RESEARCH ARTICLE

Correlation of Glasgow coma scale (GCS) score and neuroimaging radiological interpretation system (NIRIS) in patients with traumatic brain injury (TBI)

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Abstract

Objective: To determine the correlation of the Glasgow Coma Scale score and different Neuroimaging Radiological Interpretation System categories in patients with traumatic brain injury.

Method: The prospective observational study was conducted at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma, Karachi, from July to December 2023, and comprised patients aged at least 18 years with documented traumatic brain injury. The patient underwent assessment in the emergency department. The mechanism of injury, and Glasgow Coma Scale score at the time of hospital arrival were noted. A non-contrast head computed tomography scan was done to acquire images of sufficient quality for Neuroimaging Radiological Interpretation System classification. Data was analysed using SPSS 23.

Results: Of the 388 patients with mean age 33.44±18.51 years, 319(82.2%) were males and 69(17.8%) were females. Road traffic accidents accounted for 283(72.9%) cases. Glasgow Coma Scale-based severity classification revealed mild traumatic brain injury in 185(47.7%), moderate in 100(25.8%) and severe in 103(26.5%) patients. Neuroimaging Radiological Interpretation System category distribution showed category 2 being the most frequent 165(42.5%), while category 0 was least common 5(1.3%). There was a strong negative correlation between Glasgow Coma Scale scores and Neuroimaging Radiological Interpretation System categories (p=0.001), with the coefficient of determination indicating that 27.4% of Glasgow Coma Scale score variance was explained by Neuroimaging Radiological Interpretation System classification.

Conclusion: There was a negative correlation between Neuroimaging Radiological Interpretation System category and Glasgow Coma Scale score in patients with traumatic brain injury.

Key Words: Traumatic brain injury, Glasgow Coma Scale, NIRIS.

(JPMA 75: 1883; 2025) **DOI: https://doi.org/10.47391/JPMA.25-23187**

Introduction

Traumatic brain injury (TBI) is a leading cause of morbidity and mortality among patients with traumatic injuries worldwide.[1] An estimated 69 million individuals are affected by TBIs each year, with road traffic accidents (RTAs) being the most common mechanism of trauma.[2] The Neuroimaging Radiological Interpretation System (NIRIS) was developed in 2018 to address critical gaps in TBI imaging interpretation and clinical decision-making, and represents a paradigm shift from descriptive radiology reporting to management-oriented classification.[3] The system consolidates complex neuroimaging findings into five ordinal categories (NIRIS 0-4) based on increasing severity of brain injury, with each category corresponding to specific clinical management pathways (Table 1). Unlike traditional classification systems focused primarily on outcome prediction, NIRIS was specifically designed to guide immediate clinical decision-making regarding patient disposition, monitoring requirements, and intervention timing.[4]

The Glasgow Coma Scale (GCS) was developed to assess impaired consciousness which was then used to predict outcomes in patients with severe brain injury.[5,6] While NIRIS provides objective imaging-based assessment, GCS remains the gold standard for clinical neurological evaluation in TBI patients. GCS shows inter-rater variability, especially in intubated patients, and clinical assessment may be confounded by substance use, sedation or other injuries.[7] The relationship between these complementary assessment tools has important clinical implications, as combined clinical and imaging evaluation may provide superior patient assessment compared to either tool alone. Understanding the correlation between NIRIS categories and GCS scores is essential for developing integrated assessment protocols and optimising patient management strategies.

Multiple validation studies have demonstrated NIRIS superiority over existing TBI classification systems in predicting patient management needs. Wu et al. reported

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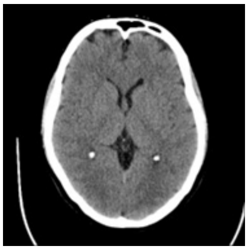
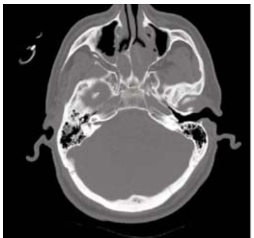
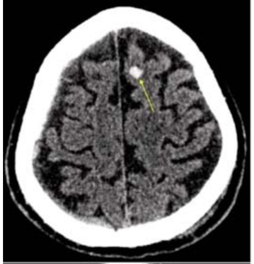
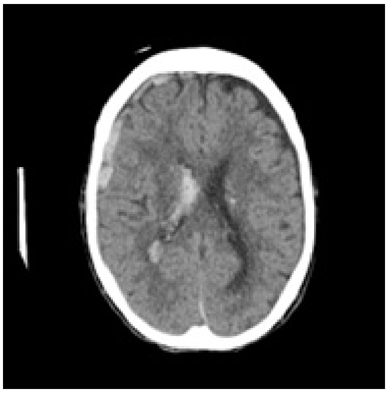
Submission complete: 10-01-2025 **First Revision received:** 26-04-2025

Acceptance: 13-08-2025 **Last Revision received:** 12-08-2025

Table-1: The Neuro-Imaging Radiological Interpretation System (NIRIS).

