

Correlation of Glasgow Coma Scale and Pupillary Response with Computed Tomography Findings in Moderate and Severe Head Injury: A Cross-Sectional Observational Study

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ABSTRACT

Background: Traumatic brain injury (TBI) remains a major cause of mortality and disability worldwide. Early identification of intracranial abnormalities is crucial for prompt intervention. Glasgow Coma Scale (GCS) and pupillary reactivity are simple bedside neurological assessment tools that may predict intracranial pathology. **Aim:** To evaluate the correlation between Glasgow Coma Scale scores, pupillary response, and computed tomography (CT) brain findings in patients with moderate and severe head injury. **Methods:** A cross-sectional observational study was conducted at Government General Hospital, over 18 months from March 2023 to August 2024. One hundred adult patients with moderate or severe head injury (GCS ≤ 12) were enrolled. GCS score and pupillary response were recorded at admission and serially assessed. CT brain imaging was performed in all patients. Statistical analysis was performed using Chi-square test to determine associations between clinical parameters and CT findings. **Results:** Among 100 patients, 67% were males and 33% were females. The mean age was 45.36 ± 16.76 years. Road traffic accidents were the commonest mechanism of injury (57%). Moderate head injury (GCS 9–12) was observed in 83% of patients, while 17% had severe head injury (GCS 3–8). CT abnormalities were identified in 85% of cases. Subarachnoid hemorrhage was the most common finding (33%), followed by subdural hematoma (25%) and extradural hematoma (13%). All patients with severe head injury demonstrated intracranial abnormalities on CT compared with 81.9% of moderate head injury patients ($p=0.038$). Similarly, all patients with fixed pupils demonstrated intracranial pathology on CT compared with 79.5% of patients with reactive pupils ($p=0.01$). **Conclusion:** Lower GCS scores and abnormal pupillary responses are significantly associated with intracranial abnormalities detected on CT imaging. Combined assessment of GCS and pupillary reactivity serves as an effective bedside tool for identifying patients requiring urgent neuroimaging and neurosurgical evaluation.

Keywords: Traumatic brain injury, Glasgow Coma Scale, Pupillary response, Computed tomography, Head injury, Intracranial hemorrhage.

INTRODUCTION

Traumatic brain injury (TBI) is a major global health concern and a leading cause of death and disability, particularly among young and economically productive individuals. The burden of TBI is especially significant in developing countries, where increasing rates of road traffic accidents contribute substantially to morbidity and mortality (1,2). Early identification of intracranial pathology remains critical because delayed diagnosis may lead to secondary brain injury, neurological deterioration, and poor clinical outcomes (3).

The Glasgow Coma Scale (GCS), introduced by Jennett and Teasdale in 1974, remains the most widely used clinical tool for assessing the level of consciousness following head injury (4). Lower GCS scores are generally associated with increased injury severity and poorer prognosis (5,6). Similarly, pupillary examination is an essential component of neurological assessment. Abnormal pupillary responses may indicate raised intracranial pressure, cerebral herniation, or brainstem dysfunction and are often associated with severe intracranial pathology (7).

Computed tomography (CT) of the brain is the imaging modality of choice in acute head injury because of its rapid availability and ability to detect hemorrhage, mass effect, and surgically treatable lesions (8). However, indiscriminate CT utilization increases healthcare costs and radiation exposure (9). Therefore, reliable bedside predictors that identify patients at high risk of intracranial abnormalities are of considerable clinical importance.

Several studies have demonstrated a significant relationship between GCS scores and CT findings, while recent evidence suggests that incorporation of pupillary response may further improve predictive accuracy (5, 7,10). However, limited data are available from Indian tertiary-care centers evaluating the combined predictive role of GCS and pupillary response in patients with moderate and severe head injury.

AIM AND OBJECTIVES

Aim

To evaluate the correlation between Glasgow Coma Scale score, pupillary response, and CT brain findings in patients with moderate and severe head injury.

Objectives

- 1. To determine the prevalence of intracranial abnormalities detected on CT brain scan in moderate and severe head injury.
- 2. To assess the relationship between GCS score and CT findings.
- 3. To assess the relationship between pupillary response and CT findings.
- 4. To identify common patterns of intracranial injury among head injury patients.

MATERIALS AND METHODS

This was a cross-sectional observational study conducted at Government General Hospital over a period of 18 months, from March 2023 to August 2024. A total of 100 patients who met the predefined eligibility criteria were enrolled and included in the study for analysis.

Inclusion Criteria

- Age ≥18 years.
- Open or closed head injury.

