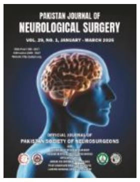

PAKISTAN JOURNAL OF NEUROLOGICAL SURGERY (QUARTERLY) – OFFICIAL JOURNAL OF PAKISTAN SOCIETY OF NEUROSURGEONS

Original Research

Clinical Management and Outcomes of Traumatic Brain Injury: A Comparative Study of High-Resource and Low-Resource Hospital Settings

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ABSTRACT

Objective: To compare and evaluate outcomes of Traumatic Brain Injury (TBI) in high-resource versus low-resource hospital settings.

Materials & Methods: This multicenter, prospective observational study included all patients with traumatic brain injury. Data was collected using a standardized questionnaire that included demographics, medical history, injury details, GCS scores, and GOSE outcomes. A brain CT scan was performed within 24 hours of injury, and follow-up assessments were conducted at two weeks. Statistical analysis was performed using SPSS version 27, with chi-square test and logistic regression used to assess associations between variables and hospital setups.

Results: Among 124 traumatic brain injury patients, 74% were males with a mean age of 41.63 ± 15.39; equally distributed between low- and high-resource hospitals. Road traffic accidents caused 75% of injuries, with 39.5% classified as severe TBI. Surgical interventions were performed more frequently in high-resource settings (22.6% vs. 4.8%). The majority of low-resource patients (82.3%) had hospital stays ≤3 days compared to 48.4% in high-resource hospitals. At two weeks, unfavorable outcomes (GOSE) were more common in low-resource hospitals (41.9% vs. 33.9%). Co-morbidities increased the likelihood of unfavorable outcomes (OR = 10.868, p = 0.066), as did peripheral injuries (OR = 1.332, p = 0.708). Mild (OR = 0.002, $p < 0.001$) and moderate (OR = 0.024, $p < 0.001$) TBI significantly reduced the risk of unfavorable outcomes compared to severe TBI.

Conclusion: In high-resource settings, a larger proportion of patients experienced severe traumatic brain injuries, underwent surgical interventions, had longer hospital stays, and showed relatively better recovery outcomes.

Keywords: Traumatic Brain Injury, Road traffic accidents, CT head, Length of stay, Hospitals.

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Date of Submission: 01-01-2025
Date of Revision: 25-03-2025
Date of Acceptance: 27-03-2025
Date of Online Publishing: 31-3-2025
Date of Print: 31-3-2025

DOI: 10.36552/pjns.v29i1.1066

INTRODUCTION

Traumatic brain injury (TBI) is defined as a forceful blow or jolt to the head that is categorized as minor, moderate, or severe depending upon the extent of damage to the brain. The mechanism of TBI can be better understood as primary TBI which results from the immediate damage to the brain at the time of insult whereas the secondary TBI is the representation of the later damage that occurs if the primary insult is not aided timely.[1,2] An external force initiates a primary injury that damages brain tissue, resulting in parenchymal injury, intracerebral bleeding, and axonal disruption. This trauma triggers secondary biochemical and cellular processes that impact recovery and prognosis, often lasting for months or even years post-injury. These processes include inflammation, brain edema, blood-brain barrier dysfunction, oxidative stress, neuronal damage, and disturbances in mitochondrial and metabolic functions.

TBI is one of the leading challenges and major causes of death especially in the U.S. The recent statistics from the CDC claim that around 69 thousand people died due to TBI in 2021. While two hundred thousand people were hospitalized in 2020. In these, the majority of complex cases or deaths were observed in an elderly population.[3,4] Globally, one-third of head injury patients in Africa experience poor outcomes, and individuals with severe head injuries face nearly twice the risk of mortality compared to those in high-income countries.[5] A prospective observational study was carried out in the Department of Neurosurgery at JPMC, specifically examining severe TBI cases. The mortality rate at 3 months was found to be 35.13% (98 patients).[6]

