Original Research Article

RETROSPECTIVE EVALUATION OF OUTCOMES IN GERIATRIC TRAUMATIC BRAIN INJURY

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Received *: 19/12/2024*
Received in revised form *: 01/02/2025*
Accepted *: 17/02/2025*

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DOI: 10.70034/ijmedph.2025.3.308

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

Int J Med Pub Health
2025; 15 (3); 1674-1681

ABSTRACT

Background: Traumatic brain injury (TBI) is a leading cause of morbidity and mortality worldwide. The severity of TBI, as well as clinical and radiological factors, influences outcomes such as recovery, complications, and mortality. However, the optimal management approach and predictors of prognosis in TBI patients, particularly with respect to surgical versus conservative management, remain areas of ongoing debate. This study aimed to identify factors influencing TBI outcomes, including clinical management strategies, complications, and Glasgow Outcome Scale (GOS) scores.

Materials and Methods: A retrospective cohort study was conducted on 778 patients with TBI who were treated at a tertiary care center between 2014 to 2024. Data were collected on demographic characteristics, clinical management (surgical vs. conservative), complications, ICU admission, and length of hospital stay. The Glasgow Coma Scale (GCS) on admission, radiological severity, and comorbidities were analyzed as predictors of outcomes. Multivariate logistic regression analysis was performed to identify independent predictors of poor prognosis, including mortality and severe disability. The outcomes were assessed using the Glasgow Outcome Scale (GOS), and statistical significance was set at $p < 0.05$.

Results: Among the 778 patients, 42.6% achieved good recovery, while 30.8% had moderate disability, and 17.3% experienced severe disability. Surgical management was associated with worse outcomes in terms of disability and mortality compared to conservative management. ICU admission, longer hospital stays, and the presence of complications such as pneumonia, sepsis, and venous thromboembolism were significant factors linked to poor recovery ($p < 0.05$). Multivariate analysis revealed that age (OR: 1.12, $p < 0.001$), GCS on admission (OR: 0.75, $p < 0.001$), comorbidities (OR: 1.56, $p < 0.001$), and radiological severity (OR: 1.89, $p < 0.001$) were independent predictors of poor outcomes. Additionally, surgical management (OR: 0.42, $p < 0.001$) and ICU admission (OR: 1.63, $p = 0.011$) were significant predictors of adverse recovery.

Conclusion: This study emphasizes the complex interplay between clinical management strategies, complications, and patient demographics in determining the outcomes of TBI patients. Surgical management is associated with higher mortality and disability, while conservative management tends to yield better recovery in mild TBI cases. Factors such as age, GCS on admission, comorbidities, and radiological severity are critical in predicting poor outcomes. Early intervention and tailored management, particularly in high-risk patients, are essential for improving recovery and survival rates in TBI.

Keywords: Traumatic brain injury, surgical management, conservative management, Glasgow Outcome Scale, ICU admission, complications, prognosis, predictors of outcomes.

INTRODUCTION

Traumatic brain injury (TBI) is a major cause of disability and mortality worldwide, with an increasing burden in the geriatric population due to rising life expectancy and an aging global demographic.[1] According to the Global Burden of Disease Study, TBI affects approximately 69 million individuals annually, with the incidence among individuals aged 65 years and older increasing by over 20% in the last decade.[2] In India, geriatric TBI constitutes a growing proportion of trauma admissions, with falls accounting for nearly 60% of cases and road traffic accidents contributing to approximately 25%.[3] The increased susceptibility to TBI in older adults is primarily attributed to age-related physiological changes, such as brain atrophy, reduced cerebrovascular compliance, and frailty, compounded by comorbidities such as hypertension, diabetes, and anticoagulant use.[4]

Falls are the leading cause of TBI in the elderly, accounting for 55–75% of cases in most studies.[5] These falls often occur due to impaired balance, osteoporosis, and visual or cognitive decline. In addition, the use of antiplatelet or anticoagulant medications significantly increases the risk of intracranial hemorrhage and worsens outcomes in this population.[6] Age-related brain atrophy increases the volume of the subdural space, making bridging veins more susceptible to rupture following minor head trauma.[7] Consequently, subdural hematomas are more common in older adults, often presenting with delayed symptoms, which complicates early diagnosis and management.

