Section: Neurosurgery

Original Research Article

CLINICAL AND FUNCTIONAL OUTCOMES OF TRAUMATIC BRAIN INJURY WITH EMPHASIS ON DIFFUSE AXONAL INJURY: A PROSPECTIVE OBSERVATIONAL STUDY

Akhil Prakash[1], Mahesh Narayan Tiwari[2], Jitendra Kumar[3], Dinesh Singh[4], Prashant Sharma[4]

[1]Professor and Head, Department of Neurosurgery, LLRM Medical College Meerut, Uttar Pradesh, India
[2]Associate Professor, Department of Neurosurgery, LLRM Medical College Meerut, Uttar Pradesh, India
[3]Senior Resident, Department of Neurosurgery, LLRM Medical College Meerut, Uttar Pradesh, India
[4]Assistant Professor, Department of Neurosurgery, LLRM Medical College Meerut, Uttar Pradesh, India

Received : 16/08/2025
Received in revised form : 05/10/2025
Accepted : 22/10/2025

Keywords:
Traumatic Brain Injury, Diffuse Axonal Injury, Glasgow Coma Scale, Glasgow Outcome Scale – Extended, Prognosis, Neurosurgery.

Corresponding Author:
Dr. Jitendra Kumar,
Email: krathour31@gmail.com

DOI: 10.47009/jamp.2025.7.6.10

Source of Support: Nill,
Conflict of Interest: None declared

Int J Acad Med Pharm
2025; 7 (6); 51-57

ABSTRACT

Background: Traumatic brain injury (TBI) is a leading cause of morbidity and mortality, particularly among young adults. While various injury subtypes such as diffuse axonal injury (DAI), contusions, and hematomas present with distinct clinical challenges, few studies have systematically correlated diagnosis type, GCS score, and treatment modality with functional outcomes in the Indian context. The objective is to assess the clinical profile, radiological findings, and outcomes of TBI patients using standardized measures including the Glasgow Coma Scale (GCS) and Glasgow Outcome Scale – Extended (GOSE), with specific focus on the prognostic implications of DAI and time to hospital admission. **Materials and Methods:** This prospective observational study included 104 TBI patients admitted to the Department of Neurosurgery at SVBP Hospital, LLRM Medical College, Meerut, between October 2023 and March 2025. Data collected included demographics, injury characteristics, GCS at admission and 48 hours, radiological diagnosis, management modality, complications, and outcomes. Functional outcome was assessed using the GOSE. Data were analyzed using SPSS v26; Chi-square tests were used for association analysis, with $p < 0.05$ considered statistically significant. **Result:** The most affected age group was 30–39 years (25%), and 77.88% of patients were male. Road traffic accidents accounted for 64.42% of injuries. At admission, 44.23% had mild TBI, 31.73% moderate, and 24.04% severe. DAI (13.5% of cases) was associated with the highest mortality (64%) and poorest functional outcomes. Only 1 out of 14 DAI patients achieved good recovery (GOSE 7–8). A highly significant correlation was found between injury type and GOSE outcome ($p < 0.00001$), with better outcomes observed in cases of extradural hematoma (EDH) and depressed skull fracture. GCS at 48 hours was the strongest predictor of outcome, with mortality rates of 52% for GCS <9 compared to 2.2% for GCS >13 ($p < 0.000001$). No statistically significant association was found between time to hospital admission and mortality ($p = 0.78$). Conservative management was employed in 71.15% of cases, while surgical intervention was associated with better outcomes in select patients, particularly those with EDH or depressed fractures. A significant association was observed between management type and outcome ($p < 0.001$). The majority of patients (63.5%) were discharged within 4–11 days, and post-TBI complications included headache (54.81%), seizures (15.38%), and hemiparesis (8.66%). Overall, 52.88% of patients achieved good recovery (GOSE 7–8), 28.85% had moderate to severe disability, and 18.27% died. **Conclusion:** GCS at 48 hours, type of radiological diagnosis, and management strategy are strong predictors of functional outcome in TBI patients. DAI remains associated with the poorest prognosis, reinforcing the need for early MRI detection and intensive care. GOSE is an effective tool for stratifying recovery, and individualized treatment strategies based on clinical and radiological parameters are essential for optimizing outcomes.