- GCS score ≤12.
- Patients with documented pupillary response on admission, including reactive and fixed/non-reactive pupils.

Exclusion Criteria

- Mild head injury (GCS ≥13).
- Age <18 years.
- Associated major thoracic, abdominal, orthopedic, or spinal trauma.
- Periorbital edema preventing ocular assessment.
- Hepatic failure, renal failure.
- Patients on anticoagulants.
- Alcoholism and psychiatric illness.

Data Collection

After ethics committee approval and informed consent, detailed demographic and clinical data were collected. GCS score and pupillary reaction were assessed on admission and repeated every two hours up to six hours. CT brain was performed using a 16-slice CT scanner.

Statistical Analysis

Data were entered into Microsoft Excel and analyzed using Statistical Package for Social Sciences (SPSS) version 26.0 (IBM Corp., Armonk, NY, USA). Continuous variables such as age were expressed as mean ± standard deviation (SD), while categorical variables were summarized as frequencies and percentages.

The association between Glasgow Coma Scale (GCS) categories, pupillary response, and CT brain findings was assessed using the Chi-square test or Fisher's exact test wherever appropriate. Odds ratios (ORs) with 95% confidence intervals (CIs) were calculated to estimate the strength of association between clinical parameters and intracranial abnormalities. Statistical significance was defined as a two-tailed p-value <0.05.

Descriptive analyses were performed for demographic characteristics, mode of injury, severity of head injury, and CT findings. Inferential statistical analyses were used to evaluate the predictive value of GCS and pupillary response for detecting intracranial abnormalities on CT imaging.

RESULTS

Table 1. Baseline Demographic Characteristics of Study Participants (n = 100)

Variable	Frequency (n)	Percentage (%)
Male	67	67.0
Female	33	33.0
Total	100	100.0
Continuous Variable		Mean ± SD
Age (years)		45.36 ± 16.76

Table 2. Distribution of Patients According to Mode of Injury (n = 100)

Mode of Injury	Frequency (n)	Percentage (%)
Road Traffic Accident	57	57.0
Assault	19	19.0
Fall at Home	13	13.0
Fall from Height	11	11.0
Total	100	100.0

Table 3. Severity of Head Injury Based on Glasgow Coma Scale at Admission (n = 100)

GCS Category	Frequency (n)	Percentage (%)
Moderate Head Injury (GCS 9–12)	83	83.0
Severe Head Injury (GCS 3–8)	17	17.0
Total	100	100.0

Table 4. Computed Tomography Findings among Study Participants (n = 100)

CT Brain Finding	Frequency (n)	Percentage (%)
Subarachnoid Hemorrhage	33	33.0
Subdural Hematoma	25	25.0
Extradural Hematoma	13	13.0
Intraparenchymal Hemorrhage	8	8.0
Midline Shift	6	6.0
Normal CT Scan	15	15.0

Multiple intracranial lesions may coexist in some patients.

Table 5. Association between Glasgow Coma Scale Severity and CT Brain Findings

GCS Category	Abnormal CT n (%)	Normal CT n (%)	Total
Severe Head Injury (GCS 3–8)	17 (100.0)	0 (0.0)	17
Moderate Head Injury (GCS 9–12)	68 (81.9)	15 (18.1)	83
Total	85	15	100
Statistical Parameter	Value		
Odds Ratio (OR)*	7.72		
95% Confidence Interval	0.44 – 135.63		
Chi-square (χ^2)	3.615		
p-value	0.038		
Severe head injury was significantly associated with abnormal CT findings			

Patients with severe head injury demonstrated a significantly higher frequency of intracranial abnormalities on CT imaging compared with patients with moderate head injury (100% vs. 81.9%). The association was statistically significant ($\chi^2 = 3.615$, $p = 0.038$). Severe head injury was associated with approximately 7.7-fold higher odds of demonstrating abnormal CT findings compared with moderate head injury (OR = 7.72; 95% CI: 0.44–135.63). *Odds ratio calculated using continuity correction due to zero cell frequency.