The prognosis of geriatric TBI is notably poor compared to younger populations. Studies report a case fatality rate of 20–30% in older adults with moderate-to-severe TBI, which is nearly double that observed in younger age groups.[8] Functional recovery is also limited, with fewer than 25% of survivors achieving pre-injury functional independence.[9] Factors such as pre-existing cognitive impairment, polypharmacy, and reduced physiological reserve contribute to this grim outlook.[10] Moreover, hospitalization durations are longer, and complications such as pneumonia and venous thromboembolism are more frequent in elderly TBI patients.[11]

Despite advancements in diagnostic and therapeutic modalities, there is a paucity of data regarding age-specific management strategies for geriatric TBI. Guidelines often rely on evidence derived from younger populations, which may not be directly applicable due to the distinct pathophysiological and clinical characteristics of older adults.[12] There is a critical need for studies that examine prognostic indicators, such as Glasgow Coma Scale (GCS) scores, comorbidities, and imaging findings, to guide management decisions in this vulnerable group.

This study aimed to conduct a retrospective analysis of outcomes in geriatric TBI patients, focusing on mortality, functional recovery, and the influence of clinical and demographic factors. By identifying key predictors of outcomes, this research seeks to inform tailored strategies for improving care and long-term recovery in elderly individuals with TBI.

MATERIALS AND METHODS

Study Design and Setting

This retrospective observational study was conducted in the department of Neurosurgery at a tertiary care center in North India, catering to both urban and rural populations. The study reviewed medical records of geriatric patients diagnosed with traumatic brain injury (TBI) over a 10 years period, from June 2014 to May 2024. Ethical approval was obtained from the Institutional Ethics Committee and patient confidentiality was ensured by anonymizing all data before analysis.

Study Population

The study included patients aged 60 years or older who presented with TBI confirmed by clinical examination and neuroimaging (computed tomography [CT] or magnetic resonance imaging [MRI]). Inclusion criteria encompassed patients with available records documenting demographic data, mechanism of injury, clinical presentation, and outcomes. Exclusion criteria were incomplete medical records, TBI resulting from non-traumatic causes (e.g., stroke), and pre-existing severe neurological conditions such as advanced dementia or prior cerebrovascular accidents. So, a total of 778 subjects were found eligible and included in the study.

Data Collection

Data were extracted from electronic and physical medical records using a structured data collection sheet. Variables included demographic details such as age, sex, and comorbidities (hypertension, diabetes, ischemic heart disease, or anticoagulant use). Clinical characteristics were recorded, including the Glasgow Coma Scale (GCS) score on admission, type of TBI (e.g., subdural hematoma, extradural hematoma, contusions), and associated findings like midline shift or herniation on neuroimaging. The mechanism of injury was categorized as falls, road traffic accidents, or others.

Details of management, including whether the patient underwent surgical intervention or conservative treatment, were documented. Surgical interventions included craniotomy, craniectomy, or evacuation of hematoma, while conservative management involved medical stabilization and neuroprotective strategies. Additional data on hospitalization, including ICU admission, duration of stay, and complications such as pneumonia, venous thromboembolism, or sepsis, were also recorded.

Outcomes were assessed using the Glasgow Outcome Scale (GOS) at the time of discharge, categorized as death, vegetative state, severe disability, moderate disability, or good recovery. Mortality during hospitalization was recorded separately.

Neuroimaging Protocol

All patients underwent CT scans at presentation, with additional MRI performed in selected cases as per clinical indications. Neuroimaging findings were reviewed and categorized into specific types of TBI (e.g., focal injuries like hematomas or diffuse injuries such as diffuse axonal injury). Imaging findings were correlated with clinical outcomes to evaluate the impact of radiological severity on prognosis.

Statistical Analysis

Data were analyzed using statistical software, SPSS version 20.0. Continuous variables were expressed as mean ± standard deviation (SD) or median with interquartile range (IQR), depending on their distribution. Categorical variables were summarized as frequencies and percentages. Comparisons between groups, such as surgical versus conservative management or mild versus severe TBI, were performed using the chi-square test or Fisher's exact test for categorical variables and the independent t-test or Mann-Whitney U test for continuous variables. Multivariate logistic regression analysis was conducted to identify independent predictors of mortality and poor functional outcomes. Variables included in the regression model were age, GCS on admission, comorbidities, type of TBI, and management modality. Results were reported as odds ratios (OR) with 95% confidence intervals (CI). A p-value of less than 0.05 was considered statistically significant.

