VOLUME - 14, ISSUE - 04, APRIL - 2025 • PRINT ISSN No. 2277 - 8160 • DOI : 10.36106/gjra

Original Research Paper

Neurosurgery

LONG-TERM PROGNOSTIC ANALYSIS OF EMERGENCY DECOMPRESSIVE CRANIECTOMY FOR SEVERE TRAUMATIC BRAIN INJURY PATIENTS WITH BILATERAL FIXED DILATED PUPILS AND GCS≤8: A PROSPECTIVE OBSERVATIONAL STUDY

Dr Ashok Thanthavalia Senior Resident Neurosurgery, Department of Neurosurgery, Sawai Man Singh Medical College, Jaipur, India

Dr. Gaurav Jain* Professor, Department of Neurosurgery, Sawai Man Singh Medical College, Jaipur, India *Corresponding Author

Dr. Madhur Assistant Professor Neurosurgery, Department of Neurosurgery, Sawai Man Singh Medical College, Jaipur, India

Dr. Achal Sharma Senior Professor Neurosurgery, Department of Neurosurgery, Sawai Man Singh Medical College, Jaipur, India

ABSTRACT

Background: Severetraumatic brain injury (sTBI) remains a leading cause of morbidity and mortality worldwide, particularly in patients with bilateral fixed dilated pupils (BFDP) and low Glasgow Coma Scale (GCS) score. This study evaluated the prognostic factors associated with outcomes in patients undergoing decompressive craniectomy (DC) for sTBI with FDP and GCS ≤8. **Methods:** This prospective observational study was performed over the period of 18-months (January 2023 to June 2024) and involved 80 sTBI patients with BFDP and a GCS score of ≤8. Following emergency DC,the patients were assessed at discharge, 6-months, and 12-months. Outcomes of interest included mortality and favorable outcome, assessed with the Glasgow Outcome Scale (GOS) score of 4–5. **Results:** During the study, the overall survival rates decreased from 41.25% to 25.00%, while the favorable outcome increased from 15.00% to 17.00%. At discharge, 6-months, and 12-months, the lower preoperative GCS (OR: 2.074, 2.039, and 2.093; p<0.0001, respectively) and higher preoperative Marshall score (OR: 0.580, 0.625, and 0.547;p<0.05,respectively) were significant mortality predictors. Additionally, tracheostomy (OR: 6.380and 5.107;p<0.05, respectively) at discharge and 6-months, and male sex (OR: 3.037, p=0.034) at 6-months were significant mortality predictors. At discharge, 6-months, and 12-months, lower preoperative GCS (OR: 3.749, 4.137, and 3.760; p<0.05, respectively) and higher preoperative Marshall score (OR: 0.566, 0.525, and 0.519;p<0.05, respectively) were significant predictors of unfavorable outcome. **Conclusion:** Apart from BFDP, lower GCS scores and higher Marshall scores are critical preoperative prognostic factors of mortality and unfavorable outcomes in sTBI patients undergoing emergency DC.

KEYWORDS : Decompressive Craniectomy, Glasgow Coma Scale, Marshall Score, Outcome, Pupil Dilatation, And Traumatic Brain Injury

INTRODUCTION

Traumatic brain injury (TBI) affects about 2% of the global population annually and is a leading cause of death and disability, particularly among the young.[1] Moreover, the patients with bilateral fixed dilated pupils (BFDPs), indicating severe cerebral herniation from high intracranial pressure (ICP) due to hemorrhage or edema, face a grim prognosis, with mortality rates varying between 60% and 100%.[2]

Decompressive craniectomy (DC) has become a vital intervention for alleviating ICP and potentially improving outcomes in severe TBI (sTBI) patients.[3] However, it carries significant post-operative mortality and disability risks, posing challenges for both patients and neurosurgeons. The key prognostic factors of post-DC outcomes include preoperative Glasgow Coma Scale (GCS) score and pupillary status.[4] The Marshall classification score is also a significant predictor, with higher scores indicating more severe injuries and poorer outcomes. Comorbidities further impact prognosis, and tracheostomy often reflects the severity of the patient's condition, correlating with extended mechanical ventilation and complications.[5] Additionally, the time from injury to surgery is vital, as delays can exacerbate outcomes through prolonged raised ICP and secondary brain injury.[6]

Despite decreasing the mean ICP, DC may negatively impact long-term outcomes.[7]Long-term retrospective studies on sTBI indicate that while lower GCS scores does not always predict unfavorable outcomes, factors such as age, preoperative activated partial thromboplastin time (APTT), BFDP, and heart rate can independently forecast mortality and unfavorable outcomes at 6- and 12-months post-DC.[2,8] Another retrospective study by Dobran et al. found that GCS scores, injury-to-surgery duration, and neutrophil-to-leukocyte ratio (NLR) independently predicted outcomes at 6 months, while only injury-to-surgery duration and NLR were significant for 12-month outcomes, likely due to different methodologies, such as using a disability rating scale for measuring outcomes.[9]

While some studies highlight the benefits of DC for patients with sTBI and FDP due to brain herniation, the specific findings on its efficacy remain unclear.[10] One recent study showed positive long-term outcomes following emergency DC in patients with BFDP, noting that higher preoperative GCS scores and shorter injury-to-surgery intervals were linked to favorable outcomes. However, this study was retrospective in nature and had a small sample size.[11] Therefore, a prospective study with large sample size is needed to identify predictors of outcomes after emergency DC. In our study, we examined various baseline predictors of long-term outcomes in sTBI patients with BFDP and a GCS score ≤8.

