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Clinical and Socioeconomic Predictors of Outcomes in Severe Traumatic Brain Injury

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ABSTRACT

Background: Traumatic brain injury (TBI) is a major cause of morbidity and mortality, particularly among young people in developing countries. Limited healthcare resources complicate the management of severe TBI, making accurate prognosis prediction essential. Factors such as socioeconomic status, access to emergency care, and alcohol use significantly influence outcomes. This study aims to identify clinical and socioeconomic factors predicting patient outcomes in severe TBI cases.

Methodology: This prospective observational study was conducted over two years at King George's Medical University in Lucknow, India, involving 820 patients with isolated severe TBI. Patients were assessed at admission and again at three months using the Glasgow Outcome Scale Extended (GOSE) to determine outcomes. Statistical analysis was performed using SPSS version 21, with a significance level set at $p < 0.05$.

Results: Among the 820 TBI patients, 66.9% were male, with a mean age of 35.68; SD:17.36 years. Road traffic accidents were the leading cause of injury (82.9%), and 65.4% of patients did not survive. Key complications included seizures (10.7%) observed. The Glasgow Coma Scale (GCS) score at admission and various imaging scores (Marshall and Rotterdam) were significantly associated with outcomes, with a GCS of 5-6 indicating poor prognosis ($p < 0.0001$). Logistic regression analysis demonstrated strong predictive value for survival, achieving 77.46% sensitivity and 92.91% specificity, with an AUC of 0.9227.

Conclusion: Severe TBI mainly affects those aged 20-30, with worse outcomes for patients over 50. Poor prognosis is linked to low GCS scores, seizures, alcohol use, and abnormal pupil responses, highlighting the need for improved predictive models.

Keywords: *Traumatic Brain Injury, Prognosis, Glasgow Coma Scale, Developing Countries, Outcome Prediction.*

1. INTRODUCTION

Trauma can result in a range of injuries and complications that require prompt examination, discussion, and management in preventing death and permanent disability. [1] Shock and brain damage are the two primary causes of early death in trauma. Severe traumatic brain injury is a primary cause of illness and mortality among young people in developing countries, imposing a significant socioeconomic burden. [2] The clinical outcome following severe traumatic brain injury is difficult to predict because it is dependent on not only the major prognostic factors but also on a variety of additional factors such as nutrition, socioeconomic status, literacy, and access to health care in an emergency, all of which are more difficult to address in developing countries. [3] The fundamental concern raised by research on outcome prediction models created in rich nations is that they may not be applicable to emerging countries such as India. [4] Second, as a resource-constrained country, we require predictive models that concentrate on our facilities in critical regions. [5]

Road traffic accidents are the primary cause of traumatic brain injury (60%), followed by falls from height (20%–25%) and violence (10%). Around 15-20% of patients with TBI are discovered to have been under the influence of alcohol at the time of injury, which is a significant proportion and creates a significant health burden. The need for rehabilitation services for brain damaged people is substantial and growing year after year. India and other developing nations confront significant problems in reducing the burden of TBIs on their populations through prevention, transportation, pre-hospital treatment, and rehabilitation in their quickly changing settings.

Intensive care resources for the therapy of patients with severe diffuse brain injury (SDBI) are few in a developing country like India. Their optimal utilization is possible only if we can accurately forecast patients' prognoses at the time of admission and identify those who are unlikely to improve. Severe TBI management involves several hurdles for the neurosurgeons and intensive care specialists involved. Traumatic Brain Injury treatment is complicated further by associated damage to other organ systems. Although centers treating a high number of severe TBI may have superior outcomes in terms of mortality and quality of life, all of which are attributable to improved ICU facilities and well-trained surgeons and intensivists. Surgical and nonsurgical techniques are currently used to manage severe traumatic brain damage. The majority of severe TBI cases are handled medically [6], with the goal of optimizing intracranial pressure (ICP), maintaining appropriate cerebral blood flow (CBF), avoiding cerebral edema, and preserving the brain's metabolic environment. Surgical methods include the evacuation of intracranial hemorrhages (ICH), which are often indicated when there is a reduced level of awareness, localized neurological impairments, or evidence of raised intracranial pressure that is resistant to medical management [7].