According to Brain Trauma Foundation Guidelines 2016, the core of TBI treatment lies in admission to critical care units, with a primary focus on maintaining the airway, ensuring optimal oxygen saturation, and providing adequate hemodynamic support to minimize secondary damage caused by hypoxia and hypotension. Severe traumatic brain injury (TBI) remains a leading cause of mortality and long-term disability in young adults, especially in low- and middle-income countries where transportation-related injuries are prevalent. The limited resources, fewer preventive regulations, and higher exposure to risk factors in these regions often result in worse outcomes.[7] In our region, despite being a trauma care center, many hospitals lack essential resources such as access to CT scans, which are crucial for effective TBI management. We aimed to identify the difference in the management and outcome of traumatic brain injury in two hospital settings that differ in their levels of infrastructure, clinical resources, and access to advanced medical interventions.

MATERIALS & METHODS

Study Design and Setting

A multicenter, prospective observational study was conducted at the emergency department of Liaquat National Hospital and Abbasi Shaheed Hospital in Karachi over nine months from March 2024 to November 2024. Ethical approval was obtained from the Ethical Review Committees of both hospitals, #CHS/95-A/2024/KMDC, #1085-2024-LNH-ERC respectively, and informed consent was acquired from all participants, ensuring voluntary participation and confidentiality.

Inclusion Criteria

The study included adults diagnosed with TBI and admitted to either high-resource or low-resource hospital settings.

Low-resource hospitals were defined as those with limited imaging facilities, intensive care unit (ICU) capabilities, and a lack of specialized staff like neurosurgeons and critical care specialists, while high-resource hospitals were equipped with advanced imaging technologies and fully equipped ICUs.

Exclusion Criteria

Patients with pre-existing neurological conditions that may confound TBI outcomes including those with epilepsy, stroke history, dementia, prior traumatic brain injury, or neurodegenerative diseases such as Parkinson's or Alzheimer's disease were excluded from the study.

Sample Size

Using the prevalence of good outcomes (defined as a GOSE score of 4–5) with P1 = 42.3% in a local setting and P2 = 64.8% in an international setting, the required sample size was calculated with a test power of 80% and a 95% confidence level. Based on the WHO sample size calculation software, a total of 124 patients were needed, with 62 patients in each group.

Data Collection & Clinical Management

A standardized questionnaire will be used to collect relevant information on TBI patients. At the beginning of the questionnaire, a short consent note is included to ensure that patients understand and agree with the research objectives. The questionnaire will record the patient’s name, case number, and contact information to facilitate follow-up over two weeks. Additional data collected will include demographics, history of TBI, comorbidities, cause of injury, consciousness status, post-traumatic amnesia, any peripheral injuries, GCS score in the emergency room, GOSE score, and length of hospitalization. At follow-up, patients will report any functional deficits experienced after the trauma at the two-week mark and provide a subjective assessment of their recovery status. Within the first 24 hours following a head injury, each patient will undergo a brain CT scan, and findings will be documented. Follow-up assessments in two weeks will take place in the outpatient department. Outcomes will be evaluated using the Glasgow Outcome Scale Extended (GOSE), with scores of 4-5 indicating a favorable outcome (“Good”) and scores of 1-3 indicating an unfavorable outcome (“Poor”). Descriptive statistics, t-tests, chi-square tests, and logistic regression were used to analyze associations between independent variables (e.g., age, gender, comorbidities, hospital setting) and dependent variables (e.g., functional outcomes, incidence of moderate to severe TBI).

Data Analysis

Frequency and percentage were provided for qualitative data, and mean and standard deviation were computed for quantitative variables. The association between qualitative variables was ascertained using the chi-square/fisher exact test. In the statistical analysis, Pearson’s Chi-square test was applied for categorical variables where expected cell counts were sufficient (≥5). However, for variables with small sample sizes, such as "Previous TBI" and "Surgical Interventions Performed," Fisher’s Exact Test was used, as it is more appropriate when expected counts are <5. Additionally, for ordinal variables, such as TBI severity, a chi-square test for trend (linear-by-linear association) was applied. These statistical tests were conducted to assess associations between hospital type and various clinical parameters, ensuring appropriate methodological rigor. The statistical analyses were performed using SPSS version 27. A P-value of 0.05 or less was regarded as significant. Odd ratio was calculated through binary logistic regression.

