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Evaluation of Prognostic Scores in Patients with Head Trauma in the Emergency Department

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Abstract

Background: The aim of this study was to investigate the effectiveness of Glasgow coma scale (GCS), GCS-motor component (mGCS), and FOUR (Full Outline of Un-responsiveness) Scores in predicting the prognosis of patients who presented to the emergency department with head trauma.

Methods: In this prospective cross-sectional study, was obtained to collected data of patients with head trauma, who presented to the emergency department. Participants' demographic data, medical history, GCS, FOUR scores, the duration of emergency department stays, as well as 24-hour, 7-day, and 28-day mortality rates were recorded on the case report forms.

Result: Data from 302 patients were used to develop a risk score for detecting significant brain pathology via computed tomography (CT) scans. The regression model, incorporating total GCS and sex-based variables, explained 22.5% of variance and accurately classified 91.1% of cases. The model's area under the curve for detecting significant pathology via CT was 0.714.

Conclusion: GCS, mGCS, and FOUR scores did not achieve the necessary the diagnostic performance benchmark to be used alone to predict or exclude clinically significant brain injury in patients with head trauma.

Keywords: Glasgow Coma Scale, Head Trauma, Acute Brain Injuries, FOUR score

Introduction

Head trauma is a significant public health problem both economically and sociologically. It accounts for approximately half of all trauma-related mortality and stands as the leading cause of death among individuals aged ≤25 years [1,2]. Rapid diagnosis and early effective treatment were crucial in preventing morbidity and mortality in such patients [3]. Previous studies reported that the widely used and generally accepted Glasgow Coma Scale (GCS) and Full Outline of Un-Responsiveness (FOUR) score, developed as an alternative for the GCS to assessing trauma patients, demonstrated similar effectiveness [4–7]. Furthermore, the motor component of the GCS (mGCS) was reported to be as effective as the GCS and could be used in place it for the prehospitalization assessment of trauma patients [8]. These scores can guide clinicians in defining the clinical status of the patient at the time of admission, predicting primary brain injury in the emergency department, and to implement measures against the occurrence of secondary injuries [9]. The aim of the present study is to investigate the effectiveness of assessing trauma patients using the GCS, FOUR, and mGCS scales at the time of presentation to the emergency department in detecting clinically significant brain injury.

Materıals and Methods

Study Design: The study was initiated following approval from the local ethics committee (Ethics Committee Approval number: 274 / October 3, 2022). It was a prospective cross-sectional study involving patients who presented to the emergency department of a tertiary training and research hospital with an annual average admission of 500,000 patients. The study included patients with head trauma who presented to the emergency department between October 2022 and January 2023. Written consent was obtained from patients who agreed to participate in the study. Those who declined to participate, individuals aged <18 years, pregnant women, and patients under the influence of drugs or alcohol were excluded.

Data Collection: Patients with head trauma, who presented to the emergency department underwent examination by an emergency medicine specialist. Subsequent examinations were conducted as outlined in the Advanced Trauma Life Support Guidelines (ATLS) and treatment was organized accordingly [10]. The CT images of patients considered suitable for neuroimaging by the emergency physician, following the Canadian brain CT guidelines, were assessed alongside the associated reports, and the results were recorded in the case report form [4].

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Patients deemed unsuitable by the emergency physician did not undergo the CT imaging procedure.

Demographic data, medical history, mechanism of trauma, GCS and FOUR scores at admission for participants were meticulously recorded on the case report form. The patients' outcomes, categorized as discharge, ward admission, or intensive care unit (ICU) hospitalization, were also documented on the case report form. Mortality statuses of the patients at 24 hours, 7 days, and 28 days after admission were retrieved from the patient record system and meticulously recorded in the case report form. It's essential to note that no alterations were made to the examination, follow-up, and treatment procedures for the patients included in the study.

Clinically significant brain injury associated with head trauma was defined as any acute brain result on brain computed tomography (CT) that typically required hospitalization and neurosurgical follow-up. All brain injuries were considered clinically important unless the patient remained neurologically intact and exhibited one of the following lesions on CT: solitary contusion of less than 5 mm in diameter, localized subarachnoid blood less than 1 mm thick, smear subdural hematoma less than 4 mm thick or closed depressed skull fracture not extending through the inner table. This definition aligns with the criteria outlined in the "Canadian CT Head Rule" validation study conducted by Stiel IG et al. [11].

Statistical Analysis

The Statistical Package for the Social Sciences (SPSS v.29, IBM Corp., Released 2019. IBM SPSS Statistics for Windows, Version 29.0. Armonk, NY: IBM Corp) was employed for statistical analyses of the data. The normal distribution of continuous data was assessed using the Shapiro–Wilk test. In case where no continuous variable exhibited a normal distribution, the Mann–Whitney-U Test was utilized for intergroup comparisons, and the data were presented as median (25%–75% quartiles). Categorical data were expressed as frequency (%), with Chi-Squared test and Fisher Exact test applied for intergroup comparisons as necessary.