The goal of our study is to share our experience of Severe traumatic brain injury patients in regards with their demographic profile, radiological assessment and their course of illness. Moreover, we will be evaluating various clinical, pathological and socioeconomic factors which might predict the outcome of the patients and this knowledge can be applied on appropriate assessment of prognosis and for counselling of the relatives on presentation.

2. MATERIAL AND METHODOLOGY

This prospective observational study was conducted in the Department of Neurosurgery at King George's Medical University in Lucknow, Uttar Pradesh, India. The study spanned a period of 1.5 years and involved a total sample size of 820 patients. This duration and sample size allowed for a comprehensive analysis of the subjects' conditions and outcomes, providing valuable insights into the various aspects under investigation in the field of neurosurgery.

Inclusion and exclusion criteria

All the patients with isolated severe traumatic head injury admitted to neurosurgery trauma Centre KGMU LUCKNOW from 20/12/2019- 31 July 2021.Patients with other significant torso injury (chest injury, abdominal trauma, spine injury, pelvic injury).Patient with absent brainstem reflex on presentation.

Clinical examination

All patients with severe traumatic head injury were evaluated by history, clinical examination, laboratory and radiological investigations. After optimizing the clinical condition of the patient, conservative or operative management were followed. If surgical procedure was needed, patient's relative was explained about the risks of surgery and potential adverse effects and complications in detail. Patients was assessed as per questionnaire based performa. Initial CT finding was evaluated using Marshall and Rotterdam Scoring system.

Follow-up evaluation

Patients was assessed on admission, and at 3 months follow up.

Final outcome was seen at 3 months. Outcome was assessed based on Glasgow outcome scale extended (GOSE) which are as follows: Good outcome (GOSE – 6-8), Bad outcome (GOSE - 2-5), and Death (GOSE - 1).

Statistical analysis

Statistical analysis was performed using SPSS software (SPSS Inc., Chicago, IL, USA) for Windows program (21.0 version). The dichotomous variables were presented in number/frequency. To compare the frequency between the two/three groups, Chi-square test was used to find the significance of study parameters on a categorical scale and $P < 0.05$ was considered statistically significant.

3. RESULT

Demographical and clinical characteristics of study population

Table 1 makes evident the demographical, clinical and outcome status of severe traumatic brain injury patients. The mean±SD of age was 35.68±17.36 with range 3-75 years. The frequency of males (549, 66.9%) was dominant than that of the females (271, 33.1%). Out of 820 TBI patients, 452 (55.1%) were from rural areas and 368 (44.9%) from urban areas. The leading mode of injury (MOI) was RTA was most common (680, 82.9%). The mean±SD for time lack from injury to admission was 17.0±16.11. Most of the patients (441, 53.8%) had a GCS score of 5-6 at the time of admission. Out of 820 TBI patients, 536 (65.4%) were expired and 284(34.6%) were alive at a time of admission.

Table 1: Patient Demographics, Injury Characteristics, and Outcomes in Severe Traumatic Head Injury Cases

Variables	N=820 N(%)
Age (years) mean±SD Range	35.68±17.36 3-75
Gender Male Female	 549(66.9) 271(33.1)
Residence Urban Rural	 368(44.9) 452(55.1)
Seriocomical status Lower Middle Upper	 353(43.1) 446(54.4) 04(0.5)
Mode of injury Assault Fall Firearm injury Animal hit RTA Unknown	 52(6.3) 71(8.6) 05(0.6) 03(0.4) 680(82.9) 09(1.1)
Time lag in minutes mean±SD	17.0±16.11
GCS score at admission 3-4 5-6 7-8	 233(28.4) 441(53.8) 146(17.8)
Outcome Alive Expired	 284(34.6) 536(65.4)
Management Conservative Operation	 501(61.1) 319(38.9)

Abbreviations: RTA: Road Traffic accident; GCS: Glasgow Coma Scale; MOI: Mode of injury

Complications observed in TBI patients

Out of 820 patients, 88 (10.7%) had seizures and 528 (64.4%) patients had abnormal pupil size. 135 (16.5%) patients had complained of CSF leaking. Marshall 4 was the most common, observed in 319 (38.9%) TBI patients, while Rotterdam 4 was seen in 301 (36.7%) patients. Out of 820 TBI patients, 302 (36.8%) had a best motor response at two stages. Epidural hematoma (EDH) was absent in 726 (88.5%) and IVH was absent in 673 (82.1%). The MLS score with <5mm was observed in 267 (32.6%) TBI patients while >5mm observed in 553 (67.4%) of them. Lesions smaller than 25 mL were observed in 239 (29.2%) patients, while lesions larger than 25 mL were found in 316 (38.5%) patients in the study population (Table 2).