Category	Definition		CT Scan/GCS
NIRIS 0	No abnormal finding		Normal CT GCS 15/15
NIRIS 1	Fracture ± Extra-axial hematoma, parenchymal hematoma or parenchymal contusion < 0.5 cc ± Subarachnoid haemorrhage		Left Occipital Fracture GCS 15/15
			Left Frontal Parenchymal contusion GCS 14/15
			Right Subarachnoid Haemorrhage GCS 14/15
NIRIS 2	Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 0.5 cc ± Diffuse axonal injury ± Intraventricular haemorrhage ± Mild hydrocephalus ± Midline shift 0-5mm		Right Suddural Hematoma with Intraventricuar Haemorrhage GCS 11/15

NIRIS 3	Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 5 cc ± Moderate hydrocephalus ± Midline shift > 5mm ± Focal herniation		Right Extradural Hematoma with Uncal Herniation GCS 10/15
			Left Subdural Hematoma with Mildline shift >5mm GCS 9/15
NIRIS 4	Extra-axial hematoma, parenchymal hematoma or parenchymal contusion > 25 cc ± Severe hydrocephalus ± Diffuse herniation/Duret haemorrhage		Left Subdural Hematoma with Mildline shift >5mm GCS 9/15

GCS: Glasgow Coma Scale, CT: Computed tomography.

91.2% accuracy for predicting patient management decisions using NIRIS, outperforming both Marshall and Rotterdam classifications.[8] Similarly, Zhou et al. confirmed excellent inter-rater reliability (kappa [κ]=0.85) and strong correlation with clinical outcomes across diverse patient populations[4], similar to Chen et al., and Vehviläinen et al., who also demonstrated NIRIS clinical utility across different populations.[9,10] Sadighi et al. also confirmed NIRIS superior performance for management decisions while maintaining similar mortality prediction compared to Marshall and Rotterdam systems.[11]

The current study was planned to evaluate the correlation between NIRIS categories and GCS scores in TBI patients.

Patients and Methods

The prospective, observational study was conducted at the Shaheed Mohtarma Benazir Bhutto Institute of Trauma, Karachi, from July to December 2023. After approval from the institutional ethics review committee, the sample was raised using consecutive, non-probability sampling technique. The sample size was calculated based on estimated TBI prevalence of 20.48% (p)[12] with a relative precision of 20% (d) using the formula: N= 4pq/ d^2.[13] The 20% relative precision was chosen to ensure adequate representation of higher NIRIS categories[3-4] which are less common, but clinically critical. This approach ensured sufficient statistical power across all NIRIS categories while maintaining clinical relevance.

All aged at least 18 years with documented TBI were included. Patients who were pregnant, had pre-existing neurological conditions affecting baseline neurological functions (dementia, stroke, brain tumour), comfort care designation at presentation, concurrent extracranial injuries requiring surgical intervention, and previous cranial surgery (altered anatomy affecting imaging interpretation) were excluded.

Consecutive patients meeting the inclusion criteria were prospectively enrolled upon presentation to the emergency department (ED) after taking informed consent. Clinical data and imaging studies were collected in real-time using standardised data collection forms completed for each patient at the time of presentation. The mechanism of injury and GCS score documented at the time of hospital arrival were noted. Non-contrast head computed tomography (CT) images of sufficient quality for NIRIS classification were acquired. The patients were stratified by initial GCS scores using established criteria: severe TBI: GCS 3-8; moderate TBI: GCS 9-13; and mild TBI: GCS 14-15. Injury mechanism stratification was defined as RTAs, falls from height (>3 feet), falls from standing height, assault/violence-related, sports-related and other mechanisms. Time window specifications were defined as injury to hospital arrival <6 hours, hospital arrival to GCS assessment <2 hours, and GCS assessment to CT scan <4 hours.

