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Original Article

Predictors of Neurosurgical Outcomes in Traumatic Brain Injury: A Study from Banda Aceh, Indonesia

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Abstract

Introduction: Traumatic brain injury (TBI) remains a major global health challenge and frequently requires neurosurgical intervention. Various clinical, surgical, and systemic factors may influence postoperative morbidity and mortality. This study aimed to identify key predictors of postoperative outcomes in patients with TBI undergoing neurosurgical procedures.
Subject and Method: A prospective cohort study was conducted at Dr. Zainoel Abidin General Hospital in Banda Aceh from July to October 2024, involving 48 TBI patients who were selected through total sampling. Statistical analysis using chi-square tests and multiple logistic regression identified significant predictors.
Results: We enrolled 48 patients, with an overall postoperative morbidity rate at 58.3%, and the mortality rate was 22.9%. Morbidity was significantly associated with preoperative GCS score (p=0.001), injury-to-surgery time (p=0.039), respiratory (p=0.007), and cardiovascular system (p=0.001). Mortality was significantly associated with preoperative GCS score (p=0.002), surgery duration (p=0.041), respiratory (p=0.041), and cardiovascular system (p=0.004). Multivariate analysis confirmed the preoperative GCS score was the most significant predictor of both morbidity and mortality (p<0.05).
Conclusion: A low preoperative GCS score is a strong predictor of poor postoperative outcomes in patients with TBI. Optimizing perioperative management may improve clinical outcomes in TBI patients undergoing neurosurgical intervention

Keywords: Traumatic brain injury, morbidity, mortality, neurosurgery, prognostic factors

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Introduction

Traumatic Brain Injury (TBI) is a severe type of head injury and a leading cause of morbidity and mortality worldwide.[1] As the most common neurological disorder, TBI places a significant burden on public health systems globally.[2] External mechanical forces cause TBI and are typically categorized as either a closed or open head injury.[3] Over 27 million new cases of TBI require medical attention globally each year, with an age-standardized incidence rate of 369 cases per 100,000 population.[4] More than 55 million people worldwide are living with TBI, which represents approximately 0.7% of the global population. Recent national surveys indicate a high prevalence of head injuries in Indonesia, reported at 11.9%, highlighting the increasing burden of trauma-related neurological disorders.[2,4]

Several demographic and clinical factors contribute to the increasing rates of morbidity and mortality associated with TBI.[5] A comprehensive understanding of the variables contributing to postoperative morbidity, which is characterized

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by the severity of complications and mortality rates, is crucial for enhancing patient management protocols.[6] Neurosurgical intervention is a critical component of TBI management, despite its significant perioperative and postoperative risks. Studies indicate a mortality rate of 21.4% for TBI patients undergoing craniotomy, with a postoperative morbidity rate of 38.9%. These findings underscore the severity of traumatic head injuries and the inherent risks of invasive surgical procedures.[7]

The factors contributing to the postoperative morbidity and mortality in patients with TBI include preoperative Glasgow Coma Scale (GCS) scores, the type and severity of trauma, the time elapsed from injury to emergency treatment and surgery, the duration of the surgical procedure, total blood loss, and the patient's respiratory and cardiovascular status.[6,8] Multivariate analysis effectively assesses the complex relationships between these variables and clinical outcomes in TBI patients undergoing neurosurgery.[9] This study identified clinical and surgical predictors of morbidity and mortality within 30 days after neurosurgery. The findings provide valuable insights for healthcare professionals to optimize patient management strategies, reduce postoperative complications, and improve survival outcomes.

Subject and Method

Study Design

This prospective cohort study was carried out at Dr. Zainoel Abidin General Hospital in Banda Aceh from July to October 2024. The study population included all patients with TBI who underwent neurosurgical procedures. Participants who met the inclusion and exclusion criteria were selected using a total sampling method. Data collection was conducted using secondary sources.

Sample Criteria

The study included all patients diagnosed with TBI who required neurosurgical intervention and underwent surgery at Dr. Zainoel Abidin General Hospital in Banda Aceh between July and October 2024. Eligible participants were those who were within 30 days post-neurosurgical procedure and had complete clinical and operative data available. Patients were excluded from the study if their TBI resulted from brain tumors, strokes, or infections, had a prior history of neurosurgical procedures, their medical records were incomplete, or they declined to participate in the study. Furthermore, patients were also excluded after enrollment if they were transferred to another hospital following surgery, refused medically necessary treatment during hospitalization, or requested to be discharged against medical advice during the study period.