Table 2: Complications and Imaging Findings in Severe Traumatic Head Injury Patients

Complications	N=820; N(%)
Seizure	
Yes	88(10.7)
No	732(89.3)
Blood pressure	
Hypotension	127(15.5)
Normal	621(75.7)
Hypertension	72(8.8)
Pulse rate	
Bradycardia	32(3.9)
Normal	604(73.7)
Tachycardia	184(22.4)
Pupil Size	
Abnormal	528(64.4)
Normal	292(35.6)
Best Motor response	
1	143(17.4)
2	302(36.8)
3	157(19.2)
4	130(15.9)
5	88(10.7)
CSF leak	
Yes	135(16.5)
No	685(83.5)
MLS	
<5	267(32.6)
>5	553(67.4)
Lession (mL)	
<25	239(29.2)
>25	316(38.5)
No	265(32.3)
EDH	
Absent	726(88.5)
Present	94(11.5)
IVH	
Absent	673(82.1)
Present	147(17.9)
MARSHALL	
1	17(2.1)

2	69(8.4)
3	300(36.6)
4	44(5.4)
5	319(38.9)
6	71(8.7)
Rotterdam	
1	16(1.9)
2	64(7.8)
3	92(11.2)
4	301(36.7)
5	241(29.4)
6	106(12.9)

Outcome of the patients based on their clinical characteristics

The RTA was most common MOI in expired patients (431, 80.4%). Among expired patients, 459 (85.6%) had seizures. The GCS score at admission with 5 to 6 was significantly associated with the survival ($p<0.0001$). The pupil size, CSF leaking, basal cistern, MLS score with >5mm, lesions with >25mL, abnormal IVH and Rotterdam score were significantly associated with death of TBI patients ($p<0.001$) (Table 3).

Table 3: Association of Variables with Outcome in Severe Traumatic Head Injury Patients

Variables	Alive (N=284) N(%)	Expired (N=536) N(%)	p-value
MOI			
Assault	15(5.3)	37(6.9)	
Fall	19(6.7)	52(9.7)	0.066
Firearm injury	0	5(0.9)	
Hit by animal	0	3(0.5)	
RTA	249(87.7)	431(80.4)	
Unknown mode of injury	1(0.3)	8(1.5)	
Alcohol			
Yes	19(6.7)	139(25.9)	<0.0001*
No	265(93.3)	397(74.1)	
Seizure			
Yes	273(96.1)	459(85.6)	<0.0001*
No	11(3.9)	77(14.4)	
GCS at admission			
3-4	47(16.5)	186(34.7)	<0.0001*
5-6	130(45.8)	311(58.0)	
7-8	107(37.7)	39(7.3)	
Motor response			
1	3(1.1)	140(26.1)	

2 3 4 5	66(23.2) 71(25.0) 75(26.4) 69(24.3)	236(44.0 86(16.0) 55(10.3) 19(3.6)	<0.0001*
Blood pressure Hypotension Normal Hypertension	 10(3.5) 257(90.5) 17(6.0)	 117(21.8) 364(67.9) 55(10.3)	<0.0001*
Pulse rate Bradycardia Normal Tachycardia	 3(1.1) 244(85.9) 37(13.0	 29(5.4) 360(67.2) 147(27.4)	<0.0001*
Pupil size Abnormal Normal	 125(44.0) 159(56.0)	 403(75.2) 133(24.8)	<0.0001*
CSF leak Yes No	 29(10.2) 255(89.8)	 430(80.2) 106(19.8)	0.004*
Basal cistern Compressed Absent No	 23(8.1) 174(61.3) 87(30.6)	 101(18.8) 340(63.4) 95(17.7)	<0.0001*
MLS <5 >5	 192(67.6) 92(32.4)	 75(14.0) 461(86.0)	<0.0001*
Lession (mL) <25 >25 No	 97(34.2) 90(31.6) 97(34.2)	 142(26.4) 226(42.3) 168(31.3)	0.008*
EDH Present Absent	 244(85.9) 40(14.1)	 482(89.9) 54(10.1)	0.086
IVH Present Absent	 257(90.5) 27(9.5)	 416(77.6) 120(22.4)	<0.0001*
Rotterdam score 1 2 3	 16(5.6) 54(19.0) 69(24.3)	 0 10(1.9) 23(4.3)	<0.0001*