RESULTS

Age and Gender Distribution

The current study included a total of 124 patients, with 25.8% female and 74.2% male participants. The majority (40.3%) were aged between 31 and 50 years, with a mean age of 41.63±15.39 years. In terms of employment, 48.4% of patients were employed full-time.

Demographics of the Studied Population

Regarding educational background, 20.2% had no formal education, 20.2% had completed primary education, 23.4% had secondary education, and 36.3% had higher education. Half of the patients (50%) were treated in low-resource hospitals, while the other half (50%) were treated in high-resource hospitals. Table 1 displays comprehensive descriptive statistics of the study population's demographic characteristics.

Table 1: *Descriptive statistics of demographic characteristics of the study population (n=124).*

Parameters	n (%)
Education	
Higher	45(36.3)
No formal education	25(20.2)
Primary	25(20.2)
Secondary	29(23.4)
Employment Status:	
Full Time	60(48.4)
Un Employed/Retired	48(38.7)
Part-Time	16(12.9)
Hospital Type:	
Low Resource Hospital	62(50)
High Resource Hospital	62(50)
Previous TBI	
Yes	5(4)
No	119(96)
Cause of injury	
Assault	13(10.5)
Fall	14(11.3)
Road Traffic Accident	93(75)
Others	4(3.2)
Injury Characteristics and Interventions	
Loss of consciousness at the time of injury	94(75.8)
Presence of Post traumatic amnesia	70(56.5)
Presence of Peripheral Injury	74(59.7)
Surgical Interventions performed	17(13.7)
Type of Intervention (n=17)	
Craniotomy	12(70.6)
EVD	3(17.6)
Others	2(11.8)
Level of TBI	
Mild	49(39.5)
Moderate	26(21)
Severe	49(39.5)
Type of Complications observed within 2 weeks (n=10)	
Left PCA infarction	1(10)
Focal fits	3(30)
Hospital-acquired infections	5 (50)
Right vision loss	1(10)
Recovery Achieved	
Yes	61(49.2)
No/dead	32(28.2)
Partial	13(10.5)
Loss to follow up	15(12.1)
CT head Findings	
Normal	12(9.7)
Abnormal	112(90.3)
Pupils at the Time of Admission	
Non-Reactive	34(27.4)
Reactive	85(68.5)
Sluggish	5(4)
Management	
Conservative	107(86.3)
Surgical	17(13.7)
GCS Severity at the Time of Admission	
Severe (3-8)	50(40.3)
Moderate (9-12)	20(16.1)
Mild (13-15)	54(43.5)
Clinical Outcomes	
Parameters	***Mean ± SD***
Hospital Stay (days) mean ± std. dev	3.99±3.51
GOSE at the time of admission, mean ± std. dev	4.52±2.27
GOSE after 2 weeks, mean ± std. dev	5.29±2.01

Injury Characteristics, Interventions, and Outcomes

Among the 124 patients, road traffic accidents accounted for 75% of the injury causes, whereas 10% had a history of assault. Post-traumatic amnesia was observed in 56.5% of patients, peripheral injuries in 59.7%, and loss of consciousness at the time of injury in 75.8% of patients. Of the 17 patients who had interventions, 12 (70.6%) had craniotomies, 3 (17.6%) had EVDs, and 2 (11.8%) had other interventions. Among the patients, 39.5% had mild TBI, 21% had moderate TBI, and 39.5% had severe TBI. Recovery was achieved in 49.2% of patients, while 28.2% did not recover or died, 10.5% had partial recovery, and 12.1% were lost to follow-up. Of the patients, 90.3% had abnormal CT head findings and 9.7% had normal findings. Figure 1 shows abnormal CT Findings among patients.