INTRODUCTION

Traumatic brain injury (TBI) is a leading cause of death and disability worldwide, affecting individuals across all age groups but particularly those in the productive years of life. Globally, millions suffer from TBI each year, with outcomes ranging from full recovery to severe disability or death.[1-3] The burden is especially acute in low- and middle-income countries due to insufficient prehospital care, delayed access to neurosurgical facilities, and lack of standardized rehabilitation systems.

In India, the incidence of TBI is rising at an alarming rate, primarily driven by the increasing number of road traffic accidents (RTAs).[1] National data suggest that more than 400,000 road crashes occur annually, with a significant proportion resulting in head injuries.[2] These injuries often affect young males, representing a critical public health issue with major social and economic consequences.

TBI encompasses a wide spectrum of clinical presentations, from mild concussions to severe brain injuries requiring intensive care and neurosurgical intervention. Mild TBI accounts for the majority of cases and may often go underdiagnosed or undertreated.[4] On the other end of the spectrum, severe forms such as diffuse axonal injury (DAI) are associated with poor outcomes and are frequently caused by high-velocity trauma or rotational acceleration, as seen in falls, RTAs, and assaults.[5–7] DAI, in particular, represents a neuropathological challenge, often diagnosed through imaging or confirmed post-mortem, and is linked with a disproportionately high mortality and poor neurological recovery.[6,7] Despite its clinical relevance, the diagnosis and management of DAI and other intracranial pathologies are inconsistently addressed in routine trauma care in India.

Given the heterogeneity in injury types, treatment approaches, and patient outcomes, there remains a need for localized data to guide clinical decision-making. This study was therefore undertaken to evaluate the clinical profile, radiological characteristics, and functional outcomes of TBI patients in a tertiary care setting in India, with particular emphasis on the prognostic significance of GCS scores, time to admission, and diagnosis subtypes such as DAI.

Objectives

Primary objective:

- To evaluate the clinical, radiological, and functional outcomes of patients with traumatic brain injury (TBI) admitted to a tertiary care hospital.

Secondary Objectives:

- To analyze the association between Glasgow Coma Scale (GCS) scores at admission and at 48 hours with patient outcomes, including mortality and functional recovery.
- To assess the impact of diagnosis subtypes (e.g., diffuse axonal injury, EDH, SDH, contusions) on prognosis.
- To examine the relationship between time to hospital admission and final outcomes.
- To compare functional outcomes based on different treatment modalities (conservative vs. surgical).

MATERIALS AND METHODS

This prospective observational study was conducted in the Department of Neurosurgery at SVBP Hospital, LLRM Medical College, Meerut, over a period of 18 months, from October 2023 to March 2025. The study included 104 patients who were admitted with clinical and radiological evidence of traumatic brain injury (TBI). Inclusion criteria were patients aged 18 years and above, with a confirmed diagnosis of TBI, admitted within 48 hours of injury, and who provided informed consent either personally or via a legally authorized representative. Patients with penetrating head injuries, polytrauma requiring major surgical interventions in other specialties, or pre-existing neurological or psychiatric disorders were excluded from the study.

Data were collected using a structured pro forma at the time of admission and during the hospital stay. Collected variables included demographic details (age and sex), mode and mechanism of injury, and time elapsed between trauma and hospital presentation. Neurological status was assessed using the Glasgow Coma Scale (GCS) at the time of admission and again at 48 hours post-admission. Radiological diagnoses were obtained through non-contrast computed tomography (CT) or magnetic resonance imaging (MRI), and included findings such as diffuse axonal injury (DAI), extradural hematoma (EDH), subdural hematoma (SDH), haemorrhagic contusions, and depressed skull fractures. Management strategies were categorized as either conservative or surgical, with surgical interventions including craniotomy with hematoma evacuation, decompressive craniectomy, and elevation of depressed fractures.