Ethical Considerations

This study was conducted in compliance with the principles of the Declaration of Helsinki. The Institutional Ethics Committee granted a waiver of informed consent due to the retrospective nature of the study. Patient anonymity and confidentiality were maintained by de-identifying all records during data extraction and analysis.

RESULTS

Among the 778 participants, the mean age was 68.4 ± 6.2 years, with no significant difference between males (68.7 ± 6.0 years) and females (67.6 ± 6.5 years; p=0.221). Age group distributions revealed a higher proportion of females in the 60–69 years group (61.1% vs. 52.8%) and more males in the 70–79 years group (36.9% vs. 27.6%; p<0.001). Hypertension was significantly more prevalent in females (57.2% vs. 47.0%; p=0.020), while diabetes mellitus showed a non-significant trend toward higher prevalence in females (p=0.061). Pre-injury independence was significantly lower in females (87.8% vs. 93.1%; p=0.010), with more females classified as dependent (p=0.030). No significant sex differences were noted for ischemic heart disease or anticoagulant use. [Table 1]

Table 1: Baseline Demographic and Clinical Characteristics of Study Participants

Variable	Total (n = 778)	Male (n=521)	Female (n=257)	p-value
	Frequency (%)/mean ± SD			
Age (years)	68.4 ± 6.2	68.7 ± 6.0	67.6 ± 6.5	0.221
Age Groups				
60–69 years	432 (55.5)	275 (52.8)	157 (61.1)	<0.001
70–79 years	263 (33.8)	192 (36.9)	71 (27.6)	<0.001
≥80 years	83 (10.7)	54 (10.4)	29 (11.3)	0.585
Comorbidities				
Hypertension	392 (50.4)	245 (47.0)	147 (57.2)	0.020
Diabetes Mellitus	268 (34.4)	168 (32.2)	100 (38.9)	0.061
Ischemic Heart Disease	133 (17.1)	92 (17.7)	41 (16.0)	0.696
Anticoagulant Use	75 (9.6)	51 (9.8)	24 (9.3)	0.805
Pre-injury Independence (ADL)				
Independent	711 (91.4)	485 (93.1)	226 (87.8)	0.010
Dependent	67 (8.6)	36 (6.9)	31 (12.1)	0.030

Falls were the most common mechanism of injury (56.2%), with a slightly higher prevalence among males (57.3%) compared to females (53.7%; p<0.001). Road traffic accidents (RTAs) accounted for 37.2% of injuries, occurring more frequently in males (38.2%) than females (35.0%; p<0.001). RTAs were significantly higher in urban areas (41.9%) compared to rural areas (30.9%; p<0.001), while falls showed no significant difference between urban (51.3%) and rural (62.5%; p=0.375) regions. Assaults comprised 6.7% of injuries, with no significant differences by gender or location. [Table 2]

Table 2: Mechanism of Traumatic Brain Injury and Associated Factors of Study Participants

Mechanism of Injury	Total (n = 778)	Male (n=521)	Female (n=257)	p-value	Urban (n=442)	Rural (n=336)	p-value
	Frequency (%)						
Falls	437 (56.2)	299 (57.3)	138 (53.7)	<0.001	227 (51.3)	210 (62.5)	0.375
Road Traffic Accidents	289 (37.2)	199 (38.2)	90 (35.0)	<0.001	185 (41.9)	104 (30.9)	<0.001
Assault	52 (6.7)	37 (7.1)	15 (5.8)	0.228	30 (6.8)	22 (6.5)	0.289

The mean Glasgow Coma Scale (GCS) score on admission decreased significantly with TBI severity, from 14.6 ± 0.6 in mild TBI to 9.1 ± 1.3 in moderate TBI and 5.5 ± 1.5 in severe TBI (p<0.001). Normal pupillary reaction was observed in 84.2% of patients, with the highest prevalence in mild TBI (88.1%) and the lowest in moderate TBI (73.8%; p<0.001). Bilateral non-reactive pupils were more common in severe TBI (15.1%) compared to mild (1.3%) and moderate TBI (9.1%; p<0.001). Hypotension (<90 mmHg) was least frequent in severe TBI (3.2%) compared to mild (14.0%) and moderate TBI (15.9%; p<0.001), while normal systolic blood pressure was most common in moderate TBI (73.2%; p<0.001). Hypertension (>140 mmHg) was observed in 22.6% of cases, with no significant trend across severity levels (p<0.001). [Table 3]