Variables and Data Collection

The study utilized the medical records of patients for data collection. The independent variables analyzed included sex, age, preoperative GCS score, the number and type of trauma, time interval from injury to surgery, duration of surgery, total blood loss, and the condition of the respiratory and cardiovascular systems. The dependent variables were morbidity and mortality within 30 days following surgery.

Statistical Analysis

Data analysis was conducted using categorical data, which was evaluated through the chi-square correlation test. The significance level was established based on the p-value, with a result of $\leq$ 0.05, indicating statistical significance. Following this, a multivariate analysis was performed using multiple logistic regression to identify the most influential factors.

Ethical Clearance

This study received approval from the Ethics Committee of the Faculty of Medicine at Syiah Kuala University in Banda Aceh, Indonesia. Patient confidentiality was upheld throughout the study, and all data were used exclusively for research purposes.

Result

This study was conducted at Dr. Zainoel Abidin General Hospital in Banda Aceh to analyze the factors contributing to morbidity and mortality

Table 1. Study Characteristics

Variable	n	%
Gender	32	66.7
Male	16	33.3
Female		
Age		
median; min-max	28; 8-65	
Infants and toddlers	0	0.0
Children	2	4.2
Adolescents	15	31.3
Adults	25	52.1
Elderly	6	12.5
Preoperative GCS score		0.0
12-15	19	39.6
8-12	16	33.3
3-8	13	27.1
Type of mechanism trauma		
Penetrating	0	0.0
Non-penetrating	48	100.0
Multiple trauma		
None	34	70.8
Present	14	29.2
Type of head trauma		0.0
Epidural Hematoma (EDH)	14	29.2
Subdural Hematoma (EDH)	5	10.4
Intracerebral Hemorrhage (ICH)	20	41.7
Depressed Skull Fracture	3	6.3
Mixed	6	12.5
The time interval from injury to initial ER management		
In minutes (median; min-max)	50; 30-80	
≤ 1 hour	38	79.2
> 1 hour	10	20.8
The time interval from injury to surgery		
≤ 6 hour	9	18.8
> 6 hour	39	81.3
Duration of surgery		
≤ 3 hour	26	54.2
> 3 hour	22	45.8
Total blood loss		
≤ 15% Estimated Blood Volume (EBV)	23	47.9
> 15% Estimated Blood Volume (EBV)	25	52.1
Respiratory system		
SpO_2 > 94% with a maximum of nasal cannula or FiO_2 ≤ 40%	30	62.5
Any SpO_2 with a simple mask or FiO_2 > 40%	18	37.5
Cardiovascular system		
MAP > 70 without support	37	77.1
Any MAP with support	11	22.9
Total	48	100.0

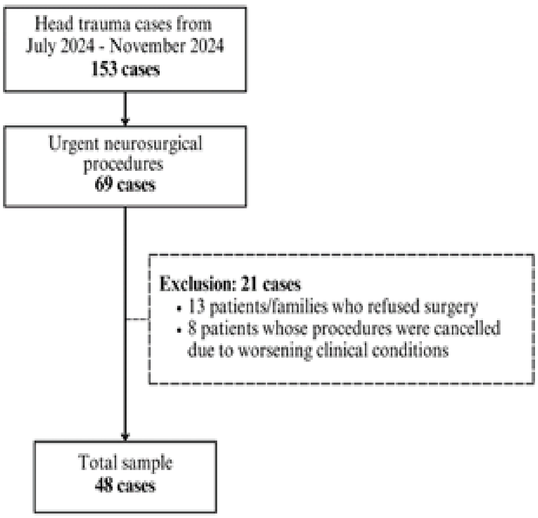

Figure 1. Sample Selection Flowchart

within 30 days postoperatively in patients with traumatic brain injuries undergoing neurosurgical procedures. Data collection took place from July 1, 2024, to November 30, 2024, in the Emergency Department, operating room, and postoperative care unit. A total of 153 cases of head trauma were recorded, with 69 cases scheduled for urgent neurosurgical procedures during this period. These 21 cases were excluded from the study, including 13 patients/families who refused surgery and eight patients whose procedures were excluded due to worsening clinical conditions (Figure 1).