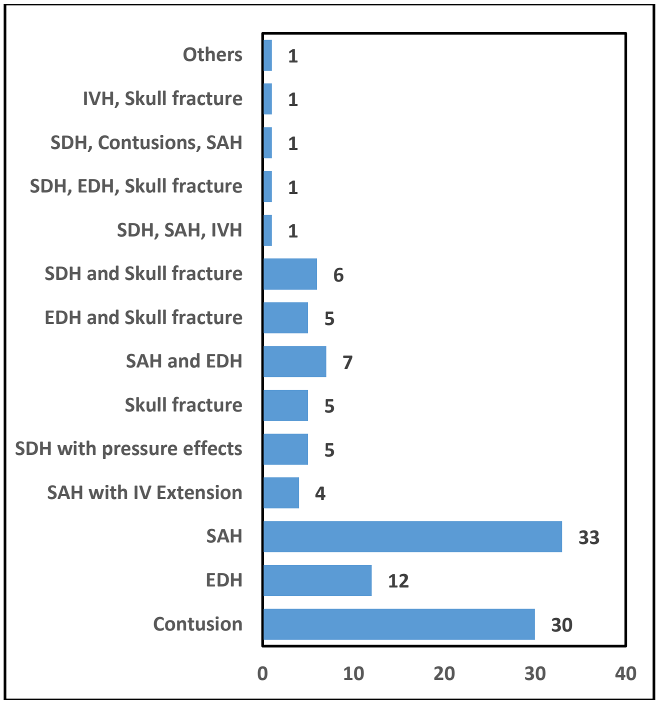

Figure 1: *Distribution of abnormal CT findings (n=112).*

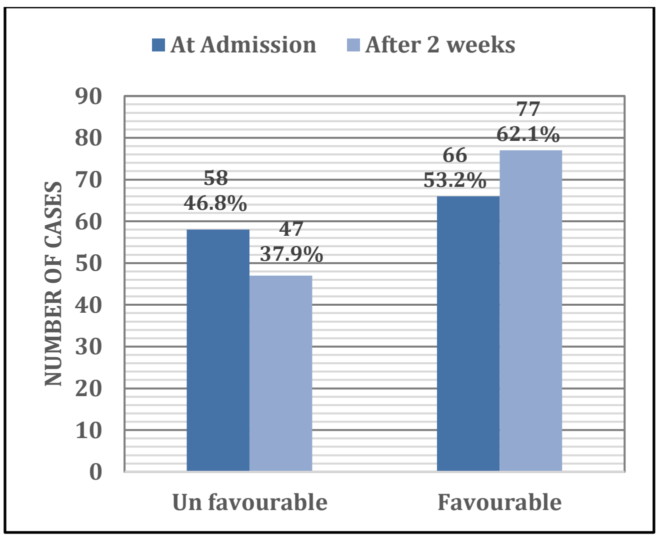

Figure 2: *Outcome by GOSE score at admission and after 2 weeks.*

Length of Hospitalization and GOSE Score Over Time

Mean hospital stay was 3.99±3.51 days whereas 65.3% of patients were hospitalized for three days or less. At admission and two weeks later, the mean GOSE was 4.52±2.27 and 5.29±2.01, respectively. Among the 124 patients, as shown in Figure 2, 53.2% had a favorable outcome upon admission, which increased to 62.1% after two weeks.

Comparison of Patient Characteristics and Outcomes Between Low- and High-Resource Hospital Settings

Comparison of Demographics and clinical characteristics with Low and High resource setup:

Gender (p = 0.004), level of education (p = 0.035), history of hypertension (p = 0.001), cause of injury (p = 0.010), loss of consciousness at the time of trauma (p < 0.001), presence of post-traumatic amnesia (p < 0.001), surgical interventions received (p = 0.004), recovery outcomes (p = 0.001), pupillary response at admission (p = 0.008), and duration of hospital stay (p < 0.001) were all significantly associated with the type of hospital (low-resource vs. high-resource settings). In contrast, the presence of comorbid conditions (p = 0.096) apart from hypertension, prior history of traumatic brain injury (p = 1.000), associated peripheral injuries (p = 0.714), Glasgow Coma Scale (GCS) severity at admission (p = 0.185), and the Glasgow Outcome Scale–Extended (GOSE) score at admission and 2 weeks (p = 1.000) did not demonstrate statistically significant associations with hospital type.