Complications during hospital stay, including seizures, cerebrospinal fluid (CSF) leaks, hemiparesis, vomiting, and post-traumatic headaches, were documented. The duration of hospitalization was recorded, and the final outcome was assessed using the Glasgow Outcome Scale – Extended (GOSE) at the time of discharge.

Data were entered and cleaned in Microsoft Excel and analyzed using IBM SPSS Statistics for Windows, version 26.0 (IBM Corp., Armonk, NY, USA). Categorical variables were expressed as frequencies and percentages. The Chi-square test was applied to assess associations between variables such as GCS scores, diagnosis types, treatment modalities, and patient outcomes. A p-value of less than 0.05 was considered statistically significant.

ISSN(O):2687-5365;ISSN(P):2753-6556

RESULTS

1. Demographics and Injury Characteristics

A total of 104 patients with traumatic brain injury (TBI) were included in the study. The cohort was predominantly male and composed mostly of individuals in their second to fourth decades of life. Road traffic accidents (RTAs) were the leading cause of injury, followed by falls and physical assaults.

A substantial proportion of patients presented to the hospital more than four hours after the injury, reflecting delays in emergency response or referral systems. Patient demographics, timing of hospital presentation, and mechanisms of injury are summarized in [Table 1–3].

Table 1: Age and Gender Distribution of TBI Patients (n = 104)

Age Group (Years)	Female (n)	Male (n)	Total (n)	Percentage (%)
10–19	8	12	20	19.23
20–29	2	22	24	23.08
30–39	6	20	26	25.00
40–49	5	17	22	21.15
50–59	2	7	9	8.65
60–70	0	3	3	2.88
Total	23	81	104	100.00

Table 2: Time Interval Between Injury and Hospital Admission

Time Interval	Number of Patients (n)	Percentage (%)
< 1 hour	9	8.65
1–4 hours	23	22.12
> 4 hours	72	69.23
Total	104	100.00

Table 3: Mechanism of Injury in TBI Patients

Type of Injury	Female (n)	Male (n)	Total (n)	Percentage (%)
Fall	9	21	30	28.85
Physical Assault	2	5	7	6.73
Road Traffic Accident (RTA)	12	55	67	64.42
Total	23	81	104	100.00

2. Injury Severity and Glasgow Coma Scale at Admission

At the time of presentation, patients were categorized by Glasgow Coma Scale (GCS) into mild, moderate, and severe TBI groups. The largest proportion had mild TBI, followed by moderate and severe injuries.

Assessment of the time lapse between trauma and admission showed a skew toward delayed presentations; however, no statistically significant association was observed between time to hospital admission and mortality (Chi-square test, p = 0.78).

GCS distribution at admission is presented in [Table 4], and the time-to-admission and outcome associations are visualized in [Figure 1].

Table 4: Glasgow Coma Scale (GCS) Scores at Admission (n = 104)

GCS Category	Number of Patients (n)	Percentage (%)
Severe (3–8)	25	24.04
Moderate (9–12)	33	31.73
Mild (13–15)	46	44.23
Total	104	100.00

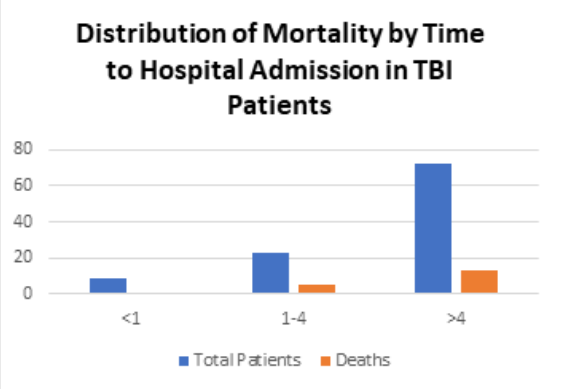

Figure 1. Mortality Distribution by Time Lapse Between Injury and Hospital Admission

(Bar graph showing mortality counts for <1 hour, 1–4 hours, and >4 hours' time groups.)