4	100(35.2)	201(37.5)	
5	38(13.4)	203(37.9)	
6	7(2.5)	99(18.5)	

*p<0.05 was considered as statistically significant.

Outcome of patients based on the different scoring of TBI patients

GOSE scores with 5-6 was significantly associated with the poor outcome of the patients (p<0.0001). In the Marshall classification, most poor outcome patients had 5, which is also significantly associated with the disease outcome (p<0.0001). The Rotterdam scores also showed a significant disparity, with poor outcome patients frequently having 4 score and found significant (Table 4).

Table 4: Outcome association with GOS, Marshall, and Rotterdam Scores in Severe Traumatic Head Injury Patients

Variables	Poor outcome N=650; N(%) (GOSE 1-6)	Good Outcome N=170; N(%) (GOSE 7-8)	p-value
GOS			
3-4	211(32.5)	22(12.9)	<0.0001*
5-6	357(54.9)	84(49.4)	
7-8	82(12.6)	64(37.6)	
Marshall			
1	7(1.1)	10(5.9)	
2	35(5.4)	34(20.0)	<0.0001*
3	255(39.2)	45(26.5)	
4	22(3.4)	22(12.9)	
5	260(40.0)	59(34.7)	
6	71(10.9)	0	
Rotterdam			
1	6(0.9)	10(5.9)	
2	29(4.5)	35(20.6)	<0.0001*
3	56(8.6)	36(21.2)	
4	240(36.9)	61(35.9)	
5	216(33.2)	25(14.7)	
6	103(15.8)	3(1.8)	

The above table showed the Classification table of Outcome of Logistic regression analysis. This Logistic regression analysis rendered a sensitivity of 77.46% and specificity of 92.91% in its ROC curve. Overall, it proved that the above parameters showed better predictor for outcome with AUC of 0.9227 and Accuracy of 87.56% in its ROC curve. Sensitivity predicted that 77.46% were confirm mortality out of 100%. (Table 5, fig.1)

Table 5: ROC curve of Logistic regression analysis of different parameters with outcome.

Variables	Suc-Obs	Fail-Obs	AUC	Sensitivity	Specificity	Accuracy
Suc-Pred	220	38	0.92	77.46%	92.91%	87.56%
Fail-Pred	64	498				