Logistic Regression Analysis

Patients with co-morbidities were more likely to experience unfavorable outcomes than those without co-morbidities (adjusted odds ratio [aOR] = 10.868, *p* = 0.066). Similarly, patients with peripheral injuries had a higher likelihood of unfavorable outcomes compared to those without peripheral injuries (aOR = 1.332, *p* = 0.708). Conversely, patients with mild (aOR = 0.002, *p* < 0.001) and moderate (aOR = 0.024, *p* < 0.001) TBI were significantly less likely to experience unfavorable outcomes compared to those with severe TBI.

DISCUSSION

In high-resource settings, a greater proportion of patients experienced severe traumatic brain injuries, underwent surgical interventions, and had longer hospital stays. While recovery rates were lower in low-resource settings, there was no significant difference in the GOSE outcome scores at admission or after two weeks.

In our study, traumatic brain injuries (TBIs) were most frequently observed among younger male individuals, with road traffic accidents identified as the leading cause. These findings are consistent with those reported in other settings, including a study conducted in Paris and another from neighboring India.[7,8] Additionally, mild and severe TBI cases were observed in equal proportions, each accounting for 39.5% of the cases. This contrasts with findings from England and Nigeria, where mild TBI cases were more commonly observed.[9,10] Regarding neuroimaging, subarachnoid hemorrhage was the most common finding in our study, followed by contusions and extradural hematoma formation. In contrast, studies conducted in India and Tanzania reported higher incidences of skull fractures. Furthermore, around 59.7% of all cases had injuries at other sites, which is comparable to studies from central India, where the incidence was 50.6%.[7]

In terms of surgical intervention, 13.7% of our cases underwent neurosurgical procedures, which is notably lower than the 36.2% reported by Qasim et al, at JPMC. This difference

Table 2: *Demographic & Clinical characteristics among low and high resource setups.*

	Hospital Type		p-value
	Low Resource	High Resource	
Previous TBI	2(3.2)	3(4.8)	1.000
Co-morbidities	19(30.6)	28(45.2)	0.096
Cause of injury			
Assault	2(3.2)	11(17.7)	0.01*
Fall	7(11.3)	7(11.3)	
Road Traffic Accident	49(79)	44(71)	
Other head injuries	4(6.5)	0(0)	
Loss of consciousness at the time of injury	38(61.3)	56(90.3)	<0.001*
Presence of Post-traumatic amnesia	20(32.3)	50(80.6)	<0.001*
Presence of Peripheral Injury	38(61.3)	36(58.1)	0.714
Surgical Interventions performed	3(4.8)	14(22.6)	0.004*
Level of TBI			
Mild	20(32.3)	29(46.8)	0.200
Moderate	16(25.8)	10(16.1)	
Severe	26(41.9)	23(37.1)	
Complications observed within 2 weeks	4(6.5)	6(9.7)	0.510
Recovery achieved			
Yes	31(50)	30(48.4)	0.001*
No	25(38.6)	10(16.1)	
Partially	2(3.2)	11(17.7)	
Lost to follow up	4(6.5)	11(17.7)	
CT head findings			
Normal	7(11.3)	5(8.1)	0.544
Abnormal	55(88.7)	57(91.9)	
Pupils at the time of admission			
Non-Reactive	21(33.9)	13(21)	0.008*
Reactive	36(58.1)	49(79)	
Sluggish	5(8.1)	0(0)	
Management			
Conservative	59(95.2)	48(77.4)	0.004*
Surgical	3(4.8)	14(22.6)	
Hospital Stay			
≤3 days	51(82.3)	30(48.4)	<0.001*
4-7 days	9(14.5)	22(35.5)	
>10 days	2(3.2)	10(16.1)	
GCS severity at admission			
Severe (3-8)	28(45.2)	22(35.5)	0.185
Moderate (9-12)	12(19.4)	8(12.9)	
Mild (13-15)	22(35.5)	32(51.6)	
Outcome by GOSE score at the time of admission			
Unfavorable Outcome (1-4)	29(46.8)	29(46.8)	1.000
Favorable Outcome (5-8)	33(53.2)	33(53.2)	
Outcome by GOSE score after 2 weeks			
Unfavorable Outcome (1-4)	26(41.9)	21(33.9)	0.355
Favorable Outcome (5-8)	36(58.1)	41(66.1)	