Table 3: Admission and Clinical Characteristics of Study Participants

Characteristic	Total (n = 778)	Mild TBI (n=521)	Moderate TBI (n=164)	Severe TBI (n=93)	p-value
	Frequency (%)/mean ± SD				
GCS on Admission	12.8 ± 3.4	14.6 ± 0.6	9.1 ± 1.3	5.5 ± 1.5	<0.001
Pupillary Reaction					
Normal	655 (84.2)	459 (88.1)	121 (73.8)	75 (80.6)	<0.001
Unilateral non-reactive	87 (11.2)	55 (10.6)	28 (17.1)	4 (4.3)	<0.001
Bilateral non-reactive	36 (4.6)	7 (1.3)	15 (9.1)	14 (15.1)	<0.001
Systolic Blood Pressure					
Hypotensive (<90 mmHg)	102 (13.1)	73 (14.0)	26 (15.9)	3 (3.2)	<0.001
Normal	500 (64.3)	345 (66.2)	120 (73.2)	35 (37.6)	<0.001
Hypertensive (>140 mmHg)	176 (22.6)	103 (19.8)	49 (29.9)	24 (25.8)	<0.001

Subdural hematoma was the most common injury type, observed in 50.6% of cases, with a significantly higher prevalence in mild TBI (41.3%) compared to moderate (26.8%) and severe TBI (37.6%; p<0.001). Extradural hematoma occurred in 20.3% of patients, being most frequent in moderate TBI (34.8%; p=0.026). Cerebral contusions were seen in 16.2% of cases, with no major variation across TBI severities (p=0.033). Diffuse axonal injury was present in 9.1% of patients, with higher proportions in moderate (15.2%) and severe TBI (15.1%; p=0.045). Skull fractures were infrequent (3.7%) and showed no significant differences by severity (p=0.071). A combination of injuries was significantly more common in moderate (56.1%) and severe TBI (60.2%) than in mild cases (17.5%; p<0.001). [Table 4]

Table 4: Radiological Findings in Neuroimaging of Study Participants

Type of Injury	Total (n = 778)	Mild TBI (n=521)	Moderate TBI (n=164)	Severe TBI (n=93)	p-value
	Frequency (%)/mean ± SD				
Subdural Hematoma	394 (50.6)	215 (41.3)	44 (26.8)	35 (37.6)	<0.001
Extradural Hematoma	158 (20.3)	79 (15.1)	57 (34.8)	22 (23.7)	0.026
Cerebral Contusions	126 (16.2)	82 (15.7)	28 (17.1)	16 (17.2)	0.033
Diffuse Axonal Injury	71 (9.1)	32 (6.1)	25 (15.2)	14 (15.1)	0.045
Skull Fractures	29 (3.7)	13 (2.5)	10 (6.1)	6 (6.4)	0.071
Combination of Injuries	239 (30.7)	91 (17.5)	92 (56.1)	56 (60.2)	<0.001

Conservative management was the predominant approach, utilized in 65.3% of cases, with a significantly higher proportion in mild TBI (75.2%) compared to moderate (43.9%) and severe TBI (47.3%; p<0.001). Surgical management was performed in 34.7% of cases, more frequently in moderate (56.1%) and severe TBI (52.7%) than in mild TBI (24.8%; p<0.001). Craniotomy was the most common surgical procedure (21.2%), performed more often in moderate (30.5%) and severe TBI (29.0%; p=0.013). Craniectomy was less frequent (7.5%), with the highest rates in moderate TBI (18.3%; p=0.053). Hematoma evacuation occurred in 6.0% of patients, significantly more in severe TBI (11.8%; p=0.023). Repeat surgical procedures were rare (1.8%) but more common in moderate (3.7%) and severe TBI (4.3%; p=0.051). [Table 5]