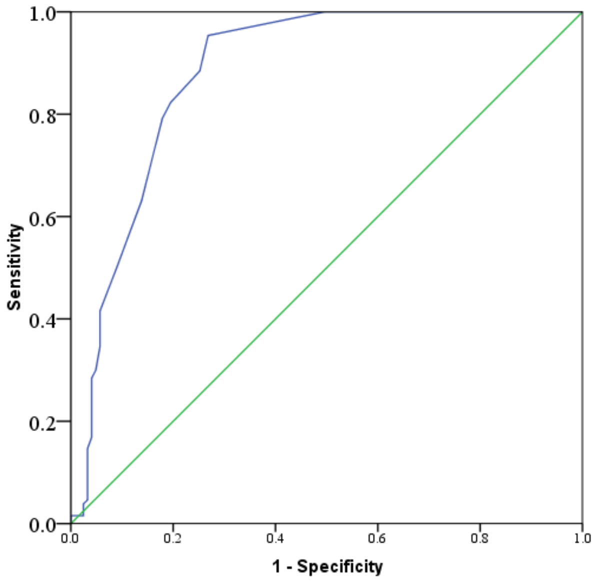

Figure 1: ROC curve for survival analysis

4. DISCUSSION

TBI, particularly in patients over the age of 65, is a leading cause of mortality and disability worldwide [14,15]. TBI accounts for approximately 66,000 deaths annually in Europe, and as life expectancy increases and more advanced therapies for chronic conditions become available, it is becoming an increasingly significant public health concern [16]. Although TBI is less common in the elderly population, its severity leads to substantial long-term morbidity and mortality. Previous studies have demonstrated a correlation between higher mortality rates in the elderly and the increased death rate compared to younger adults. Contributing factors include comorbidities, diminished physical reserves, and polypharmacy, all of which worsen outcomes in this age group [17-21].

In our study of 820 patients with isolated severe TBI, we found that RTAs (82.93%) were the most common cause, with 63.38% of patients dying. Alcohol use was associated with higher mortality, as 87.97% of alcoholic patients died. Seizure activity was observed in 10.73% of cases, with a high mortality rate of 87.50%. Hypotension (92.13%) and hypertension (76.39%) were significant risk factors for mortality, with hypotension being a strong prognostic indicator. Clinical parameters such as the Marshall score (MLS), pulse, GCS at admission, and pupil reactivity were all strongly associated with outcomes. Logistic regression analysis showed a sensitivity of 77.81%, specificity of 92.35%, and an AUC of 0.92, highlighting these factors as reliable predictors of mortality in severe TBI cases.

In severe TBI cases, older patients tend to experience longer hospital stays and extended rehabilitation needs, underscoring the greater morbidity and financial burden associated with managing this demographic [14]. As a result, early clinical indicators in the emergency department (ED), such as hemodynamic parameters and pupillary response, have become increasingly valuable in predicting outcomes. These indicators help guide clinical decision-making, inform family counseling, evaluate the quality of care, and allocate medical resources. While several prognostic models have been developed for TBI outcomes, none have thoroughly examined the influence of respiratory failure (RF) and secondary neurological decline during ED management on mortality and outcomes in elderly patients with isolated severe TBI [14,22].

RF and secondary neurological decline are strongly associated with higher mortality and poorer outcomes in elderly patients with isolated severe TBI. This study aimed to identify the predictive factors that influence outcomes following isolated severe head injury. In this prospective observational study, 820 patients with isolated TBI were enrolled. RTAs accounted for the majority of cases (82.93%), with 249 patients (36.62%) surviving and 431 patients (63.38%) succumbing to their injuries. These findings align with those of Ravi et al., who also found that two-wheeler RTAs were the most common cause of TBI and had the highest associated mortality rate (63.9%) [23]. Among the total cohort, 158 patients were alcoholics, with 87.97% of these patients dying (GOSE 1). In contrast, Tien et al. reported that higher blood alcohol concentrations (BACs) were linked to an increased risk of death (OR = 1.73, 95% confidence interval (CI): 1.05, 2.84), whereas lower BAC levels were associated with a protective effect (OR = 0.76, 95% CI: 0.52, 0.98), suggesting that alcohol's impact on mortality may vary depending on other injuries present [24]. Although our study focused only on isolated head injuries, we observed a notably higher mortality rate among alcoholic patients.

Most patients (732) did not experience seizures, while 88 patients (10.73%) did, with the majority of these patients dying

(87.50%) with GOSE 1. The highest mortality rates were observed in patients with hypotension (92.13%), followed by hypertension (76.39%). Hypotensive patients exhibited GOSE 1 in 92.13% of cases. Kamal et al. identified hypotension (adjusted OR (AOR) (95% CI) = 7.2 (3.4 to 15.0)) and absence of pupillary reactivity (AOR (95% CI) = 5.8 (2.1 to 16.4)) as strong prognostic factors [25]. Consistent with these findings, we also found a significant association between hypotension and increased mortality.

We analyzed a range of clinical parameters, including Marshall score (MLS), intraventricular hemorrhage (IVH), GCS at admission, age, pulse, pupil size, and reaction, all of which showed significant associations with patient outcomes. Among these, MLS had the highest OR (50.914), followed by pulse (OR = 20.313) and GCS at admission (OR = 5.749). A higher OR indicates a greater likelihood of mortality. A statistically significant association was observed between these parameters and patient outcomes ($p < 0.0001$). Logistic regression analysis demonstrated a sensitivity of 77.81% and specificity of 92.35%, with a receiver operating characteristic (ROC) curve showing an area under the curve (AUC) of 0.92 and accuracy of 87.32%, indicating that these parameters are strong predictors of outcome.