Receiver Operating Characteristics (ROC) analysis was employed to investigate the diagnostic performance, and area under the curve (AUC) was calculated accordingly. Logistic regression was utilized in multivariate analysis. Correlations between variables and variance inflation factor were analyzed to test multicollinearity. The goodness of fit of the model was determined using the Hosmer–Lemeshow test. Statistical significance was denoted by $p < 0.05$ for all analyses conducted in this study.

Results

The present study examined a total of 388 patients with head trauma who presented to the emergency department. Exclusions from the study comprised patients, who declined to participation(43), those under the influence of alcohol or drugs (32), individuals who left the hospital without permission (8), and pregnant women (3) were excluded. The data collected from the remaining 302 patients included in the study were thoroughly assessed. The median age of the patients was 44 years, with 206 (68.2%) male participants and 96 (31.8%) female participants. The most prevalent reason for presentation was "fall from same level" observed in 106 (35.1%) cases. The median GCS and FOUR levels were 15 (15–15) and 16 (16–16), respectively. Clinically significant pathology was confirmed via CT in 33 patients (10.9%), representing the primary endpoint. Among the patients 270 (89.4%) were discharged following the completion of emergency department follow-up, 22 (7.3%) were hospitalized in the relevant ward, and 10 (3.3%) were admitted to the ICU. Two patients (0.7%) succumbed within 28 days (Table 1). Patients enrolled in the study were classified into two groups based on the presence or absence of clinically significant pathology on brain CT, which served as the primary endpoint. The scores from GCS and its components, as well as the FOUR and its components were

Table 1: Baseline descriptive characteristics of patients included in the study

Age	44 (30–67)
Sex (male)	206 (68.2%)
GCS	15 (15–15)
FOUR Score	16 (16–16)
Hypertension	63 (20.9%)
Diabetes Mellitus	32 (10.6%)
CAD	27 (8.9%)
Heart failure	7 (2.3%)
CRF	3 (1%)
Chronic obstructive pulmonary disease	16 (5.3%)
History of ischemic stroke	17 (5.6%)
Active malignancy	5 (1.7%)
Neurodegenerative disease	11 (3.6%)
Epilepsy	13 (4.3%)
Trauma mechanism	
Non-vehicle traffic accident	20 (6.6%)
Vehicular traffic accident	13 (4.3%)
Fall from same level	106 (35.1%)
Battery	69 (22.8%)
Tumbling down the stairs	15 (5%)
Motorcycle accident	46 (15.2%)
Fall from scooter	4 (1.3%)
Hit a hard place	9 (3)
Falling from height	20 (6.6%)
Patients hospitalized in the relevant ward	26 (8.6%)
Length of ward stay (days)	4 (3–7)
Patients admitted to the intensive care unit	14 (4.6%)
Duration of intensive care unit stay (days)	7 (1–40)
Mortality (28 days)	2 (0.7%)
Clinically significant pathology by CT	33 (10.9%)

CT Brain: Computed tomography of the brain, FOUR: Full Outline of Un-Responsiveness, GCS: Glasgow Coma Scale. CAD: Coronary artery disease CRF: Chronic renal failure significantly lower in the group of patients with pathology on CT scan (p < 0.001 for all variables). No significant intergroup differences were observed in terms of other variables (Table 2). The AUC of total GCS, total FOUR score, and their individual components were calculated through ROC analysis. The first four variables with the highest diagnostic performance were total FOUR score, total GCS score, FOUR eye response, and GCS verbal response (AUC = 0.665, 0.664, 0.650, and 0.649, respectively) (Table 3). Analysis was conducted based on the optimal thresholds of the GCS sensitivities. The analyses indicated that the sensitivity of GCS for detecting the occurrence of clinically significant pathology on CT was 33.3% (95%CI = 18–51.8), FOUR score sensitivity was 15.2% (95%CI = 5.1–32) and GCS motor score sensitivity was 27.3% (95%CI = 13.3–45.5). Additionally the specificity of GCS was 99.3% (95%CI = 97.3–99.9), specificity of FOUR score was 99.6% (95%CI = 98–99.9) and specificity of GCS motor score was 99.6% (95%CI = 97.9–99.9). The test performance metrics of the three scores are briefly summarized in Table 4. A logistic regression analysis that includes all variables to identify independent predictors of the occurrence of clinically significant pathology on brain CT could not be performed due to the similarity between the variables, resulting in multicollinearity. However, the aim of this study was to develop a risk score based on the data included in the study in o determine the occurrence of clinically significant pathology via brain CT. The regression model that best suited this purpose included the total GCS and sex variables (Table 5). The model was fitted, predicted the outcome at a statistically significant level, and explained 22.5% of the variance (Hosmer & Lemeshow p = 1, p < 0.001, Nagelkerke R2 = 0.225, respectively). Through the model, we were able to accurately classify 91.1% of cases. Regarding the performance of the model in detecting the occurrence of clinically significant pathology via CT, the AUC value was 0.714 (95%CI = 0.610–0.817) (Figure 1).