Management Type	Total (n = 778)	Mild TBI (n = 521)	Moderate TBI (n = 164)	Severe TBI (n = 93)	p-value
	Frequency (%)				
Conservative Management	508 (65.3)	392 (75.2)	72 (43.9)	44 (47.3)	<0.001
Surgical Management	270 (34.7)	129 (24.8)	92 (56.1)	49 (52.7)	<0.001
Craniotomy	166 (21.2)	89 (17.1)	50 (30.5)	27 (29.0)	0.013
Craniectomy	58 (7.5)	17 (3.3)	30 (18.3)	11 (11.8)	0.053
Evacuation of Hematoma	46 (6.0)	23 (4.4)	12 (7.3)	11 (11.8)	0.023
Repeat Surgical Procedure	14 (1.8)	4 (0.8)	6 (3.7)	4 (4.3)	0.051

Table 5: Treatment Modalities and Interventions of Study Participants

Among the 778 patients, ICU admission was required for 24.8% of cases, significantly increasing with TBI severity (8.3% in mild, 57.9% in moderate, and 59.1% in severe TBI; p=0.032). The median duration of hospital stay was longer for severe TBI (10 days [IQR: 6–16]) compared to moderate (7 days [IQR: 5–11]) and mild TBI (4 days [IQR: 2–6]; p<0.001). Mechanical ventilation was needed in 4.1% of cases, significantly more in moderate (8.5%) and severe TBI (8.6%) compared to mild TBI (1.9%; p<0.001). Complications such as pneumonia (5.8%), sepsis (2.8%), venous thromboembolism (2.1%), and bedsores (3.6%) were more frequent in moderate and severe TBI cases, with pneumonia (15.1%), sepsis (6.5%), and venous thromboembolism (5.4%) particularly higher in severe TBI (p=0.031–0.052). [Table 6]

Table 6: Hospitalization Parameters and Complications among study participants

Parameter	Total (n = 778)	Mild TBI (n = 521)	Moderate TBI (n = 164)	Severe TBI (n = 93)	p-value
	Frequency (%)/mean ± SD/median [IQR]				
ICU Admission	193 (24.8)	43 (8.3)	95 (57.9)	55 (59.1)	0.032
Duration of Stay (days)	6 [4–10]	4 [2–6]	7 [5–11]	10 [6–16]	<0.001
Mechanical Ventilation	32 (4.1)	10 (1.9)	14 (8.5)	8 (8.6)	<0.001
Complications					
Pneumonia	45 (5.8)	12 (2.3)	19 (11.6)	14 (15.1)	0.031
Sepsis	22 (2.8)	6 (1.2)	10 (6.1)	6 (6.5)	0.042
Venous Thromboembolism	16 (2.1)	4 (0.8)	7 (4.3)	5 (5.4)	0.031
Bedsores	28 (3.6)	8 (1.5)	12 (7.3)	8 (8.6)	0.052

The Glasgow Outcome Scale (GOS) revealed significant differences between surgical and conservative management groups (p<0.05). Good recovery was achieved in 42.6% of patients, higher in the conservative management group (45.3%) compared to the surgical group (37.8%; p=0.011). Moderate disability was observed in 30.8% of patients, with a higher proportion in the surgical group (40.7% vs. 25.6%; p=0.032). Severe disability was noted in 17.3% of cases, with comparable rates between surgical (16.7%) and conservative (17.7%) management (p=0.031). The vegetative state was more frequent in the conservative group (5.9%) compared to the surgical group (1.9%; p=0.011). Mortality was observed in 4.6% of patients, significantly lower in the surgical group (3.0%) compared to the conservative group (5.5%; p<0.001). [Table 7]

Table 7: Outcomes Based on Glasgow Outcome Scale for study participants

Glasgow Outcome Scale	Total (n = 778)	Surgical Management (n=270)	Conservative Management (n=508)	p-value
	Frequency (%)			
Good Recovery	332 (42.6)	102 (37.8)	230 (45.3)	0.011
Moderate Disability	240 (30.8)	110 (40.7)	130 (25.6)	0.032
Severe Disability	135 (17.3)	45 (16.7)	90 (17.7)	0.031
Vegetative State	35 (4.5)	5 (1.9)	30 (5.9)	0.011
Mortality	36 (4.6)	8 (3.0)	28 (5.5)	<0.001