Standardised NIRIS classification forms were developed. Systematic review approach for each scan was used, including survey for skull fractures, assessment for extra-axial collections, evaluation of parenchymal lesions, measurement of midline shift, assessment of ventricular system and volume measurement. All classifications were documented immediately after review.

All non-enhanced head CT scans were interpreted by two trained neurosurgeons with minimum 3 years of experience who underwent NIRIS classification training workshop prior to the study initiation. They were in current active practice with regular CT interpretation duties and had familiarity with institutional CT protocols and NIRIS classification criteria. Neurosurgeons independently reviewed each CT scan using standardised NIRIS criteria. Discrepancies between the interpreters were resolved through discussion and consensus. All interpretations were documented immediately after review.

Data was managed using Microsoft Excel 2019 and it was analysed using SPSS 23. Mean ± standard deviation was calculated for continuous variables, while categorical variables were presented as frequencies and percentages. The correlation between GCS score and NIRIS categories was evaluated using Spearman's rank correlation coefficient over Pearson's correlation due to the ordinal nature of both GCS scores and NIRIS categories, non-normal distribution of variables, and potential for non-linear monotonic relationships between clinical and imaging severity measures. $P<0.05$ was considered significant.

Results

Of the 388 patients with mean age 33.44±18.51 years (range 18-80 years), 319(82.2%) were males, and 93(23.9%) were aged 21-30 years. RTAs were the predominant injury mechanism 283(72.9%), followed by fall from height 85(21.9%). Based on initial GCS scores, mild TBI was the most common 185(47.7%), followed by severe TBI 103(26.5%), and moderate TBI 100 (25.8%). NIRIS category 2 was the most frequent classification 165(42.5%), followed by category 1 153(39.4%). NIRIS categories 3 and 4 were present in 34(8.8%) and 31(8.0%) patients, respectively, while only 5(1.3%) had NIRIS category 0 (Table 2).

Table-2: Demographic, clinical and radiological parameters.

Characteristic	n (%) or Mean ± SD
Age (years)	
Mean ± SD	33.44 ± 18.51
Age groups (years)	
1-10	45 (11.6)
11-20	57 (14.7)
21-30	93 (23.9)
31-40	73 (18.9)
41-50	49 (12.7)
51-60	37 (9.5)
61-70	27 (6.9)
71-80	7 (1.8)
Gender	
Male	319 (82.2)
Female	69 (17.8)
Injury Mechanism	
Road traffic accident	283 (72.9)

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Fall from height	85 (21.9)
Assault	13 (3.4)
Fall from standing height	4 (1.0)
Other	3 (0.8)
TBI Severity (GCS Score)	
Severe (3-8)	103 (26.5)
Moderate (9-12)	100 (25.8)
Mild (13-15)	185 (47.7)
NIRIS Category	
0	5 (1.3)
1	153 (39.4)
2	165 (42.5)
3	34 (8.8)
4	31 (8.0)

TBI: Traumatic brain injury, GCS: Glasgow Coma Scale, NIRIS: Neuro-Imaging Radiological Interpretation System, SD: Standard deviation.

the current study, suggesting a greater severity of TBIs. The majority of the patients with mild TBI with GCS score of 13-15 fell in the NIRIS category 1 compared to patients with moderate and severe TBIs falling into NIRIS category 2. NIRIS categories 3-4 had the highest proportion of patients with severe TBI.

Based on established statistical guidelines, the Spearman's correlation coefficient of rs=-0.52 represented a strong negative association between GCS scores and NIRIS categories. Cohen's conventions classify correlation strengths as small (r=0.10-0.29), medium (r=0.30-0.49) and large (r≥0.50).[17] Th current findings exceeded the threshold for a large effect size, indicating a robust and clinically meaningful relationship between the assessment tools. This strong correlation magnitude is consistent with other validation studies in the literature.[3,10] The consistency of these strong correlations across diverse populations supports the fundamental relationship between imaging severity and clinical neurological function in TBI patients.

Table-3: Correlation analysis results.

Analysis	n	Correlation Coefficient	95% CI	p-value	R^2
Spearman's correlation(GCS vs NIRIS)	388	-0.523	[-0.590, -0.450]	<0.001	0.274

GCS: Glasgow Coma Scale, NIRIS: Neuro-Imaging Radiological Interpretation System, CI: Confidence interval

There was a significant strong negative correlation between GCS scores and NIRIS categories (rs=-0.523, p=0.001, 95% confidence interval [CI] -0.590--0.450). The coefficient of determination (R^2=0.274) indicated that 27.4% of the variance in GCS scores was explained by NIRIS categories (Table 3).