Note: Although more deaths occurred in the >4-hour group, statistical analysis did not reveal a significant association (p = 0.78).

3.Diagnosis and Outcome Associations

Patients were diagnosed with a range of traumatic brain injuries, including diffuse axonal injury (DAI), extradural hematoma (EDH), subdural hematoma (SDH), haemorrhagic contusions, and depressed skull fractures. Among these, DAI was associated with the highest mortality, followed by SDH.

Statistical analysis revealed a highly significant association between diagnosis type and mortality (p<0.000001), indicating that the type of intracranial

ISSN(O):2687-5365;ISSN(P):2753-6556

pathology has a strong prognostic impact on survival.

The distribution of diagnoses and associated mortality is summarized in [Table 5] and visualized in [Figure 2].

Table 5: Diagnosis Type and Mortality Among TBI Patients (n = 104)

Diagnosis	Number of Patients (n)	Deaths (n)	Mortality Rate (%)
Diffuse Axonal Injury (DAI)	14	9	64.3
Depressed Fracture	5	0	0.0
Extradural Hematoma (EDH)	18	2	11.1
Hemorrhagic Contusion	55	3	5.5
Subdural Hematoma (SDH)	12	5	41.7
Total	104	19	18.3

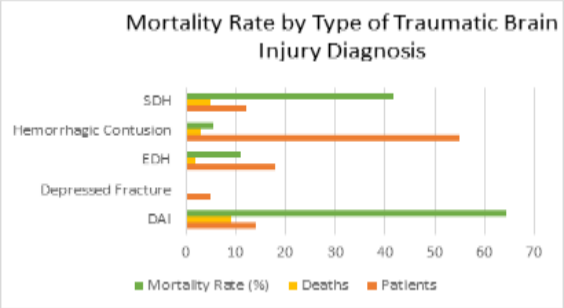

Figure 2: Mortality Rate by Diagnosis Type in TBI Patients

4. Glasgow Coma Scale and Functional Outcomes: Patient outcomes were assessed using the Glasgow Outcome Scale – Extended (GOSE), based on GCS at admission. A strong correlation was observed between initial GCS severity and final functional outcome.

Patients with severe TBI (GCS 3–8) had the highest mortality and lowest rates of good recovery. In contrast, those with mild TBI (GCS >13) demonstrated a significantly better prognosis, with over 90% achieving good functional recovery.

Chi-square analysis showed a highly significant association between GCS category and outcome level ($p< 0.00001$), supporting the prognostic utility of GCS in TBI management.

GOSE distribution by GCS category is presented in [Table 6], and visualized in [Figure 3].

Table 6. Glasgow Coma Scale at Admission and Corresponding GOSE Outcomes (n = 104)

GCS Category	Death (GOSE 1)	Vegetative (2)	Severe Disability (3–4)	Moderate Disability (5–6)	Good Recovery (7–8)	Total (n)
Severe (3–8)	13	3	5	4	0	25
Moderate (9–12)	5	2	6	11	9	33
Mild (>13)	1	0	3	4	42	46
Total	19	5	14	19	51	104