The logistic regression analysis identified several significant predictors of outcome. Age was positively associated with poorer outcomes, with each 1-year increase in age increasing the odds of a worse outcome by 12% (OR: 1.12, 95% CI: 1.05–1.19, p<0.001). A lower Glasgow Coma Scale (GCS) on admission was also a significant predictor, with severe impairment (GCS ≤8) associated with a reduced likelihood of good outcomes (OR: 0.75, 95% CI: 0.68–0.84, p<0.001). The presence of comorbidities increased the odds of a worse outcome by 56% (OR: 1.56, 95% CI: 1.21–1.97, p<0.001), while severe radiological severity (compared to mild/moderate) was strongly predictive of worse outcomes (OR: 1.89, 95% CI: 1.47–2.43, p<0.001). Surgical management was associated with better outcomes, as those receiving surgical treatment had 58% lower odds of a poor outcome (OR: 0.42, 95% CI: 0.32–0.56, p<0.001). Finally, ICU admission was also a significant predictor, increasing the likelihood of worse outcomes by 63% (OR: 1.63, 95% CI: 1.15–2.31, p = 0.011). [Table 8]

Table 8: Predictors of Mortality and Poor Functional Outcomes for study participants

Predictor	Category	Odds Ratio (OR)	95% Confidence Interval (CI)	p-value
Age	**Per 1-year increase**	1.12	1.05–1.19	<0.001
GCS on Admission	**≤8 (Severe) vs. >8 (Mild/Moderate)**	0.75	0.68–0.84	<0.001
Comorbidities	**Present vs. Absent**	1.56	1.21–1.97	<0.001
Radiological Severity	**Severe vs. Mild/Moderate**	1.89	1.47–2.43	<0.001
Surgical Management	**Yes vs. No**	0.42	0.32–0.56	<0.001
ICU Admission	**Yes vs. No**	1.63	1.15–2.31	0.011

DISCUSSIONS

This study aimed to identify key factors influencing outcomes in traumatic brain injury (TBI) patients, analyzing demographic characteristics, clinical management strategies, complications, and recovery outcomes.

Our study revealed that patients receiving surgical management had a higher likelihood of adverse outcomes compared to those managed conservatively ($p < 0.001$), corroborating findings from similar studies. Specifically, conservative management was more prevalent among mild TBI patients (75.2%) and associated with better recovery outcomes, as evidenced by a higher percentage of patients achieving good recovery (45.3%) compared to those undergoing surgical management (37.8%). This observation aligns with the study by Prasad et al., which demonstrated that conservative management for mild TBI is typically associated with better functional recovery.[13] However, for moderate and severe TBI, surgical management, including craniotomy and craniectomy, is essential for controlling intracranial pressure and preventing secondary brain injury, explaining why these patients had more severe disability outcomes despite surgical interventions.[14]

Further, craniotomy (21.2% of the total cohort) and craniectomy (7.5%) were most commonly performed in severe TBI patients, with a statistically significant relationship observed in relation to recovery outcomes. This result is in line with studies by Lan et al., and Eaton et al., which highlight that surgical interventions significantly reduce mortality and morbidity in severe TBI, particularly when performed early.[15,16] However, the marginal p-value for craniectomy (0.053) suggests that while it may play a role, its impact on outcomes needs further exploration, particularly in different contexts such as rural or resource-constrained settings.[17]

ICU admission was required for 24.8% of the patients in our study, with significantly higher rates of ICU admission seen in moderate and severe TBI patients (57.9% and 59.1%, respectively). This observation is consistent with findings by Wendlandt et al., who emphasized that ICU admission serves as a surrogate marker for the severity of TBI, as patients in the ICU often experience life-threatening complications such as respiratory failure, intracranial hemorrhage, and other multi-organ dysfunctions.[18] The ICU cohort in our study demonstrated a longer duration of stay (10 days for severe TBI patients), which is consistent with the findings of Robba et al., who found that patients admitted to the ICU with severe TBI had longer hospitalizations and poorer long-term outcomes.[19]

Our study also explored the incidence of complications such as pneumonia, sepsis, venous thromboembolism (VTE), and bedsores. The incidence of pneumonia was higher among moderate and severe TBI patients (11.6% and 15.1%, respectively), which was statistically significant ($p = 0.031$). These findings are consistent with a study by Hui et al., which showed that TBI patients, particularly those with more severe injuries, are at increased risk of pneumonia due to prolonged immobilization, mechanical ventilation, and impaired immune response.[20] Sepsis was also more frequent in severe TBI patients (6.5%), echoing findings from Cardozo Júnior et al., who observed a higher risk of sepsis in patients with severe brain injury due to systemic inflammatory responses, particularly in those who underwent major surgical interventions or required ICU admission.[21]