The majority of patients were male (66.7%), and ages ranged from 8 to 65 years, with a median age of 28 years. Adults made up the largest group at 52.1%, followed by adolescents at 31.3%. Most TBI patients (39.6%) had mild traumatic brain injury, defined as a GCS score between 12 and 15. All patients experienced blunt (non-penetrating) trauma, with 29.2% suffering from multiple traumas that affected other body parts, while 70.8% had isolated head trauma. The most common type of head injury was intracerebral hemorrhage (ICH), occurring in 41.7% of cases. The median time from injury to emergency treatment was 50 minutes, with a range of 30 to 80 minutes. Most patients (79.2%) received care within an hour, while 20.8% were treated after waiting more than an hour.

The majority of TBI patients (81.3%) underwent operations more than six hours after their injury, and 54.2% of surgeries were completed within three hours of starting. Blood loss exceeded 15% of estimated blood volume (EBV) in 52.1% of cases. In terms of respiratory function, 62.5% of patients had an oxygen saturation (SpO_2) of 94% or higher with nasal cannula support or a fraction of inspired oxygen (FiO_2) of 40% or less. Cardiovascular assessments showed that 77.1% of patients had a mean arterial pressure (MAP) greater than 70 mmHg without any support.

The overall morbidity rate within 30 days postoperatively in patients with TBI was notably high at 58.3%, signifying that more than half of the patients encountered postoperative complications. Meanwhile, the mortality rate of 22.9% suggests that nearly a quarter of the patients did not survive within the same period. Figure 2 demonstrates that most patients survived, implying that despite the considerable mortality rate, most patients still have a significant chance of survival after surgery.

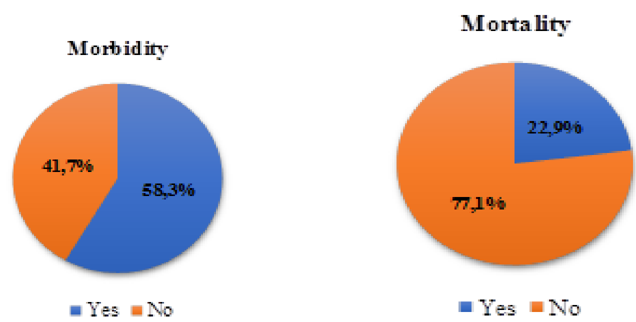

Figure 2. Morbidity and Mortality Rate

Table 2a. Factors Associated with Morbidity and Mortality Rates

Variable	Morbidity		p-value	Mortality		p-value
	Yes	No		Yes	No	
	N=28	N=20		N=11	N=37	
Gender						
Male	16(57.1)	16(80.0)	0.098	9(81.8)	23(62.2)	0.225
Female	12(42.9)	4(20.0)		2(18.2)	14(37.8)	
Age						
Infants and toddlers	0(0.0)	0(0.0)	0.428	0(0.0)	0(0.0)	0.834
Children	2(7.1)	0(0.0)		0(0.0)	2(5.4)	
Adolescents	7(25.0)	8(40.0)		4(36.4)	11(29.7)	
Adults	16(57.1)	9(45.0)		6(54.5)	19(51.4)	
Elderly	3(10.7)	3(15.0)		1(9.1)	5(13.5)	
Preoperative GCS score						
12-15	5(17.9)	14(70.0)	0.001**	0(0.0)	19(51.4)	0.002**
8-12	12(42.9)	4(20.0)		4(36.4)	12(32.4)	
3-8	11(39.3)	2(10.0)		7(63.6)	6(16.2)	
Multiple trauma						
None	22(78.6)	12(60.0)	0.163	9(81.8)	25(67.6)	0.361
Present	6(21.4)	8(40.0)		2(18.2)	12(32.4)	
Type of head trauma						
EDH	5(17.9)	9(45.0)	0.186	1(9.1)	13(35.1)	0.317
SDH	3(10.7)	2(10.0)		1(9.1)	4(10.8)	
ICH	15(53.6)	5(25.0)		5(45.5)	15(40.5)	
Depressed Skull Fracture	1(3.6)	2(10.0)		1(9.1)	2(5.4)	
Mixed	4(14.3)	2(10.0)		3(27.3)	3(8.1)	
The time interval from injury to initial ER management 4(14.3)						
≤ 1 hour	22(78.6)	16(80.0)	0.914	9(81.8)	29(78.4)	0.805
> 1 hour	6(21.4)	4(20.0)		2(18.2)	9(24.3)	
The time interval from injury to surgery						
≤ 6 hour	8(28.6)	1(5.0)	0.039**	2(18.2)	7(18.9)	0.956
> 6 hour	20(71.4)	19(95.0)		9(81.8)	30(81.1)	
Duration of surgery						
≤ 3 hour	12(42.9)	14(70.0)	0.063	3(27.3)	23(62.2)	0.041**
> 3 hour	16(57.1)	6(30.0)		8(72.7)	14(37.8)	
Total blood loss						
≤ 15% EBV	12(42.9)	11(55.0)	0.406	7(63.6)	16(43.2)	0.235
> 15% EBV	16(57.1)	9(45.0)		4(36.4)	21(56.8)	
Respiratory system						
SpO_2 > 94% with a maximum of nasal cannula or FiO_2 ≤ 40%	13 (46.4)	17 (85.0)		7(63.6)	11(29.7)	
Any SpO_2 with a simple mask or FiO_2 > 40%	15(53.6)	3(15.0)				