Discussion

TBI is a major cause of mortality and morbidity, with RTAs being the most common cause in many parts of the world, including Southeast Asia (56%).[2] Young males between aged 21-40 years were the most affected population segment (42.8%) in the current study, which was similar to another study conducted by Yaqoob et al., at a tertiary centre in Pakistan (39.6%), with RTAs being the most common mode of trauma (39%).[14] Studies in other low- and middle-income countries (LMICs), like India, also reported RTAs as the major cause of TBIs (60%) .[15] This correlates with younger population in Pakistan with lack of public awareness and disregard for road safety, speeding, helmet and seat belt use, and road infrastructure.[16]

The most common NIRIS category was 1 for patients aged 18-20 years, while the most common NIRIS category was 2 in the age group 21-80 years. A study conducted using the Finnish Intensive Care Consortium database in 2022 showed that the NIRIS 2 was the most frequent category .[10] Patients with RTAs had a higher NIRIS category compared to patients with a history of fall from height in

The coefficient of determination (R^2=0.27) indicated that NIRIS categories explained 27% of the variance in GCS scores among the current TBI patients. While this represented a substantial proportion of explained variance, the remaining 73% reflected the multifactorial nature of neurological presentation in TBIs, which includes factors not captured by structural imaging alone, like physiological variables (hypoxia, hypotension, metabolic derangements), medication effects (sedation, paralysis, intoxication), and pre-existing neurological conditions. Understanding this relationship helps clinicians appreciate that while NIRIS provides valuable objective information, it should complement rather than replace comprehensive clinical assessment. The combination of both tools likely captures a more complete picture of injury severity than either assessment alone.

The observed negative correlation between GCS scores and NIRIS categories reflected the underlying pathophysiological relationship between structural brain injury and neurological dysfunction.[18] Higher NIRIS categories[3-4] are characterised by larger hematomas (>5cc and >25cc, respectively) and significant midline shift (>5mm), which create mass effect compressing critical structures, including the brainstem reticular activating system. This compression directly impairs consciousness mechanisms, resulting in reduced eye opening responses and altered arousal states reflected in lower GCS scores.[18] Progressive intracranial hypertension associated with expanding haemorrhages and cerebral oedema in higher NIRIS categories leads to decreased cerebral perfusion pressure and secondary brain injury. This pathophysiological cascade manifests as motor dysfunction, with patients progressing from purposeful movement (GCS motor 6) to abnormal posturing (GCS motor 2-3) as intracranial pressure increases.[18] Diffuse axonal injury and cortical contusions present in NIRIS categories 2-4 disrupt neural networks essential for higher cognitive function. These structural injuries directly correlate with impaired verbal responses and confusion, contributing to lower verbal component scores in the GCS assessment.[18] The extent of parenchymal injury visible on CT imaging, thus providing an objective correlate to the subjective clinical assessment of neurological function.

NIRIS was developed to predict management and clinical outcomes in patients with TBIs based on non-contrast head CT scan findings. It has been validated by several studies and found to be a good adjunct in deciding patient disposition and guiding clinical management and decision-making regarding treatment options for patients with TBI. Wu et al. conducted a comprehensive comparison of NIRIS, Marshall and Rotterdam classifications in 882 moderate-to-severe TBI patients, finding that NIRIS had the strongest correlation with mortality (odds ratio [OR] 4.83; 95%CI: 3.2-7.1) and achieved 91.2% accuracy for predicting patient management decisions, significantly outperforming Marshall (78.3%) and Rotterdam (82.1%) classifications.[8] The superior management prediction capability of NIRIS stems from its outcome-based design philosophy. Unlike Marshall classification, which focuses primarily on CT morphology, NIRIS categories directly correspond to management algorithms: NIRIS 0-1 typically require observation, NIRIS 2 indicates need for intensive monitoring, NIRIS 3 suggests neurosurgical consultation, and NIRIS 4 mandates immediate intervention. This direct clinical applicability was validated by Sadighi et al., who reported 89% concordance between NIRIS categories and actual management decisions versus 71% for Marshall classification.[11] NIRIS also demonstrates superior inter-rater reliability compared to traditional systems. Zhou et al. reported excellent agreement for NIRIS classification (κ=0.85; 95%CI: 0.78-0.92) compared to moderate agreement for Marshall classification (κ=0.64) in the same patient cohort.[4] This improved reliability stems from NIRIS's clear volumetric thresholds and standardised terminology, reducing subjective interpretation variability that affects traditional systems. The simplified five-category structure of NIRIS offers practical advantages over more complex systems. Chen et al. demonstrated that NIRIS could be accurately applied by non-radiologist physicians after brief training, with agreement rates >90% compared to expert interpretations.[9] This accessibility facilitates implementation in resource-limited settings where specialised neuroradiology expertise may be unavailable.