MATERIALS AND METHODS

Study Design

This prospective observational study was performed over a period of 18 months (January 2023 to June 2024) in the Department of Neurosurgery of a tertiary care hospital. The study was approved by the Institutional Ethical Committee and written informed consent of the patients was taken.

Patients

The study included patients of all age groups and both sexes who presented with sTBI, a GCS score of 3-8, BFDP (both pupils ≥4 mm and absence of light reflex), and underwent emergency DC within 2 hours of admission. While the patients with spinal cord injury, penetrating head injury, alcohol intoxication, pre-existing neurological disorders, and previous craniectomy were excluded.

Quantitative Variables

Data related to patient demographics (age and sex), comorbidities, adverse habits, mechanism of injury, associated injuries, preoperative GCS score, Marshall score, injury-surgery duration, surgical approach, tracheostomy, hospital stays, and Glasgow Outcome Scale score was collected. Head computed tomography (CT) scans revealed subdural hematomas, epidural hematomas, contusions, and diffuse axonal injuries, with midline shift or significant mass effect on CT scans indicating severe TBI.[12] ICP levels, which typically ranged from 5-15 mmHg, exceeded 20 mmHg in severe TBI cases, and levels above 25 mmHg often indicated poor outcomes and necessitated interventions like DC.[13] Following DC, the patients were evaluated at discharge, 6-months, and 12-month.

To optimize the reduction of ICP, a standardized DC approach was used, incorporating both unilateral (UDC) and bilateral (BDC) procedures. The decision between UDC and BDC was made based on brain CT results, following the method described by Li et al.[14] UDC was performed for patients with unilateral brain swelling, while BDC was chosen for those with generalized brain swelling. The procedure typically involved suturing and ligating the superior sagittal sinus, opening the dura mater, sectioning the falx at the anterior skull base, and performing duraplasty when feasible. The area covered by UDC was approximately 12 cm × 15 cm, while BDC covered around 10 cm × 25 cm.

Postoperative Therapy

After DC, all severe TBI patients were treated in intensive care units equipped for advanced neurosurgical management. Post-operative care included administering 20% mannitol (average of 250 mL over 6 hours) and gastric acid inhibitors. Key priorities were keeping airways clear, maintaining stability in homeostasis, blood pressure, blood glucose, and oxygen saturation, preventing dehydration or excessive diuresis, and using sensitive antibiotics to prevent infections as needed.[15] Cranioplasty was scheduled approximately three months post-DC, once brain swelling and infection were fully resolved.

Outcomes

The outcomes included survivors and non-survivors at each follow-up visit. Additionally, GOS data was used for the assessment of clinical status during the reassessment period: at discharge, 6-months, and 12-months after emergency DC: 1, death; 2, persistent vegetative state; 3, severe disability (conscious but disabled); 4, moderate disability (disabled but independent); and 5, mild or no disability; a GOS score of 4-5 was defined as a favorable outcome.[16]

Sample Size Calculation

Sample size was calculated according to the methodology of Tian et al. where the overall survival was 36.4% (16/44) at discharge and 25.0% (11/44) at 6 and 12 months, 36.4% at 90% power and 0.05 alpha error.[11]

It was calculated by following formula-

$N = 4pq/L^2$

The calculated sample size was 75. To drop out the failure it was rounded of to 80 patients.

Statistical Analyses

SPSS (IBM, Armonk, NY, USA) version 23.0 for Windows was used to analyze the data. The continuous and categorical variables are represented as mean (standard deviation, SD) and frequencies (percentages), respectively.The independent sample t-test and the Chi-square test were used to determine the association between continuous and categorical variables, respectively.The survival favorable outcomes were categories into dichotomous outcome:outcomes included "survivors" or "non-survivors" and "favorable" or "unfavorable", respectively. The predictors of mortality and favorableoutcomes were assessed with binary logistic regression analysis. The findings are represented as odds ratio (OR) with 95% confidence interval (95%CI). A two-tailed p<0.05 was regarded as significantly significant.