Note: Bivariate analysis using Chi-square test. **p<0.05 (statistically significant association)

Table 2b. Factors Associated with Morbidity and Mortality Rates

Variable	Morbidity		p-value	Mortality		p-value
	Yes	No		Yes	No	
	N=28	N=20		N=11	N=37	
Cardiovascular system						
MAP > 70 without support	17(60.7)	20(100.0)	0.001**	5(45.5)	32(86.5)	0.004**
Any MAP with support	11(39.3)	0(0.0)		6(54.5)	5(13.5)	

Note: Bivariate analysis using Chi-square test. **p<0.05 (statistically significant association)

Table 3. Multivariate Analysis

	Variable	**p-value**	**OR**	**95% CI**	
				Lower	Upper
Morbidity	Preoperative GCS score	0,040*	0.29	0.087	0.946
	Injury-to-surgery time	0,089	8.61	0.721	1.029
	Respiratory system	0,677	0.65	0.090	2.782
	Cardiovascular system	0,999	0.50	0.020	1.002
Mortality	Preoperative GCS score	0,020*	0.18	0.040	0.764
	Surgery duration	0,205	0.30	0.047	1.928
	Respiratory system	0.587	0.61	0.105	3.591
	Cardiovascular system	0,060	0.17	0.028	1.078

The statistical analysis using the Chi-square test in Table 2 showed the factors that significantly associated (p<0.05) with the 30-day morbidity rate in TBI patients undergoing neurosurgery are preoperative GCS score (p=0.001), injury-to- surgery time (p=0.039), respiratory (p=0.007), and cardiovascular system (p=0.001). The factors that were significantly associated (p<0.05) with the 30-day mortality rate are GCS score (p=0.002), surgery duration (p=0.041), respiratory (p=0.041), and cardiovascular system (p=0.004). Multivariate analysis confirmed the preoperative GCS score as the most influential predictor for morbidity and mortality (p<0.05) (Table 3).

Discussion

This study analyzed factors influencing 30-day postoperative morbidity and mortality among patients with TBI who underwent neurosurgical procedures. Most patients were male and within the adult age group, consistent with national and international findings that show that men are disproportionately affected by TBI (70%), particularly in the adolescent to elderly age range (15–74 years).[10] The study also indicated that most patients with lower GCS scores had more severe injuries, classified as moderate (GCS 9–12) or severe (GCS 3–8). A low GCS score upon arrival at the emergency department (ED) suggests significant brain injury. The more severe the injury, the higher the risk of brain function impairment, which increases the likelihood of mortality.[11,12] A study by Salotto et al. (2021) reported similar findings, showing that most TBI patients admitted to the ED had low GCS scores and poorer outcomes.[13]

The majority of cases of TBI involved non-penetrating brain injuries caused by strong external forces. This finding may indicate lower socioeconomic conditions in the study population, where many individuals rely on motorcycles for transportation, a common cause of non-penetrating TBI.[1] Another study found that several preoperative factors increased the 30-day mortality risk in TBI patients undergoing craniotomy, including older age, ventilator dependence, kidney failure, and multiple traumas.[14] The findings also showed that most patients arrived at the ED and received initial treatment within less than an hour. The time between injury and initial treatment significantly affects recovery and mortality risk after neurosurgery. Rapid ED intervention can reduce complications and improve recovery chances, whereas delays can worsen the patient's condition by increasing intracranial pressure and causing further damage. Trauma patients have a "golden hour," a critical 60-minute window to receive proper treatment before morbidity and mortality risks rise significantly.[8]