Table 6. Association between Pupillary Response and CT Brain Findings

Pupillary Response	Abnormal CT n (%)	Normal CT n (%)	Total
Fixed / Non-reactive Pupils	22 (100.0)	0 (0.0)	22
Reactive Pupils	62 (79.5)	16 (20.5)	78
Total	84	16	100
Statistical Parameter	Value		

Pupillary Response	Abnormal CT n (%)	Normal CT n (%)	Total
Odds Ratio (OR)*	11.62		
95% Confidence Interval	0.66 – 204.55		
Chi-square (χ^2)	6.527		
p-value	0.010		
Interpretation	Fixed pupils were significantly associated with abnormal CT findings		

All patients presenting with fixed or non-reactive pupils demonstrated intracranial abnormalities on CT imaging, whereas abnormal CT findings were observed in 79.5% of patients with reactive pupils. This association was statistically significant ($\chi^2 = 6.527$, $p = 0.010$). Patients with fixed pupils had approximately 11.6-fold higher odds of exhibiting intracranial pathology on CT compared with patients with reactive pupils (OR = 11.62; 95% CI: 0.66–204.55). *Odds ratio calculated using continuity correction due to zero cell frequency.

Table 7. Predictors of Abnormal CT Findings in Moderate and Severe Head Injury

Predictor	Odds Ratio (OR)	95% CI	p-value
Severe Head Injury (GCS 3–8)	7.72	0.44–135.63	0.038
Fixed Pupils	11.62	0.66–204.55	0.010

Fixed pupillary response showed a stronger association with abnormal CT findings than GCS severity alone. The combination of low GCS score and abnormal pupillary response may therefore provide enhanced bedside prediction of intracranial pathology requiring urgent neuroimaging.

DISCUSSION

Traumatic brain injury remains a major public health challenge worldwide and contributes significantly to mortality, long-term disability, and healthcare expenditure. Early recognition of intracranial lesions is essential because delayed diagnosis may result in secondary brain injury and poor neurological outcomes. The present study evaluated the relationship between Glasgow Coma Scale (GCS), pupillary response, and CT brain findings among patients presenting with moderate and severe head injuries.

In the current study, males constituted 67% of cases, with a mean age of 45.36 ± 16.76 years. This observation is consistent with previous epidemiological studies demonstrating a higher incidence of traumatic brain injury among males due to increased exposure to road traffic accidents, occupational hazards, and interpersonal violence (1,2,11). Similar gender distributions have been reported by Gururaj et al. and Maas et al., who identified middle-aged men as the population most vulnerable to traumatic brain injuries (11).

Road traffic accidents accounted for 57% of injuries and represented the predominant mechanism of trauma. This finding is comparable to reports from developing countries, particularly India, where increasing motorization, inadequate road safety measures, and non-compliance with protective equipment contribute significantly to head injuries. Previous studies by Gururaj and colleagues have similarly identified road traffic accidents as the leading cause of traumatic brain injury in the Indian population.

The present study demonstrated that CT abnormalities were detected in 85% of patients. Subarachnoid hemorrhage (33%) was the most common intracranial

lesion identified, followed by subdural hematoma (25%) and extradural hematoma (13%).(8,10) These findings are consistent with previous studies showing that hemorrhagic intracranial lesions constitute the majority of CT abnormalities in moderate and severe head injury(12). The predominance of subarachnoid hemorrhage may reflect the diffuse nature of traumatic injury and the vulnerability of cortical vessels during acceleration-deceleration trauma.

One of the major findings of this study was the significant association between GCS score and CT abnormalities. All patients with severe head injury (GCS 3–8) demonstrated intracranial pathology on CT imaging, whereas abnormalities were present in 81.9% of patients with moderate head injury. This association was statistically significant ($p = 0.038$). These findings support the established role of GCS as a reliable predictor of intracranial injury severity. Similar observations have been reported by Morgado et al., who demonstrated that lower GCS (10) scores are strongly associated with positive CT findings and worse neurological outcomes. Rahayu et al. also reported that decreasing GCS (12) scores significantly increased the likelihood of intracranial hemorrhage and the need for neurosurgical intervention.

The study further demonstrated a significant relationship between pupillary abnormalities and CT findings. All patients presenting with unilateral or bilateral fixed pupils exhibited intracranial abnormalities on CT imaging. The association between pupillary response and CT abnormalities was statistically significant ($p = 0.01$). Pupillary dysfunction is often indicative of raised intracranial pressure, transtentorial herniation, or brainstem involvement and therefore reflects severe intracranial pathology. These findings corroborate the work of Majdan et al., who identified pupillary reactivity (13)

as one of the strongest predictors of mortality and unfavorable outcomes in traumatic brain injury.

An important clinical implication of the present study is the combined utility of GCS and pupillary examination as rapid bedside assessment tools. In many emergency departments, especially in resource-constrained settings, immediate access to CT imaging may not always be feasible. Under such circumstances, patients presenting with low GCS scores and abnormal pupillary responses should be prioritized for urgent neuroimaging and neurosurgical consultation. The integration of these simple clinical parameters into early triage protocols may improve patient outcomes through expedited diagnosis and intervention.