Despite ongoing research, the most reliable prognostic variables for severe TBI remain uncertain. Nevertheless, this study offers valuable insights for clinicians and families or surrogate decision-makers when addressing severe TBI cases. Key predictive factors such as MLS, IVH, GCS at admission, age, pulse, pupil size and reaction, alcohol use, seizure activity, and the status of the basal cistern were all significantly associated with patient outcomes.

The strength of this study lies in its large sample size of 820 patients, prospective design, and comprehensive approach that integrates both clinical and socioeconomic factors, offering a more holistic understanding of outcomes in severe TBI. The use of established scales like GOSE and robust statistical methods, including logistic regression, provides reliable and clinically relevant predictions. Additionally, the study's context in a developing country enhances its applicability to settings with limited healthcare resources. However, a limitation is that the study was conducted at a single center, which may limit the generalizability of the findings to other regions or healthcare settings. Moreover, the observational nature of the study means that causality cannot be firmly established, and factors such as patient compliance or post-discharge care were not accounted for.

In cases of severe TBI, the most reliable prognostic variables remain unknown. This present study provides critical information for physicians and patient families/surrogate decision makers to consider while addressing severe TBI cases. While analyzing parameters like MLS, IVH, GCS at admission, age, pulse, pupil size, pupil reaction, alcohol intake, and seizure, basal cistern showed significant association with outcome. However, MLS showed higher OR (-61.019) followed by pulse (-14.857) and alcohol intake (-7.755). The higher the OR, the higher the chance of occurrence of death. The predictive value of above parameter while applying logistic regression, we observed that the Log likelihood (Expired) was -529 and Log likelihood (Alive) was -222.5. Overall, a statistically significant association was observed ($p<0.0001$) between outcome and these parameters. In the present scoring system, the probability of good outcomes increases with increase in scores and expected to be 100% with 18 points. We recommend further multicentric study to gain a better understanding of TBI prognostic factors.

5. CONCLUSIONS

This study aimed to identify the predictive factors influencing the outcomes of isolated severe TBI. A total of 820 TBI patients were enrolled in this prospective observational study, which revealed a high mortality rate of 65.4%. Severe TBI was most common in the 20-30 years age group, with younger patients generally exhibiting a better prognosis. In contrast, older individuals, particularly those over 50 years of age, had a significantly worse prognosis, with mortality rates increasing after the age of 50. The prognosis was found to be independent of gender and injury mechanism. Certain clinical factors, such as the occurrence of seizures, alcohol intake, and a lower GCS score on admission, were associated with poorer outcomes. Additionally, a higher best motor response on admission was linked to better prognosis, while both hypotension and hypertension were found to worsen the prognosis, with hypotension proving to be more dangerous. Abnormal heart rate (both bradycardia and tachycardia), pupil abnormalities, and cerebrospinal fluid (CSF) leaks (including otorrhoea, rhinorrhoea, and brain matter leakage) were also associated with poorer outcomes. The presence of basal cistern absence and a midline shift greater than 5mm significantly worsened prognosis. Furthermore, the presence of IVH was identified as a predictor of poor outcomes. Scores such as the Marshall and Rotterdam scales were also associated with a worse prognosis.

Logistic regression analysis demonstrated that several parameters, including midline shift (MLS), pulse, GCS at admission, age, pupil size, and pupil reaction, were significantly associated with mortality. Among these, MLS had the highest OR (51.128), followed by pulse (27.281) and GCS at admission (6.260), indicating their strong predictive value for mortality. The model's sensitivity was 77.46%, and its specificity was 92.91%, with an area under the curve (AUC) of 0.9227 and accuracy of 87.56%, confirming the model's robust performance. The integration of these clinical parameters into a prognostic model significantly improved the ability to predict patient outcomes, highlighting the complexity of prognosis determination in severe TBI and the importance of multiple variables in shaping patient survival chances.

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