Blood loss of less than 15% of EBV is generally considered mild and can be compensated by the body without causing severe hemodynamic disturbances.[15] In TBI patients undergoing neurosurgery, minor blood loss (<15% EBV) usually has minimal impact on the risk of complications or death within 30 days postoperatively. However, monitoring EBV is crucial, as uncontrolled blood loss can worsen brain hypoperfusion, increasing complications and mortality risks.[16] These results indicate that TBI patients had an SpO_2 level above 94%, a nasal cannula or $FiO_2 \leq 40\%$, and a mean arterial pressure (MAP) above 70 without support. Other research highlighted the role of the respiratory system in TBI patient mortality.[6] The Brain Injury Association states that head injuries accompanied by hypoxia are more likely to worsen compared to head injuries of similar severity (based on GCS score) without hypoxia.[17] The Brain Trauma Foundation (BTF) guidelines recommend maintaining cerebral perfusion pressure (CPP) between 60 and 70 mmHg for TBI patients. CPP is calculated as the difference between MAP and intracranial pressure (ICP).[18] Epidural hematoma (EDH) was the most frequent lesion in this study, consistent with previous findings showing EDH in 1–5% of TBI cases, with mortality rates up to 20%.[19] Epidemiological data from Dr. Soetomo General Hospital, Surabaya, recorded 1,178 TBI cases per year, with a mortality rate of 6.2% to 11.2%, higher than the international standard of 3% to 8%.[20] Mortality rates due to TBI in the United States from 1999 to 2017 were also high, with an estimated 99,796 deaths among children and adolescents (ages 0–19). Since 2013, the mortality rate has steadily increased, reaching 5.17 per 100,000 people in 2017. Other studies supporting these findings reported a 30-day post-trauma mortality rate of 12%, with death rates varying by age: 6% in those aged 15–54, 11% in those aged 55–64, 11% in those aged 65–74, 23% in those aged 75–84, and 24% in those aged 85 and older.[10] The results of this study address questions raised in previous research about the factors associated with morbidity and mortality rates in TBI patients undergoing surgery.

Novel Insight

This study presents a comprehensive multivariate evaluation of perioperative and systemic factors affecting postoperative outcomes in TBI patients within a regional Indonesian context. While several international studies have identified similar predictors, few have examined these relationships in low-resource environments where logistical and systemic barriers substantially affect outcomes. These findings highlight the importance of early triage, optimized perioperative management, and ICU preparedness to improve survival and recovery among TBI patients in developing countries.

Limitations

The small sample size may limit the generalizability of the findings, and the single-center study may not reflect outcomes in diverse healthcare settings. Selection bias may have occurred due to the exclusion of patients who refused surgery, deteriorated before intervention, or were transferred to other facilities, potentially underestimating the actual morbidity and mortality associated with TBI requiring neurosurgical procedures. Future multicenter studies with larger cohorts and extended follow-up are needed to validate these findings and refine strategies for improving TBI patient care.

Conclusion

In conclusion, the 30-day postoperative morbidity and mortality rates in patients with TBI undergoing neurosurgical procedures were reported at 58.3% and 22.9%, respectively. Morbidity was significantly associated with factors such as the preoperative GCS score, the time between injury and surgery, and the conditions of the respiratory and cardiovascular systems. Similarly, mortality rates were influenced by the preoperative GCS score, the duration of surgery, and the status of the respiratory and cardiovascular systems. Notably, the preoperative GCS score emerged as the most critical factor affecting morbidity and mortality rates within the first 30 days postoperatively for TBI patients.

These findings underscore the necessity for hospitals to improve their triage systems and expedite the management of TBI patients to enhance clinical outcomes. Strengthening healthcare resources, particularly neurosurgical equipment and intensive care facilities, should be a priority to reduce postoperative complications. Furthermore, increasing public awareness of TBI risk factors and promoting preventive measures are crucial for lowering incidence rates and minimizing severe consequences.

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