RESULTS

Tables 1 – 6 depict the clinical characteristics of the patients at discharge, 6-, and 12-months follow-up. The mean age of the study population was 38.81 (16.76) years (range: 3.5 – 74 years). Around three-fourth of the patients were male (73.75%) and around two-third of the injuries were due to road traffic accidents (86.75%). Bone fractures (7.5%) and hypertension (5.0%) were the most commonly associated injuries and comorbidities, respectively. The mean preoperative GCS and Marshall scores were 5.68 (1.81) and 4.0 (1.43), respectively. All the patients received DC treatment within 2 hours of hospitalization, and the mean interval from injury to surgery was 3.03 (0.91) hours. The overall survival rates at discharge, 6-months, and 12-months were 41.25%, 37.50%, and 25.00%, respectively. The favorable outcome (GOS score 4-5) after injury increased from 15.00% at discharge to 16.25% and 17% at 6-, and 12-months, respectively.

At discharge (Table 1), 6-months (Table 3), and 12-months (Table 5), lower preoperative GCS score (all p<0.0001), high Marshall score (p<0.0001, 0.005, and 0.002, respectively), and shorter hospital stay (p=0.001, 0.003, and 0.030, respectively) were significantly associated with mortality. Additionally, comorbidities (p=0.012) and tracheostomy (p=0.001) were significantly associated with mortality at discharge, while male sex (p=0.030) and tracheostomy (p=0.005) were significantly associated with mortality at 6-months.

At discharge (Table 2), 6-months (Table 4), and 12-months (Table 6), lower preoperative GCS score (all p<0.0001), higher Marshall score (p<0.0001, 0.005, and p=0.003, respectively), and shorter hospital stay (p=0.026, 0.012, and 0.004, respectively) were significantly associated with unfavorable outcome. Additionally, younger age (p=0.024) and comorbidities (p=0.031) were significantly associated with unfavorable outcome at discharge, while tracheostomy was significantly associated with unfavorable outcome at 6- and 12-months (p=0.037 and 0.026, respectively).

Based on the binary logistic regression analysis,at discharge, 6-months, and 12-months, lower GCS (OR: 2.074, 95%CI: 1.491–2.884, p<0.0001; OR: 2.039, 95%CI: 1.460–2.846, p<0.0001; and OR: 2.093, 95%CI: 1.405–3.116, p<0.0001, respectively) and high Marshall score (OR: 0.580, 95%CI: 0.409–0.821, p=0.002; OR: 0.625, 95%CI: 0.443–0.882, p=0.007; and OR: 0.547, 95%CI: 0.365–0.819, p=0.003; respectively) were significant predictors of mortality. Additionally, tracheostomy was a significant predictor of mortality at discharge (OR: 6.380; 95%CI: 1.937–21.016; p=0.002) and at 6-months (OR: 5.107; 95%CI: 1.551–16.815; p=0.007), while male sex (OR: 3.037; 95%CI: 1.088–8.479; p=0.034) was an independent predictor of mortality at 6-months.

Further analysis suggested that lower GCS and high Marshall score were significant predictor of unfavorable outcome at discharge (OR: 3.749, 95%CI: 1.551–9.058, p=0.003; and OR: 0.566, 95%CI: 0.347–0.921, p=0.022; respectively), 6-months (OR: 4.137, 95%CI: 1.657 – 10.330, p=0.002 and OR: 0.525, 95%CI: 0.322–0.856 p=0.010; respectively), and 12-months (OR: 3.760, 95%CI: 1.676–8.434, p=0.001; and OR: 0.519, 95%CI: 0.322–0.835, p=0.007; respectively).

DISCUSSION

The principal findings of the study suggested reduction in overall survival rates over the study period i.e., from 41.25% at discharge to 25.00% at 12-months. Though the favorable outcome increased, it was marginal i.e., from 15.00% at discharge to 17% at 12-months. The lower preoperative GCS and higher preoperative Marshall score were significant predictors of mortality at all the intervals studied. Additionally, male sex and tracheostomy significantly predicted mortality at 6-months. Similar to the mortality predictors, lower preoperative GCS and higher preoperative Marshall score were significant predictors of unfavorable outcome at discharge, 6-months, and 12-months.

Tian et al. reported survival rates of 36.4% at discharge for patients with sTBI and brain herniation who underwent DC, which fell to 25.0% at 6 and 12 months.[11] Our study corroborates these findings, showing survival rates of 41.25% at discharge, decreasing to 37.5% at 6 months and 25% at 12 months. Moreover, Skrifvars et al. found that approximately 20% of patients experienced poor neurological outcomes at 12-month follow-up, consistent with our findings of a significant decline in 12-month survival rates. This underscores that, despite good initial survival rates, the long-term prognosis for many with sTBI is unfavorable, potentially due to differing methodologies – survival was assessed based on time to death and absolute risk differences to evaluate favorable outcomes.[17]Tian et al. reported that 20.45% had favorable outcomes after a year, even with preoperative GCS scores as low as 3.[11] However, our study reported only marginal increase of 2% in favorable outcomes at 12 months. In contrast, Tang et al. reported a 30-day mortality rate of 78.7% and a 6-months poor outcome rate of 89.4% in sTBI patients with BFDP who underwent DC.[2]