Table 2: Results of univariate analysis of variables

	Without pathology on CT Brain	With pathology on CT Brain	p value
Age	44 (30–67)	50 (28–70)	0.948
Sex (male)	179 (66.5%)	27 (81.8%)	0.075
GCS	15 (15–15)	15 (12–15)	<0.001
Eye response	4 (4–4)	4 (3–4)	<0.001
Verbal response	5 (5–5)	5 (4–5)	<0.001
Motor response	6 (6–6)	6 (5–6)	<0.001
FOUR Score	16 (16–16)	16 (13–16)	<0.001
Brain stem	4 (4–4)	4 (4–4)	<0.001
Respiration	4 (4–4)	4 (4–4)	<0.001
Eye response	4 (4–4)	4 (3–4)	<0.001
Motor response	4 (4–4)	4 (3–4)	<0.001
Hypertension	53 (19.7%)	10 (30.3%)	0.157
Diabetes Mellitus	29 (10.8%)	3 (9.1%)	0.526
CAD	23 (8.6%)	4 (12.1%)	0.339
Heart failure	6 (2.2%)	1 (3%)	0.559
CRF	3 (1.1%)	0 (0%)	0.706
COPD	14 (5.2%)	2 (6.1%)	0.540
CVA	15 (5.6%)	2 (6.1%)	0.575
Active malignancy	5 (1.9%)	0 (0%)	0.558
Neurodegenerative disease	9 (3.3%)	2 (6.1%)	0.343
Epilepsy	11 (4.1%)	2 (6.1%)	0.426

CT Brain: Computed tomography of the brain, FOUR: Full Outline of Un-Responsiveness, GCS: Glasgow Coma Scale, CAD: Coronary artery disease, CRF: Chronic renal failure, COPD: Chronic obstructive pulmonary disease, CVA: Cerebrovascular accident.

Table 3: Analysis of the performance of the scores and their components in detecting the occurrence of clinically significant pathology on CT

	AUC (95%Confidence Interval)
Total FOUR	**0.665 (0.549–0.781)**
Total GCS	**0.664 (0.547–0.780)**
GCS-Motor response	0.635 (0.519–0.751)
GCS Verbal response	**0.649 (0.533–0.765)**
GCS Eye response	0.620 (0.504–0.735)
FOUR Brain stem	0.559 (0.447–0.670)
FOUR Respiration	0.545 (0.435–0.656)
FOUR Eye response	**0.650 (0.534–0.766)**
FOUR Motor response	0.635 (0.519–0.751)

AUC: Area under the curve, CT: Computed tomography, GCS: Glasgow Coma Scale, FOUR: Full Outline of Un-Responsiveness

Discussion

The primary objective of the current study was to assess the effectiveness of GCS, mGCS, and FOUR scores in predicting clinically significant brain injury among patients presenting to the emergency department with head trauma. To achieve this, epidemiologic data, such as age, sex, comorbid diseases, medication use, and the mechanism of trauma at admission, were systematically recorded. The investigation aimed to determine whether these data had any influence on the follow-up and treatment procedures of the patient in

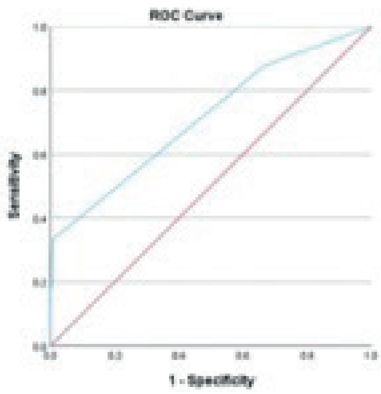

Figure 1: Performance of the regression model to detect the occurrence of clinically significant pathology on CT (ROC: Receiver Operating Characteristics).