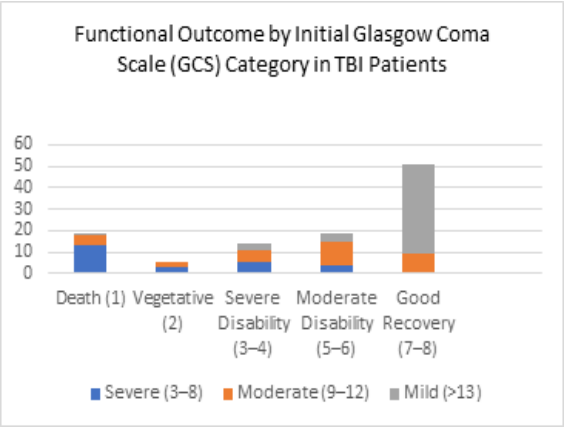

Figure 3: Functional Outcome (GOSE) by Initial GCS Category

5.Management Modalities and Outcomes

The majority of patients (71.15%) were managed conservatively. Surgical interventions were performed in 28.85% of patients and included craniotomy with hematoma evacuation, decompressive craniectomy, and elevation of depressed fractures.

Among all treatment groups, patients managed conservatively had the highest proportion of good recovery. However, this is likely influenced by the lower initial injury severity in this group. Mortality was highest in the decompressive craniectomy group, reflecting the severity of the underlying pathology rather than treatment failure.

Treatment-wise outcomes are summarized in [Table 7] and visualized in [Figure 4].

Table 7: Treatment Modality and Corresponding Outcomes (n = 104)

Treatment	Total Patients (n)	Good Recovery	Moderate Disability	Severe Disability	Vegetative State	Deaths
Conservative	74	45	12	5	2	10
Craniotomy & Hematoma Evac.	14	6	4	2	1	1
Decompressive Craniectomy	11	3	2	1	0	5
Elevation of	5	1	1	1	0	2

ISSN(O):2687-5365;ISSN(P):2753-6556

Depressed Fx.						
Total	104	55	19	9	3	19

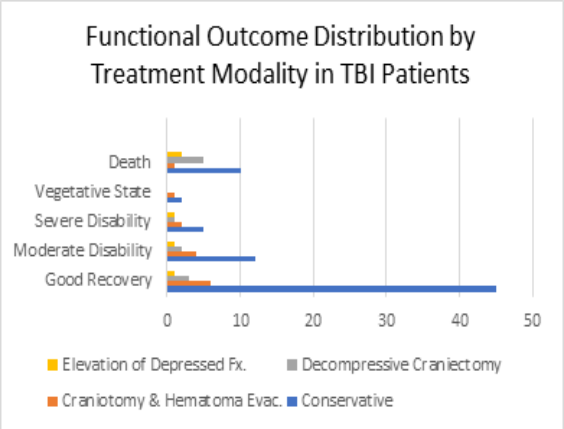

Figure 4: Outcome Distribution by Treatment Modality

6. Complications and Hospital Stay: During hospitalization, a range of complications were recorded. The most frequent was post-traumatic headache (54.8%), followed by seizures (15.4%) and hemiparesis (8.6%). Cerebrospinal fluid (CSF) leaks, including otorrhea and rhinorrhoea, were reported in a small subset of patients. Notably, 11.5% of patients experienced no complications during their hospital stay.

The length of hospital stay ranged from 4 to 31 days. Most patients (63.5%) were discharged within 4 to 11 days, with no significant difference in stay duration by gender ($p = 0.74$).

Complication rates and hospital stay durations are shown in [Table 8 and 9], respectively.

Table 8: In-Hospital Complications Among TBI Patients (n = 104)

Complication	Number of Patients (n)	Percentage (%)	Complication
Headache	57	54.81	Headache
Seizures	16	15.38	Seizures
Left Hemiparesis	5	4.81	Left Hemiparesis
Right Hemiparesis	4	3.85	Right Hemiparesis
CSF Otorrhea	4	3.85	CSF Otorrhea
CSF Rhinorrhoea	3	2.88	CSF Rhinorrhoea
Seizure + R Hemiparesis	2	1.92	Seizure + R Hemiparesis
Vomiting	1	0.96	Vomiting
No Complications	12	11.54	No Complications

Table 9: Hospital Stay Duration by Gender

Duration (Days)	Female (n)	Male (n)	Total (n)	Percentage (%)
4–7	9	32	41	39.42
8–11	11	33	44	42.31
12–15	2	10	12	11.54
16–19	0	3	3	2.88
24–27	0	2	2	1.92
28–31	1	1	2	1.92
Total	23	81	104	100.00

7. Mortality Analysis: The overall mortality rate in the study cohort was 18.3% (19 out of 104 patients). Mortality varied significantly with the Glasgow Coma Scale (GCS) at 48 hours post-admission. Among patients with GCS <9 at 48 hours, over half succumbed to their injuries.