In the present study, lower GCS and higher Marshall scores were consistent predictors of mortality at discharge as well as at 6- and 12-months. Additionally, the need for tracheostomy was significant predictors of mortality at discharge and 6-months, while male sex significantly predicted mortality at 6-months. In their study, Tang et al. observed that advanced age, prolonged prothrombin, and low GCS as significant predictors of 30-day mortality, while advanced age was the sole independent predictor of poor prognosis at 6-months.[2] In a long-term follow-up study, Liu et al. reported unfavorable outcome in 26.4% patients and the independent risk factors associated with unfavorable outcome were age, admission GCS score, heart rate, platelets count, and tracheotomy.[8] Moreover, Maarouf et al. found that lower GCS scores are strongly correlated with poorer neurological outcomes following TBI, reinforcing the notion that initial neurological status is a key determinant of long-term recovery.[18] Our study corroborates this, with lower GCS scores consistently associated with increased mortality across the follow-up intervals (OR: 2.074, 2.039, and 2.093 at discharge, 6-months, and 12-months, respectively)

The Marshall score, which assesses the severity of brain injuries based on CT findings, also emerged as a significant predictor of mortality in our cohort. Higher Marshall scores were associated with increased mortality risk, aligning with findings from other studies.[19] The odds ratios for the Marshall score at discharge, 6 months, and 12 months were 0.580, 0.625, and 0.547, respectively indicating that the likelihood of mortality increases with the higher severity of the injury.

At discharge and 6-months, the need for tracheostomy was significantly associated with mortality, suggesting that patients requiring tracheostomy may have more severe respiratory compromise or neurological deficits, complicating their recovery.[20] This aligns with previous studies highlighting that tracheostomy often indicates higher severity in TBI cases, leading to extended mechanical ventilation and complications.[21]

Interestingly, male sex emerged as a significant predictor of mortality at 6 months (OR: 3.037), which aligns with broader epidemiological trends indicating that males are at higher risk for adverse outcomes following TBI.[22] This finding may be attributed to behavioral factors, such as higher rates of risk-taking and exposure to high-risk environments among males. The length of hospital stay was not addressed in this study because the majority of patients in our cohort who died (20 out of 28) did so within two days post-operation and were discharged immediately after death. As a result, the hospitalization duration for deceased patients was inevitably shorter than for those who survived. Consequently, length of stay cannot serve as a predictor of prognosis, which is reason for its exclusion from the binary logistic regression analysis.

Consistent with the predictors of mortality, lower GCS and higher Marshall scores were predictors of unfavorable outcomes at discharge as well as at 6- and 12-months. Additionally, younger age was significant predictors of unfavorable outcomes only at discharge. The mean preoperative GCS score of 5.68 and a Marshall score of 4.0 indicate sTBI with BFDP, which results from alterations in the upper brain stem and raised ICP. These factors lead to changes in cerebral blood flow post-DC, contributing to poorer outcomes. This aligns with findings from Ban et al., which show that lower GCS scores correlate with worse outcomes after DC.[23] The lower preoperative GCS scores (OR: 3.760) and higher Marshall scores (OR: 0.519) continued to be the predictors of unfavorable outcome even at 12-months, thus emerging as critical factors. The consistent association of these variables across multiple time points highlights their robustness as prognostic indicators. In contrast, younger age ($p=0.024$) and comorbidities ($p=0.031$) were only significant at discharge, suggesting that their impact may diminish over time as patients adapt or recover from their injuries.[24]

Limitations of Study

Despite being a prospective study with relatively large sample size and long-term follow-up, the present study has certain limitations. First, the study was single centric, and had non-randomized study design, which makes it susceptible to selection and information bias. Second, the data regarding preoperative and postoperative ICP monitoring were also insufficient given the economic burden and the lack of comprehensive monitoring in previous clinical work, which was a significant confounding factor associated with outcomes. Third, the GOS may not fully capture the complexities of TBI recovery. Using the Glasgow Outcome Scale-Extended (GOS-E) could provide a more comprehensive assessment of recovery, including cognitive and emotional aspects.[25]Additional randomized and multi-centric prospective studies with outcomes assessed beyond 12-months are needed to clarify this controversial issue.

CONCLUSIONS

To conclude, emergency DC for sTBI with BFDP and a GCS score of eight or less results in poor long-term survival and lower rates of favorable outcomes. At 12-months, only a quarter of patients survived and only 17% patients had favorable outcome. In this group of patients, lower preoperative GCS and higher Marshall scores consistently emerged as significant predictors of unfavorable outcomes and mortality at discharge as well as at 6- and 12-months. While male sex and need of tracheostomy predicted immediate and short-term mortality, younger age predicted immediate unfavorable outcomes. These findings underscore the importance of early assessment and intervention strategies tailored to individual patient profiles to optimize the outcomes in this challenging population.