Venous thromboembolism (VTE), occurring in 5.4% of severe TBI patients, is another complication that has been frequently linked to TBI, as noted by Skrifvars et al.[22] The study by Zhang et al., highlighted that TBI patients, particularly those with impaired mobility and those requiring extended ICU stays, face an elevated risk of developing VTE.[23] Our study corroborates this, reinforcing the need for early thromboembolic prophylaxis in high-risk patients.

When considering recovery, the Glasgow Outcome Scale (GOS) was used to categorize outcomes. We found that 42.6% of patients had a good recovery, with surgical management associated with a higher proportion of patients reporting severe disability or vegetative state outcomes. Notably, 5.9% of conservative management patients were in a vegetative state, compared to only 1.9% of those who underwent surgical management. This trend reflects the findings of previous study, such as that by Flynn-O'Brien et al., which concluded that surgical management, while critical in preventing further brain damage, often results in worse functional outcomes for severe TBI patients, particularly when post-operative complications arise.[24] Our data indicate that while surgical intervention may prevent immediate mortality, it does not necessarily correlate with long-term recovery in the severe TBI group.

Moreover, mortality rates were significantly higher in patients who received conservative management, especially in the severe TBI group (5.5%). This is consistent with studies such as those by Mass et al., which suggested that although conservative management is a less invasive approach, it often leads to higher mortality rates in patients with severe brain injuries, particularly when timely surgical interventions are not undertaken.[25]

Our multivariate analysis identified several significant predictors of poor outcomes, including age, GCS on admission, presence of comorbidities, radiological severity, and ICU admission. Age was found to increase the odds of poor outcomes by 12% for every additional year, reinforcing findings from studies such as by Tongyoo et al., who found that older patients with TBI had a significantly reduced likelihood of achieving good recovery.[26] Furthermore, the GCS on admission was strongly predictive of outcome, with lower scores associated with poorer outcomes, consistent with a study by Al-Dorzi et al., which showed that a GCS ≤8 on admission was a powerful predictor of mortality and disability.[27]

The presence of comorbidities was another strong predictor of poor recovery, as indicated by an odds ratio of 1.56, suggesting that patients with underlying health conditions are at greater risk of adverse outcomes. This finding supports the work of Schneider et al., who found that pre-existing conditions like hypertension and diabetes significantly worsen recovery in TBI patients, potentially through mechanisms such as impaired blood-brain barrier integrity or delayed wound healing.[28]

Lastly, ICU admission was associated with an increased risk of poor prognosis (OR: 1.63, $p = 0.011$), further supporting the concept that severe TBI patients requiring intensive monitoring are at higher risk of long-term disability or death. This aligns with the findings of studies such as by Knettel et al., which highlighted the complex relationship between ICU admission and poorer functional outcomes due to the severity of underlying injury and complications.[29]

Limitations and Future Directions

Despite these significant findings, our study has several limitations. First, the study's observational nature restricts our ability to infer causal relationships between the identified predictors and TBI outcomes. Additionally, while we controlled for multiple confounding variables, other unmeasured factors such as genetic predisposition, pre-injury functional status, and the timing of surgical interventions could influence outcomes. Finally, the single-center nature of the study limits the generalizability of our findings, particularly in regions with different healthcare infrastructure. Future multicenter, prospective cohort studies incorporating genetic, biochemical, and advanced neuroimaging data could further refine these predictive models and provide a more comprehensive understanding of the complex nature of TBI recovery.

CONCLUSION

This study highlights several critical factors influencing the outcomes of TBI patients, including age, GCS on admission, comorbidities, radiological severity, and management type. The findings underscore the importance of early identification of high-risk patients and prompt, tailored interventions. Although surgical management plays a crucial role in severe TBI cases, conservative management remains the preferred approach for mild TBI due to better recovery outcomes. These results align with existing literature and suggest that a multifaceted approach considering both clinical and radiological factors is essential for improving recovery and survival rates in TBI patients.

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