.6%), $p=0.578$, SAH (42/66, 63.6%) and no SAH (34/54, 62.9%), $p=0.939$, cerebral hematoma (16/27, 59.2%) and no cerebral hematoma (60/93, 64.5%), $p=0.618$, brain contusion (31/49, 63.2%) and no brain contusion (45/71, 63.3%), $p=0.990$. Logistic regression stepwise analysis demonstrated an association of surgical decompression with only mass effect CT score ($p<0.001$, AUC=0.807). The proportion of surgical decompression was significantly higher for midline shift (60/78, 76.9%) compared to no midline shift (16/42, 38.09%), $p<0.001$, lateral ventricle compression (58/80, 72.5%) compared to no lateral ventricle compression (18/40, 45%), $p=0.003$, basal

cistern compression (63/82, 76.8%) compared to no basal cistern compression (13/38, 34.2%) $p<0.001$.

Inability to follow command at hospital discharge

The proportion of patients who were not able to follow command at discharge was 49.16% (59 patients). The mass effect CT score, prognostic CT score and CT-GCS deficit score were significantly lower, whereas the GCS score was higher in the patients who were not able to follow commands at discharge. The Cohen d value was significantly high for the CT-GCS deficit score (Table 3). Forward stepwise logistic regression showed that the inability to follow commands at hospital discharge was associated with CT-GCS deficit score ($p<0.001$, AUC=0.667) but neither for GCS ($p>0.05$) nor for prognostic CT score ($p>0.05$). The presence of midline shift, basal cistern compression, lateral ventricle compression and SAH was associated with the inability to follow command at hospital discharge ($p<0.005$) (Table 4).

Table 3: Association of surgical decompression.

In-hospital mortality	No (Mean $\pm$ SD)	Yes (Mean $\pm$ SD)	Wilcoxon, p-value	T-test, p-value	Cohen d
Frequency (N =120)	44 (36.7%)	76 (63.3%)			
GCS score	7.90 $\pm$ 3.02	6.51 $\pm$ 3.03	0.203	0.113	
Mass effect CT score	1.34 $\pm$ 0.88	2.38 $\pm$ 0.69	< 0.001	< 0.001	1.31
Prognostic CT score	2.43 $\pm$ 1.26	3.48 $\pm$ 1.32	< 0.001	< 0.001	0.81
CT-GCS deficit score	9.52 $\pm$ 3.70	11.97 $\pm$ 3.89	0.012	0.008	0.64

GCS - Glasgow Coma Scale, CT - Computed Tomography.

Table 4: Association of inability to follow commands at hospital discharge.

In-hospital mortality	No (Mean $\pm$ SD)	Yes (Mean $\pm$ SD)	Wilcoxon, p-value	T-test, p-value	Cohen d
Frequency (N =120)	59 (49.16%)	61 (50.84%)			
GCS score	4.96 $\pm$ 1.86	9.01 $\pm$ 2.72	< 0.001	< 0.001	1.73
Prognostic CT score	3.98 $\pm$ 1.05	2.24 $\pm$ 1.12	< 0.001	< 0.001	1.6
CT-GCS deficit score	14.01 $\pm$ 2.07	8.22 $\pm$ 3.27	< 0.001	< 0.001	2.11

GCS - Glasgow Coma Scale, CT - Computed Tomography.

Inability to follow command at three months post-discharge

At three months post-discharge only 32.5 % (n=39) patients were not able to follow command. The Cohen d was greater for the CT-GCS deficit score than for the GCS score and GCS deficit (Table 5). Logistic regression stepwise analysis showed that the

inability to follow commands at three months was significantly associated with the CT-GCS deficit score ($p < 0.001$, AUC=0.821) but not with either the GCS ($p > 0.50$) or the prognostic CT score ($p > 0.50$). Besides midline shift, basal cistern compression, lateral ventricle compression and SAH, brain contusion was significantly associated with the inability to follow command at three months post-discharge ($p < 0.005$).

Table 5: Association of inability to follow commands at three months post-discharge

In-hospital mortality	No (Mean $\pm$ SD)	Yes (Mean $\pm$ SD)	Wilcoxon, p-value	T-test, p-value	Cohen d
Frequency (N =120)	39 (32.5%)	81 (67.5%)			
GCS score	4.05 $\pm$ 1.12	8.45 $\pm$ 2.69	< 0.001	< 0.001	2.13
Prognostic CT score	4.23 $\pm$ 0.95	2.55 $\pm$ 1.23	< 0.001	< 0.001	1.52
CT-GCS deficit score	15.17 $\pm$ 1.55	9.08 $\pm$ 3.22	< 0.001	< 0.001	2.41

GCS - Glasgow Coma Scale, CT - Computed Tomography.