Table 1. Comparison Of Characteristics At Discharge Based On The Patient Survival

Characteristics	Survivors (n=33)	Non-survivors (n=47)	p

Age, years, mean (SD)	42.05 (16.60)	36.53 (16.67)	0.149
Sex, n (%)			0.085
Male	21 (63.64)	38 (80.85)	
Female	12 (36.36)	9 (19.15)	
Comorbidities, n (%)			0.012
Hypertension	4 (12.12)	0 (0)	
Diabetes and hypertension	2 (6.06)	1 (2.13)	
Adverse habits			0.836
Smoking	4 (12.12)	2 (4.26)	
Alcohol	0 (0)	1 (2.13)	
Smoking and Alcohol	0 (0)	2 (4.26)	
Mechanism of injury, n (%)			
Assault	1 (3.03)	1 (2.13)	0.799
Burst tyre injury	1 (3.03)	0 (0)	-
Fall from height	7 (21.21)	15 (31.91)	0.291
Road traffic accident	24 (72.73)	31 (65.96)	0.520
Associated injuries, n (%)			0.928
Bone fracture	2 (6.06)	4 (8.51)	
Pneumohemothorax	1 (3.03)	0 (0)	
Preoperative GCS score, mean (SD)	6.82 (1.40)	4.87 (1.62)	<0.0001
Marshall score, mean (SD)	3.39 (1.37)	4.43 (1.33)	0.001
Injury-surgery duration, h, mean (SD)	3.12 (0.93)	2.96 (0.91)	0.433
Surgical approach			0.498
UDC	32 (96.97)	44 (93.62)	
BDC	1 (3.03)	3 (6.38)	
Tracheostomy	4 (12.12)	22 (46.81)	0.001
Hospital stays, days, mean (SD)	24.00 (7.51)	16.96 (9.97)	0.001
Glasgow Outcome Scale Score, n (%)			-
4	12 (36.36)	0 (0)	
3	14 (42.42)	0 (0)	
2	7 (21.21)	0 (0)	
1	0 (0)	47 (100.00)	

Table 2. Comparison Of Characteristics At Discharge Based On The Outcome

Characteristics	Favorable (n=12)	Unfavorable (n=68)	p
Age, years, mean (SD)	48.83 (15.75)	37.04 (16.41)	0.024
Sex, n (%)			0.188
Male	7 (58.33)	52 (76.47)	
Female	5 (41.67)	16 (23.53)	
Comorbidities, n (%)			0.031
Hypertension	2 (16.67)	2 (2.94)	
Diabetes and hypertension	1 (8.33)	2 (2.94)	
Adverse habits			0.520
Smoking	2 (16.67)	4 (5.88)	
Alcohol	0 (0)	1 (1.47)	
Smoking and Alcohol	0 (0)	2 (2.94)	
Mechanism of injury, n (%)			
Assault	1 (8.33)	1 (1.47)	0.160
Burst tyre injury	0 (0)	1 (1.47)	-
Fall from height	1 (8.33)	21 (30.88)	0.107
Road traffic accident	10 (83.33)	45 (66.18)	0.237
Associated injuries, n (%)			0.245
Bone fracture	0 (0)	6 (8.82)	
Pneumohemothorax	0 (0)	1 (1.47)	
Preoperative GCS score, mean (SD)	7.67 (0.65)	5.32 (1.71)	<0.0001
Marshall score, mean (SD)	3.08 (1.24)	4.16 (1.41)	0.015
Injury-surgery duration, h, mean (SD)	3.08 (0.99)	3.01 (0.91)	0.812
Surgical approach			0.389
UDC	12 (100.00)	64 (94.12)	
BDC	0 (0)	4 (5.88)	
Tracheostomy	1 (8.33)	25 (36.76)	0.053
Hospital stays, days, mean (SD)	24.17 (6.09)	19.10 (9.97)	0.026
Glasgow Outcome Scale Score, n (%)			-
4	12 (100.00)	0 (0)	
3	0 (0)	14 (20.59)	
2	0 (0)	7 (10.29)	
1	0 (0)	47 (69.12)	

Table 3. Comparison Of Characteristics At 6-months Based On The Patient Survival

Characteristics	Survivors (n=30)	Non-survivors (n=50)	p
Age, years, mean (SD)	42.18 (17.17)	36.78 (16.35)	0.164
Sex, n (%)			0.030
Male	18 (60.00)	41 (82.00)	
Female	12 (40.00)	9 (18.00)	
Comorbidities, n (%)			0.052
Hypertension	3 (10.00)	1 (2.00)	
Diabetes and hypertension	2 (6.67)	1 (2.00)	
Adverse habits			0.648
Smoking	4 (13.33)	2 (4.00)	
Alcohol	0 (0.00)	1 (2.00)	
Smoking and Alcohol	0 (0.00)	2 (4.00)	
Mechanism of injury, n (%)			
Assault	1 (3.33)	1 (2.00)	0.712
Burst tyre injury	1 (3.33)	0 (0.00)	-
Fall from height	6 (20.00)	16 (32.00)	0.245
Road traffic accident	22 (73.33)	33 (66.00)	0.493
Associated injuries, n (%)			0.609
Bone fracture	2 (6.67)	4 (8.00)	
Pneumohemothorax	0 (0.00)	1 (2.00)	
Preoperative GCS score, mean (SD)	6.87 (1.43)	4.96 (1.63)	<0.0001
Marshall score, mean (SD)	3.43 (1.36)	4.34 (1.38)	0.005
Injury-surgery duration, h, mean (SD)	3.10 (0.96)	2.98 (0.89)	0.573
Surgical approach			0.596
UDC	29 (96.67)	47 (94.00)	
BDC	1 (3.33)	3 (6.00)	
Tracheostomy	4 (13.33)	22 (44.00)	0.005
Hospital stays, days, mean (SD)	23.90 (7.53)	17.44 (10.01)	0.003
Glasgow Outcome Scale Score, n (%)			-
5	1 (3.33)	0 (0)	
4	12 (40.00)	0 (0)	
3	16 (53.33)	0 (0)	
2	1 (3.33)	0 (0)	
1	0 (0)	50 (100.00)	