Although the current study did not collect outcome data, the observed GCS-NIRIS correlation has important theoretical implications for patient prognosis. Patients with concordant severe findings (high NIRIS categories and low GCS scores) likely represent those with both significant structural damage and functional impairment, potentially indicating worse prognoses. Conversely, patients with discordant findings may have different outcome trajectories that warrant further investigation.

The correlation between NIRIS and GCS may also predict long-term functional outcomes. Structural brain injury visible on initial CT imaging often determines the ceiling for neurological recovery, while initial GCS score reflects the baseline from which recovery occurs. Patients with high NIRIS categories, but relatively preserved GCS scores may have better recovery potential than those with concordant severe findings on both assessments. This relationship supports the development of integrated triage algorithms, incorporating both clinical and imaging assessments. For example, patients with NIRIS 3-4 categories and GCS score <8 may require immediate neurosurgical intervention, while those with NIRIS 1-2 and GCS score >12 may be appropriate for observation protocols. Such algorithms could improve resource allocation and patient safety in busy trauma centres.

Prospective studies are urgently needed to validate these theoretical relationships in Pakistani patient population. Specific research priorities include development of combined GCS-NIRIS prognostic models, validation of integrated triage algorithms, assessment of cost-effectiveness for combined assessment protocols, and evaluation of implementation barriers in resource-limited settings. Such studies would provide the evidence base necessary for clinical guideline development and quality improvement initiatives.

Studies like the current one need to be conducted on much larger scales to validate the findings in collaboration with accident and emergency centres in the country that refer patients to level 1 trauma centres. The

NIRIS should also be validated in Pakistani population to assess the predictive value in guiding clinical management and decision-making regarding treatment options for TBI patients.

The current single-centre study at a level I trauma centre may limit external validity in several ways. The institution's patient population may differ from other settings in terms of injury severity, referral patterns, and demographic characteristics. Additionally, the institutional protocols for CT imaging, clinical assessment and NIRIS interpretation may not be generalisable to centres with different resources, expertise, or patient volumes. Although the current study employed consecutive enrolment, this represents a non-probability sampling method that may have introduced selection bias. Potential sources of bias included temporal variations in patient acuity during the study period, seasonal differences in injury patterns, variations in referral patterns to the trauma centre, and potential exclusion of patients with the most severe injuries who died before assessment. These factors may have limited the generalisability of the current findings to the broader TBI population, and could have affected the strength of the observed correlation.

The lack of formal inter-rater reliability assessment for NIRIS classification represented a significant limitation that may have affected the reliability of the current imaging assessments. Additionally, GCS scoring variability between different clinical assessors was not evaluated, potentially introducing measurement error in the primary outcome variable. The interpretation of CT scans by neurosurgeons rather than neuro-radiologists may have also limited comparability with other studies using different interpreter types. The absence of functional outcome data also prevented validation of the clinical significance of the observed correlation. Without long-term follow-up, it cannot be determined whether or not the GCS-NIRIS relationship translates into meaningful differences in patient outcomes, limiting the clinical applicability of the findings.

Conclusion

There was a negative correlation between NIRIS category and GCS score in patients with TBIs. This can be used as a guide in deciding patient disposition and guiding clinical management and decision-making regarding treatment options.

Disclaimer: None.

Conflict of Interest: None.

Source of Funding: None.

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AUTHOR'S CONTRIBUTION:
MN & ASK: Concept, design, data acquisition, analysis, interpretation, drafting, revision and accountability.
MFA: Concept, design, data interpretation, revision, accountability, supervision and proof reading.
IAS, MAKR & TB: Concept, design, data interpretation, revision, accountability and proof reading.