Discussion

This study was conducted with the aim of investigating the association of GCS score, CT findings and their combined CT-GCS deficit score with the outcomes in TBI patients treated at SMS Medical College and hospitals in Jaipur, India. We found that the maximum number of patients were males of young age, and the major cause of TBI was road accidents, similar to previous reporting [1,2].

In-hospital mortality

Our study observed a significant in-hospital mortality rate of 29.2%, consistent with another study on severe TBI [18] but

contradictory to other studies, which have observed slightly less mortality (14%, 13.4%, 10.2%) [11,13,19]. The difference in pre-hospital care and well-equipped healthcare facilities in India and developed countries could be the possible reasons for the contradictions [1]. The initial low GCS score was significantly associated with in-hospital mortality. A similar GCS relationship was found in other studies [13,20]. CT-GCS deficit score had shown the greatest association (Cohen d=2.43) with in-hospital mortality compared to the GCS score, mass effect CT score, and prognostic CT score, indicating that it is a more powerful predictor of hospital mortality compared to individual GCS and CT scores. It has been well reported in previous studies that combining

GCS scores with other diagnostic metrics enhances prognostic accuracy in TBI patients [6,11,13]. In this study, the proportion of patients with SAH had a significantly higher mortality rate compared to those without SAH ($p = 0.002$) [21]. Similarly, the presence of midline shift, lateral ventricle compression, and basal cistern compression were all significantly associated with in-hospital mortality, also noted in other studies [8,22,23]. We found that EDH was not associated with in-hospital mortality, which has already been confirmed in other studies [11,13,24]. In stepwise logistic regression, the CT-GCS deficit score was found to be independently associated with in-hospital mortality. The CT-GCS deficit score was the sum of the GCS deficit score and prognostic CT score, which was created using the SAH presence. The efficiency of the CT-GCS deficit score in predicting the mortality outcome in TBI patients has already been confirmed [13].

Surgical decompression

In our study, surgical decompression was required in 63.3%, nearly equal to a previous study, and the need for surgery was largely associated with the mass effect CT score ($p < 0.001$, AUC = 0.807) [13]. Interestingly, we found that the GCS score was not predictive of surgical decompression in TBI patients, where it was less significant compared to the mass effect CT score in the study of Dunham et al. [13]. The significant association of mass effect with surgical intervention is consistent with prior studies [25,26], where increased intracranial pressure and mass effect required more aggressive management strategies, such as craniectomy or decompressive surgery. Moreover, in this study, the need for surgery was associated with the presence of midline shift, lateral ventricle compression, and basal cistern compression, emphasizing the importance of CT features in determining surgical outcomes [13,27]. However, the CT-GCS deficit score, while associated with in-hospital mortality, was less predictive of surgical decompression compared to the mass effect CT score (Cohen's $d = 1.31$). This suggests that CT imaging is the first technique required to determine the surgical needs [28], while the CT-GCS deficit score may be more relevant for long-term prognostication.

Inability to follow commands at discharge and at three months post-discharge

Approximately 49.16% of patients were unable to follow commands at discharge, which reduced to 32.5% at three months post-discharge. The GCS score, prognostics CT score and CT-GCS deficit score all were significantly able to predict the inability to follow commands both at discharge and at three months post-discharge, but the CT-GCS deficit score showed a large effect size, confirming findings from other studies that emphasize the benefit of combining clinical and radiological data [6,10,13]. Moreover, we found that SAH, midline shift, lateral ventricle compression, basal cistern compression and brain contusion were strongly linked to poorer outcomes both at discharge and three months later. These

results align with earlier research, which also emphasized that these specific indicators of increased intracranial pressure tend to signal a more difficult recovery process [8,29]. Several esteemed TBI researchers showed that the early CT score results were associated with post-hospital discharge GOS results [6,11,13].

The findings of this study suggest that the CT-GCS deficit score should be integrated into the clinical assessment of TBI patients to improve prognostic accuracy in Indian tertiary care centres. Given that the CT-GCS deficit score outperformed GCS and mass effect CT scores in predicting in-hospital mortality and inability to follow command both at hospital discharge and at three months post-discharge [13]. Moreover, the role of midline shift, SAH and other CT findings should not be overlooked in making surgical decisions. The early detection of these radiological markers may facilitate timely interventions for improving TBI patient outcomes [26,30]. The retrospective design, limited sample size and conduct at a single facility of this study may introduce bias and restrict the overall generalizability to other settings in India.

Conclusion

It is confirmed that the CT-GCS deficit score had a better association with in-hospital mortality and inability to follow commands at hospital discharge and at three months post-discharge than the GCS score or CT scores i.e. mass effect CT score and prognostic CT score used alone. The need for surgery is still better predicted with the mass-effect CT score. Therefore, it is suggested that the integrated use of GCS score and CT findings could enhance prognostic accuracy and can guide treatment decisions, especially in resource-limited settings like India. Further prospective studies with larger sample sizes are recommended to validate these findings and explore the broader applicability of the CT-GCS deficit score in different clinical settings.

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