Table 4. Comparison Of Characteristics At 6-months Based On The Outcome

Characteristics	Favorable (n=13)	Unfavorable (n=67)	p
Age, years, mean (SD)	45.35 (19.63)	37.54 (16.01)	0.125
Sex, n (%)			0.274
Male	8 (61.54)	51 (76.12)	

Female	5 (38.46)	16 (23.88)	
Comorbidities, n (%)			0.238
Hypertension	1 (7.69)	2 (2.99)	
Diabetes and hypertension	1 (7.69)	2 (2.99)	
Adverse habits			0.606
Smoking	2 (15.38)	4 ()	
Alcohol	0 (0.00)	1 (1.49)	
Smoking and Alcohol	0 (0.00)	2 (2.99)	
Mechanism of injury, n (%)			
Assault	1 (7.69)	1 (1.49)	0.190
Burst tyre injury	0 (0.00)	1 (1.49)	-
Fall from height	2 (15.38)	20 (29.85)	0.285
Road traffic accident	10 (76.92)	45 (67.16)	0.487
Associated injuries, n (%)			0.222
Bone fracture	0 (0.00)	6 (8.96)	
Pneumohemothorax	0 (0.00)	1 (1.49)	
Preoperative GCS score, mean (SD)	7.69 (0.63)	5.28 (1.69)	<0.0001
Marshall score, mean (SD)	3.00 (1.22)	4.19 (1.39)	0.005
Injury-surgery duration, h, mean (SD)	3.15 (0.99)	3.00 (0.90)	0.582
Surgical approach			0.366
UDC	13 (100.00)	63 (94.03)	
BDC	0 (0.00)	4 (5.97)	
Tracheostomy	1 (7.69)	25 (37.31)	0.037
Hospital stays, days, mean (SD)	24.46 (5.92)	18.97 (9.99)	0.012
Glasgow Outcome Scale Score, n (%)			-
5	1 (7.69)	0 (0.00)	
4	12 (92.31)	0 (0.00)	
3	0 (0.00)	16 (23.88)	
2	0 (0.00)	1 (1.49)	
1	0 (0.00)	50 (74.63)	

Table 5. Comparison Of Characteristics At 12-months Based On The Patient Survival

Characteristics	Survivors (n=20)	Non-survivors (n=60)	p
Age, years, mean (SD)	41.88 (17.41)	37.78 (16.56)	0.348
Sex, n (%)			0.304
Male	13 (65.00)	46 (76.67)	
Female	7 (35.00)	14 (23.33)	
Comorbidities, n (%)			0.253
Hypertension	2 (10.00)	2 (3.33)	
Diabetes and hypertension	1 (5.00)	2 (3.33)	
Adverse habits			0.153
Smoking	4 (20.00)	2 (3.33)	
Alcohol	0 (0.00)	1 (1.67)	
Smoking and Alcohol	0 (0.00)	2 (3.33)	
Mechanism of injury, n (%)			
Assault	1 (5.00)	1 (1.67)	0.081
Burst tyre injury	1 (5.00)	0 (0.00)	-
Fall from height	4 (20.00)	18 (30.00)	0.386
Road traffic accident	14 (70.00)	41 (68.33)	0.889
Associated injuries, n (%)			-
Bone fracture	0 (0.00)	6 (10.00)	
Pneumohemothorax	0 (0.00)	1 (1.67)	
Preoperative GCS score, mean (SD)	7.10 (1.48)	5.20 (1.65)	<0.0001
Marshall score, mean (SD)	3.15 (1.35)	4.28 (1.35)	0.002
Injury-surgery duration, h, mean (SD)	2.90 (0.91)	3.07 (0.92)	0.483
Surgical approach			0.236
UDC	20 (100)	56 (93.33)	
BDC	0 (0.00)	4 (6.67)	
Tracheostomy	3 (15.00)	23 (38.33)	0.054
Hospital stays, days, mean (SD)	23.90 (7.81)	18.52 (9.87)	0.030
Glasgow Outcome Scale Score, n (%)			-
5	3 (15.00)	0 (0.00)	
4	11 (55.00)	0 (0.00)	
3	6 (30.00)	0 (0.00)	
2	0 (0.00)	0 (0.00)	
1	0 (0.00)	47 (100.00)	