The numbers within parentheses ( ) indicate the corresponding percentages of the total patients in that group. The Chi-square/fisher exact test was applied.

*Significant result

may be attributed to the higher incidence of severe and irreversible brain injuries observed in our cases.[11] Complications were limited, with only 10 cases (8.1%) observed within two weeks, which contrasts with the literature where infection is often the leading cause of mortality in traumatic brain injury cases.[12]

A substantial number of patients in our study exhibited significantly low Glasgow Coma Scale (GCS) scores at admission. Several studies have highlighted the predictive value of the GCS score, with lower scores being associated with worse outcomes. However, findings on the predictive value of GCS vary. Lipper MH et al, suggest that the GCS score upon admission may not significantly predict outcomes in head trauma patients, whereas studies by Palekar SG et al, and Bonow RH et al, demonstrate that decreasing GCS scores are associated with a poorer prognosis, particularly in patients with severe traumatic brain injury.[13,14]

Our study made certain critical observations, such as severe traumatic brain injury cases being more common in high-resource settings, evidenced by a higher prevalence of loss of consciousness (90.3% vs. 61.3%) and post-traumatic amnesia (80.6% vs. 32.3%), likely due to better triage and referral systems. Hospital stays were notably longer in high-resource settings, with a higher proportion staying 4–7 days (35.5%) or over 10 days (16.1%) compared to low-resource hospitals (14.5% and 3.2%), reflecting better infrastructure and bed availability. Management differences were striking, as surgical interventions were more frequent in high-resource settings (22.6% vs. 4.8%), likely due to the unavailability of neurosurgeons in low-resource hospitals. Regarding recovery, a markedly higher proportion of patients in low-resource hospitals did not achieve recovery, highlighting the potential impact of disparities in care delivery and resource allocation.

One of the strengths of this study was its comparative design, which allowed us to explore outcomes in two distinct hospital settings. However, the study was limited by its observational nature and the lack of randomization, which could introduce bias. Future studies should focus on prospective, randomized trials to further investigate the impact of resource availability on TBI outcomes. Additionally, the two-week follow-up period may have been insufficient to identify significant differences in outcomes that might present over a longer timeframe. Recovery from a TBI can be a long journey and substantial differences in the result may be seen months or years after the initial assault.

CONCLUSION

In high-resource settings, a larger proportion of patients experienced severe traumatic brain injuries, underwent surgical interventions, had longer hospital stays, and showed relatively better recovery outcomes.

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Additional information

Disclosure: Authors report no conflict of interest.
Ethical review board approval: Obtained.
Human subjects: Consent was obtained by all patients/participants.
Conflicts of Interest: In compliance with the ICMJE uniform disclosure form, all authors declare the following:
Financial Relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work.
Other Relationships: All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.
Data Availability Statement: For data sharing, interested researchers can contact the corresponding authors.
Funding Sources: None.
Acknowledgment: We appreciate the support of statistician Mr. Irfan for detailed analysis and results interpretation.

AUTHORS CONTRIBUTIONS

Sr.#	Author's Full Name	Intellectual Contribution to Paper in Terms of:
1.	Almas Zafar	1. Study design and methodology.
2.	Saba Zaidi	2. Paper writing.
3.	Almas Zafar & Saba Zaidi	3. Data collection and calculations.
4.	Atiya Sabeen	4. Analysis of data and interpretation of results.
5.	Haneea Yasir	5. Literature review and referencing.
6.	Saad Akhter	6. Editing and quality insurer.