Mortality also differed notably by diagnosis type, with DAI and SDH contributing the most to fatal outcomes. However, no statistically significant association was found between time to hospital admission and mortality ($p = 0.78$), or between injury cause and mortality ($p = 0.69$).

The association between GCS at 48 hours and mortality is summarized in [Table 10].

Table 10: GCS at 48 Hours and Corresponding Mortality

GCS at 48 Hours	Total Patients (n)	Deaths (n)	Mortality Rate (%)
<9	25	13	52.0
9–12	33	5	15.2
>13	46	1	2.2
Total	104	19	18.3

Statistical Significance: Strong association between GCS at 48 hours and mortality (Chi-square = 27.25, $p < 0.00001$)

ISSN(O):2687-5365;ISSN(P):2753-6556

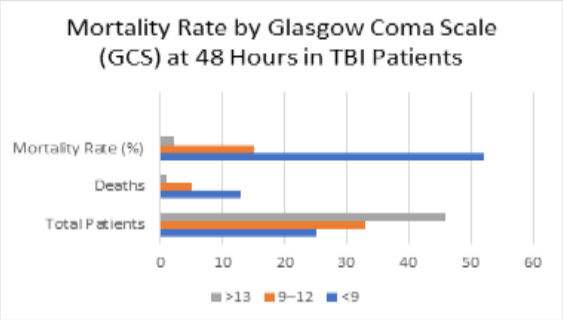

Figure 5: Mortality Rate by GCS Score at 48 Hours

DISCUSSION

This prospective observational study evaluated the clinical, radiological, and functional outcomes of patients with traumatic brain injury (TBI), with a specific focus on the prognostic implications of diffuse axonal injury (DAI) and other injury subtypes. The study utilized standardized assessment tools including the Glasgow Coma Scale (GCS) and the Glasgow Outcome Scale – Extended (GOSE), enabling a structured and reproducible analysis of outcomes.

Demographic Trends and Injury Mechanisms: The most affected age group in this study was 30–39 years, followed by 20–29 years, with males accounting for nearly 78% of the study population. This aligns with prior epidemiological data showing that TBI disproportionately affects young adult males due to higher exposure to risk-prone activities and occupational hazards (Maas et al., 2008).[8] The predominance of road traffic accidents (64.42%) as the leading cause of injury is also consistent with earlier reports by Jennett and Teasdale (1975) and Adams et al. (1982), who identified RTAs as the principal mechanism of TBI, particularly in urban populations where high-velocity impacts are common.[10,11]

Severity of Injury and Early Neurological Status: GCS at admission and at 48 hours post-injury emerged as powerful predictors of outcome. A mortality rate of 52% was observed in patients with GCS <9, reinforcing the prognostic value of early neurological assessment, as initially established by Teasdale and Jennett (1974) and later supported by Narayan et al. (2002), who showed that GCS <8 is associated with poor functional outcomes and high mortality.[12,13]

Diffuse Axonal Injury and Prognosis: Among all diagnostic categories, DAI was associated with the highest mortality rate (64%) and poorest functional recovery. Only one out of 14 DAI patients achieved a good outcome (GOSE 7–8). These findings strongly correlate with those of Smith et al. (2003), who found that fewer than 30% of patients with DAI achieve meaningful recovery, and van Eijck et al. (2018), who reported a threefold increase in poor outcomes among DAI cases compared to other TBI types.[9,14] The present findings reaffirm that DAI, characterized by widespread axonal injury from shearing forces, carries a grave prognosis, especially when presenting with low GCS scores.