Table 6. Comparison Of Characteristics At 12-months Based On The Outcome

Characteristics	Favorable (n=14)	Unfavorable (n=66)	p
Age, years, mean (SD)	44.54 (19.10)	37.59 (16.12)	0.160
Sex, n (%)			0.120
Male	8 (57.14)	51 (77.27)	
Female	6 (42.86)	15 (22.73)	
Comorbidities, n (%)			0.289
Hypertension	1 (7.14)	2 (3.03)	
Diabetes and hypertension	1 (7.14)	2 (3.03)	
Adverse habits			0.692
Smoking	2 (14.29)	4 (6.06)	
Alcohol	0 (0.00)	1 (1.52)	
Smoking and Alcohol	0 (0.00)	2 (3.03)	
Mechanism of injury, n (%)			
Assault	1 (7.14)	1 (1.52)	0.221
Burst tyre injury	0 (0.00)	1 (1.52)	-
Fall from height	2 (14.29)	20 (30.30)	0.223
Road traffic accident	11 (78.57)	44 (66.67)	0.383
Associated injuries, n (%)			-
Bone fracture	0 (0.00)	6 (9.09)	
Pneumohemothorax	0 (0.00)	1 (1.52)	
Preoperative GCS score, mean (SD)	7.64 (0.63)	5.26 (1.69)	<0.0001
Marshall score, mean (SD)	3.00 (1.18)	4.21 (1.39)	0.003
Injury-surgery duration, h, mean (SD)	3.07 (0.99)	3.02 (0.90)	0.836
Surgical approach			0.345
UDC	14 (100.00)	62 (93.94)	
BDC	0 (0.00)	4 (6.06)	
Tracheostomy	1 (7.14)	25 (37.88)	0.026
Hospital stays, days, mean (SD)	25.14 (6.24)	18.74 (9.89)	0.004
Glasgow Outcome Scale Score, n (%)			-
5	3 (21.43)	0 (0.00)	
4	11 (78.57)	0 (0.00)	
3	0 (0.00)	6 (9.09)	
2	0 (0.00)	0 (0.00)	
1	0 (0.00)	60 (90.91)	

REFERENCES

1. Stocchetti N, Carbonara M, Citerio G, Ercole A, Skrifvars MB, Smielewski P, et al. Severe traumatic brain injury: targeted management in the intensive care unit. Lancet Neurol. 2017;16(6):452-64. doi: 10.1016/S1474-4422(17)30118-7.
2. Tang Z, Yang R, Zhang J, Huang Q, Zhou X, Wan W, et al. Outcomes of traumatic brain-injured patients with Glasgow coma scale < 5 and bilateral dilated pupils undergoing decompressive craniectomy. Front Neurol. 2021;12:656369. doi: 10.3389/fneur.2021.656369.
3. Creutzfeldt C, Vilela M, Longstreth W. Paradoxical herniation after decompressive craniectomy provoked by lumbar puncture or ventriculoperitoneal shunting. J Neurosurg. 2015;123(5):1170-5. doi: 10.3171/