Table 4: Diagnostic performance measures of GCS and FOUR scores at the optimal threshold value, for detecting the occurrence of clinically significant pathology on CT Brain

	GCS (Threshold:14)	FOUR Score (Threshold:11)	GCS-motor (Threshold: 5.5)
Sensitivity	33.3% (95%CI = 18–51.8)	15.2% (95%CI = 5.1–32)	27.3% (95%CI = 13.3–45.5)
Specificity	99.3% (95%CI = 97.3–99.9)	99.6% (95%CI = 98–99.9)	99.6% (95%CI = 97.9–99.9)
Positive likelihood ratio	44.8 (95%CI = 10.4–193.5)	40.8 (95%CI = 4.9–338.4)	73.4 (95%CI = 9.6–560.9)
Negative likelihood ratio	0.67 (95%CI = 0.53–0.85)	0.85 (95%CI = 0.74–0.98)	0.7 (95%CI = 0.6–0.9)
Positive predictive value	84.6% (95%CI = 56–96)	83.3% (95%CI = 37.6–97.7)	90% (95%CI = 54.1–98.6)
Negative predictive value	92.4% (95%CI = 90.5–93.9)	90.6% (95%CI = 89.2–91.8)	91.8% (95%CI = 90.1–93.2)
Accuracy	92% (95%CI = 88.4–94.8)	90.4% (95%CI = 86.5–93.5)	91.7% (95%CI = 88–94.6)

CT Brain: Computed tomography of the brain, GCS: Glasgow Coma Scale, FOUR: Full Outline of Un-Responsiveness

Table 5: Summary of the regression model to detect the occurrence of clinically significant pathology on CT.

	Coefficient B	Wald statistic	p value	Odds ratio (95%CI)
GCS	−1.066	9.865	0.002	0.334 (0.177–0.670)
Sex (male)	-1.030	3.299	0.069	0.357 (0.118–1.085)
Constant	13.293	6.990	0.008	

CT Brain: Computed tomography of the brain, GCS: Glasgow Coma Scale

the emergency department and on the overall outcomes. In a prior study, it was noted that the prehospitalization mGCS scores in patients with head trauma, who presented to the emergency department, were equally effective as the overall GCS in detecting clinically significant traumatic brain injury. Moreover, mGCS was suggested as a potential substitute for GCS due to its relative ease of application [8]. However, a study by Chou et al. reported that the total GCS score better predicted whether the patient had clinically significant traumatic brain injury when compared to the mGCS [12]. In another study, it was reported that, unlike the GCS, the FOUR score did not include a verbal component. This characteristic makes it feasible to utilize the FOUR score in limited groups, particularly in tracheostomized, aphasic, ventilator-dependent intubated patients, and unconscious patients presented to the emergency department. Additionally, the components for respiratory and brainstem reflexes were suggested to offer a more comprehensive assessment of patients in coma or vegetative state, particularly during the diagnosis and follow-up stages [13,14]. The findings of the present study indicate that scores from GCS, mGCS, or FOUR, and their respective components did not reach the diagnostic performance threshold to be used in isolation for predicting clinically significant CT pathology in patients presenting to the emergency department with head trauma. Notably, the specificity and negative predictive values of all three scores were quite high. According to the study results, patients with GCS, mGCS, or FOUR scores below the optimal threshold (14 points for GCS, 5.5 points for mGCS, and 11 points for FOUR score) should be considered at high risk for the occurrence of clinically significant pathology on CT. Therefore, due care should be taken in the follow-up of these patients. However, considering the low sensitivity of all three scores, relying solely on a patient's full score on the GCS, mGCS or FOUR scales in insufficient to exclude clinically significant brain injury. Consistent with similar studies in the relevant literature, the majority (68.2%) of the patients presenting to the emergency department with head trauma in the present study were male [15–17]. In conclusion, the inclusion of the sex variable, along with GCS or FOUR scores, contributed toa relative improvement in the performance of the regression model for predicting the occurrence of clinically significant brain injury on CT scans. The use of blood thinners has been reported to result in differences in patient outcomes. Several previous studies have indicated that intracranial incidence and mortality were elevated in cases of comorbid heart diseases and coagulopathy [18–20]. On the other hand, other studies have reported no significant difference in intracranial hemorrhage and mortality between patients with and without blood thinners [21]. According to the results of the present study, there was no increase in the incidence of intracranial hemorrhage in patients who received blood thinners. The findings of this study revealed no significant correlation between the duration of hospital stay and GCS, mGCS, and FOUR scores, as well as their subgroups.. These results align with previous studies in the relevant literature that had larger sample sizes. [7,22].

Limitations

The primary limitation of the current study lies in its single-center nature. Despite being designed as a prospective observational research, patient follow-ups were conducted through records and the hospital information system, potentially introducing bias to the data, albeit in adherence to relevant ethical principles. Additionally, the study faced a limitation in that only two patients died during follow-up, precluding an investigation into the effectiveness of scores in predicting mortality.

Conclusion

According to the findings of the present study, it can be concluded that the GCS, mGCS, and FOUR scores did not exhibit diagnostic performance sufficient to be used in isolation for predicting and excluding clinically significant brain injury in patients with head trauma. The study suggests that patients with GCS, mGCS, or FOUR scores below the optimal threshold (14 points for GCS, 5.5 points for mGCS, 11 points for FOUR score) should be regarded as at high risk for the occurrence of clinically significant pathology on CT. Therefore, careful attention should be given to the follow-up of these patients.

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