Radiological Diagnosis and Outcome Prediction

A statistically significant correlation ($p < 0.00001$) was found between the type of radiological diagnosis and final GOSE outcome. While patients with extradural hematomas (EDH) and depressed skull fractures showed favourable outcomes, particularly when managed surgically, those with SDH and DAI had high mortality and disability rates. Wilson et al. (1998) reported similar patterns, indicating that structural focal lesions like EDH have better recovery trajectories, particularly when early surgical intervention is employed.[15] The study highlights the critical role of timely neuroimaging, including MRI, in identifying high-risk injuries like DAI, which may not be visible on initial CT scans.

Timing of Hospital Admission

Although earlier studies have underscored the importance of timely intervention, this study did not find a statistically significant association between time from injury to admission and mortality or functional outcome. While 69.23% of patients presented more than four hours post-injury, outcomes were more closely linked to injury severity and type than to timing alone. This suggests that while early intervention remains ideal, triage based on clinical and radiological severity should take precedence.

Management Modalities and Functional Outcomes: Most patients (71.15%) were managed conservatively, and surgical intervention was reserved for specific indications such as raised intracranial pressure or mass effect. Outcomes varied by treatment type, with patients undergoing elevation of depressed skull fractures demonstrating excellent recovery, whereas those requiring decompressive craniectomy had poor outcomes. These observations are in line with the findings of Cooper et al. (2011), who, in the DECRA trial, noted that while decompressive craniectomy can reduce intracranial pressure, it does not always lead to improved functional outcomes.[16] The need for individualized treatment plans—tailored to GCS scores, radiological findings, and clinical stability—is further supported by Murray et al. (2007), who advocated for early surgical intervention in selected cases.[17]

Complications and Hospital Stay

The most common in-hospital complication was post-traumatic headache (54.81%), followed by seizures (15.38%) and hemiparesis. CSF leaks were rare but indicative of basal skull fractures. The majority of patients were discharged within 4–11 days, and no significant gender differences were observed in length of stay. These findings are comparable to other observational studies of moderate-to-severe TBI in resource-constrained settings.

ISSN(O):2687-5365;ISSN(P):2753-6556

Functional Outcome Measurement

This study employed the GOSE scale, which is a widely accepted refinement of the original Glasgow Outcome Scale (GOS). GOSE provides greater granularity in capturing functional recovery, particularly in patients with moderate disability. A good recovery (GOSE 7–8) was observed in 52.88% of patients, while mortality was 18.27%. These figures are similar to those reported by Wilson et al. (1998), who emphasized the superior discriminative power of GOSE in TBI outcomes.[15]

Study Strengths and Limitations

The strength of this study lies in its prospective design, use of standardized outcome measures, and inclusion of a broad spectrum of TBI cases. However, limitations include the single-centre design, moderate sample size, and lack of long-term follow-up. Advanced imaging modalities such as diffusion tensor imaging (DTI), which can more accurately characterize DAI, were not uniformly available.

CONCLUSION

Outcomes in traumatic brain injury (TBI) are determined by clinical severity, radiological subtype, and management approach. Most patients were young adult males, with road traffic accidents as the leading cause. Diffuse axonal injury (DAI) had the highest mortality (64%) and poorest recovery, emphasizing its prognostic significance and the need for early MRI and intensive care. Extradural hematomas (EDH) and depressed fractures showed better outcomes with timely surgery, while hemorrhagic contusions had low mortality.The Glasgow Coma Scale at 48 hours was the strongest predictor of outcome. Early diagnosis, individualized treatment, and structured follow-up are vital to improving prognosis, particularly in DAI and severe TBI.

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ISSN(O):2687-5365;ISSN(P):2753-6556