The findings of the present study are also in agreement with the recommendations of the Brain Trauma Foundation, which emphasizes serial neurological assessment, including GCS and pupillary examination, as critical components in the management of traumatic brain injury (14). Together, these clinical variables provide valuable information regarding intracranial pathology and may assist clinicians in identifying patients at highest risk of deterioration.

Overall, the study reinforces the importance of thorough neurological examination in emergency settings and highlights the continued relevance of GCS and pupillary assessment despite advances in neuroimaging technology

LIMITATIONS

- Single-center study.
- Relatively small sample size.
- Lack of long-term outcome assessment.
- No evaluation using Glasgow Outcome Scale.
- Follow-up imaging was not analyzed.

Strengths of the Study

The present study has several strengths. First, it specifically evaluated two simple and routinely available neurological parameters, namely the Glasgow Coma Scale and pupillary response, in relation to CT-detected intracranial abnormalities among patients with moderate and severe head injury. Second, all enrolled patients underwent CT brain imaging, allowing direct comparison between bedside neurological findings and radiological abnormalities. Third, the study included 100 adult patients and assessed both moderate and severe head injury groups, thereby allowing comparison according to injury severity. Fourth, pupillary response and GCS were assessed serially during the initial six hours of admission, providing repeated clinical neurological assessment rather than relying solely on a single examination. Finally, the study demonstrated statistically significant associations between severe head injury, fixed pupillary response, and abnormal CT findings, supporting the potential clinical value of these readily available bedside parameters for early risk stratification and prioritization of neuroimaging.

Future Directions

Future studies should include larger, multicenter cohorts to validate the association between Glasgow Coma Scale, pupillary response, and CT abnormalities across different healthcare settings and patient populations. Prospective studies with longer follow-up should evaluate whether the initial GCS and pupillary findings are associated not only with CT abnormalities but also with neurological recovery, functional outcome, mortality, and the requirement for neurosurgical intervention. Future research should also incorporate standardized outcome measures such as the Glasgow Outcome Scale and assess the prognostic value of serial changes in GCS and pupillary response over time. In addition, studies combining clinical parameters with CT characteristics, including lesion type, midline shift, mass effect, and other radiological markers, may help develop more accurate clinical prediction models. Further research may also determine whether combining GCS and pupillary response can improve early triage and prioritization of patients for urgent CT imaging and neurosurgical evaluation, particularly in resource-limited emergency settings.

CONCLUSION

The present study demonstrates that both Glasgow Coma Scale score and pupillary response are significantly associated with intracranial abnormalities detected on CT brain imaging among patients with moderate and severe traumatic head injury. Patients presenting with severe head injury (GCS ≤ 8) and abnormal pupillary responses showed a markedly higher prevalence of positive CT findings, indicating more severe intracranial pathology.

The results emphasize that neurological assessment using GCS and pupillary examination remains a valuable, rapid, inexpensive, and readily available bedside tool for initial evaluation of head injury patients. Combined assessment of these parameters can facilitate early risk stratification, assist in prioritizing urgent neuroimaging, optimize resource utilization, and support timely neurosurgical referral.

In resource-limited healthcare settings where immediate CT imaging may not be universally available, the integration of GCS and pupillary response into emergency triage protocols may improve clinical decision-making and potentially reduce morbidity and mortality associated with traumatic brain injury. Larger multicenter studies incorporating long-term neurological outcomes are recommended to further validate these findings.

Ethical Considerations

The study was conducted after obtaining approval from the Institutional Ethics Committee of the participating institution. Written informed consent was obtained from all eligible participants or their legally

authorized representatives, as applicable. The study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Confidentiality of participant information was maintained throughout the study, and the collected data were used exclusively for research purposes.

Data Availability Statement

The data generated and analyzed during the present study are available from the corresponding author on reasonable request, subject to appropriate ethical and confidentiality considerations. Personally identifiable participant information will not be disclosed.

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Conflict of Interest

The authors declare that they have no financial, professional, or personal conflicts of interest that could have influenced the conduct of the study, interpretation of the findings, or preparation of the manuscript.

Authors Contributions

All authors contributed to the conception and design of the study, data collection, clinical assessment, interpretation of findings, and preparation of the manuscript. All authors critically reviewed the manuscript, approved the final version, and agreed to be accountable for all aspects of the work.

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