2014.11.jns141810.
4. Yılmaz İ, Ertem DH, Kılıç M, Altaş K, Mirhasilova M, Ozdemir B, et al. Factors associated with mortality in acute subdural hematoma: Is decompressive craniectomy effective? Ulus Travma Acil CerrahiDerg. 2019;25(2):147-53. doi:10.5505/tjtes.2018.48079.
5. Wettervik TS, Lenell S, Nyholm L, Howells T, Lewén A, Enblad P. Decompressive craniectomy in traumatic brain injury: usage and clinical outcome in a single centre. Acta Neurochir (Wien). 2018;160(2):229-37. doi:10.1007/s00701-017-3418-3.
6. Vaca SD, Kuo BJ, NickenigVissoci JR, Staton CA, Xu LW, Muhumuza M, et al. Temporal delays along the neurosurgical care continuum for traumatic brain injury patients at a tertiary care hospital in Kampala, Uganda. Neurosurgery. 2019;84(1):95–103. doi:10.1093/neuros/nyy004.
7. Kölbel B, Novotny A, Willms A, Kehl V, Meyer B, Mauer U-M, Krieg SM. Study protocol for a multicenter randomized controlled pilot study on decompressive laparotomy vs. decompressive craniectomy for intractable intracranial pressure after traumatic brain injury: The SCALPEL study. Brain Spine. 2023;3:102677. doi:10.1016/j.bas.2023.102677.
8. Liu C, Xie J, Xiao X, Li T, Li H, Bai X, Li Z, Wang W. Clinical predictors of prognosis in patients with traumatic brain injury combined with extracranial trauma. Int J Med Sci. 2021;18(7):1639-1647. doi:10.7150/ijms.54913.
9. Dobran M, Di Rienzo A, Carrassi E, Aiudi D, Raggi A, Iacoangeli A, et al. Post-traumatic decompressive craniectomy: Prognostic factors and long-term follow-up. Surg Neurol Int 2023;14:400. doi: 10.25259/SNI_1090_2022.
10. Göksu E, Uçar T, Akyüz M, Yılmaz M, Kazan S. Effects of decompressive surgery in patients with severe traumatic brain injury and bilateral non-reactive dilated pupils. Ulus Travma Acil CerrahiDerg. 2012;18(3):231-8. doi: 10.5505/tjtes.2012.79059.
11. Tian R, Dong J, Liu W, Zhang J, Han F, Zhang B, et al. Prognostic Analysis of Emergency Decompressive Craniectomy for Patients with Severe Traumatic Brain Injury with Bilateral Fixed Dilated Pupils. World Neurosurg. 2021;146:e1307-e1317. doi: 10.1016/j.wneu.2020.11.162.
12. Parizel PM, Philips CD. Traumatic neuroemergency: imaging patients with traumatic brain injury—an introduction. In: Hodler J, Kubik-Huch RA, von Schulthess GK, editors. Diseases of the brain, head and neck, spine 2020–2023: diagnostic imaging. Cham (CH): Springer; 2020. Chapter 7. Available from: https://www.ncbi.nlm.nih.gov/books/NBK554351/. doi:10.1007/978-3-030-38490-6_7.
13. Niu N, Tang Y, Hao X, Wang J. Non-invasive evaluation of brain death caused by traumatic brain injury by ultrasound imaging. Front Neuroinform. 2020;14:607365. Doi:10.3389/fninf.2020.607365.
14. Li G, Wen L, Yang X, Zheng X, Zhan R, Liu W. Efficacy of large decompressive craniectomy in severe traumatic brain injury. Chin J Traumatol. 2008;11(4):253-6. doi: 10.1016/S1008-1275(08)60052-8.
15. Qiu W, Zhang Y, Sheng H, et al. Effects of therapeutic mild hypothermia on patients with severe traumatic brain injury after craniotomy. J Crit Care. 2007;22(3):229–235. Doi: 10.1016/j.jcrc.2006.06.011.
16. Pettigrew LE, Wilson JT, Teasdale GM. Reliability of ratings on the Glasgow Outcome Scales from in-person and telephone structured interviews. J Head Trauma Rehabil. 2003;18(3):252-8. doi: 10.1097/00001199-200305000-00003.
17. Skrifvars MB, Luethi N, Bailey M, French C, Nichol A, Trapani T, McArthur C, Arabi YM, Bendel S, Cooper DJ, Bellomo R, EPO-TBI Investigators, ANZICS Clinical Trials Group. The effect of recombinant erythropoietin on long-term outcome after moderate-to-severe traumatic brain injury. Intensive Care Med. 2023;49(7):831–839. doi: 10.1007/s00134-023-07141-5.
18. Maarouf D, Ameen D, Khalifa A. Prognostic factors affecting neurological outcomes for patients with closed traumatic brain injury. Egyptian J Health Care. 2022;13(1):1659-1671. doi:10.21608/ejhc.2022.232022.
19. Abouhashem S, Albakry A, El-Atawy S, et al. Prediction of early mortality after primary decompressive craniectomy in patients with severe traumatic brain injury. Egypt J Neurosurg. 2021;36(1):1. doi:10.1186/s41984-020-00096-5.
20. Mollayeva T, Xiong C, Hanafy S, Chan V, Hu Z, Sutton M, Colantonio A. Comorbidity and outcomes in traumatic brain injury: protocol for a systematic review on functional status and risk of death. BMJ Open. 2017;7(10):e018626. doi:10.1136/bmjopen-2017-018626.
21. Aljefri A. Emergency management of traumatic brain injuries: current guidelines and new developments. J Health Care Sci. 2023;3(08):269-274. doi:10.52533/johs.2023.30804.
22. Patel P, Taylor D, Park MS. Characteristics of traumatic brain injury during Operation Enduring Freedom-Afghanistan: a retrospective case series. Neurosurg Focus. 2019;47(5):E13. doi:10.3171/2019.8.FOCUS19493.
23. Ban S, Son Y, Yang H, Chung Y, Lee S, Han D. Analysis of complications following decompressive craniectomy for traumatic brain injury. J Korean Neurosurg Soc. 2010;48(3):244. doi:10.3340/jkns.2010.48.3.244.
24. Xiong C, Hanafy S, Chan V, Hu ZJ, Sutton M, Escobar M, Colantonio A, Mollayeva T. Comorbidity in adults with traumatic brain injury and all-cause mortality: a systematic review. BMJ Open. 2019;9(11):e029072. doi:10.1136/bmjopen-2019-029072.
25. Lv K, Yuan Q, Fu P, Wu G, Wu X, Du Z, Yu J, Li Z, Hu J. Impact of fibrinogen level on the prognosis of patients with traumatic brain injury: a single-center analysis of 2570 patients. World J Emerg Surg. 2020;15(1):54. doi: 10.1186/s13017-020-00332-1.