Original Article

Long Term Outcome in Survivors of Decompressive Craniectomy following Severe Traumatic Brain Injury

Abstract

Background: Decompressive craniectomy (DC) is done for the management of intracranial hypertension due to severe traumatic brain injury (sTBI). Despite DC, a number of patients die and others suffer from severe neurological disability. We conducted this observational study to assess functional outcome as measured by Glasgow outcome scale-extended (GOSE) in survivors of DC. The correlation between various factors at admission and hospital with functional outcome was also obtained. **Materials and Methods:** Patients (15–65 years) posted for cranioplasty following DC due to sTBI were prospectively enrolled. Demographic profile, clinical data, and GOSE were noted at the time of admission for cranioplasty from the patient or nearest relative or both. Retrospective data noted from hospital records included admission Marshalls grading, Glasgow coma score (GCS), motor response, mean arterial pressure (MAP), and timing of DC at the time of initial admission following sTBI. **Results:** A total of 85 patients (71 males and 14 females) were enrolled over a period of 2 years. The mean age of the patients was 33.42 ± 12.70 years. The median GCS at the time of admission due to head injury, at the time of discharge, and at the time of cranioplasty was 8 (interquartile range [IQR] 3–15), 10 (IQR 4–15), and 15 (IQR 7–15), respectively. Thirty-one patients (36%) had good functional outcome (GOSE 5–8) and 54 patients (64%) had poor functional outcome (GOSE 1–4). On univariate analysis tracheostomy ($P = 0.00$), duration of hospital stay ($P = 0.002$), MAP at admission ($P = 0.01$), and GCS at discharge ($P = 0.01$) correlated with outcome [Table 1]. On multivariate analysis MAP at admission (odds ratio [OR] [95% confidence interval {CI}]; 0.07 [0.01–0.40] and tracheostomy (OR [95% CI]; 15 [1.45–162.9]) were found to be the independent predictors of functional outcome. **Conclusion:** Significant disability is seen among the survivors of DC. Tracheostomy and MAP at admission were found to be independently associated with the patient outcome.

Keywords: *Decompressive craniectomy, extended Glasgow outcome score, functional outcome, Glasgow coma scale, mean arterial pressure*

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Introduction

Traumatic brain injury (TBI) is a silent epidemic and a key public health problem worldwide. Its incidence is 0.2%–0.5% per year and increasing, predominantly in middle- and low-income countries.[1] In India, approximately 1.5–2 million people are injured, and 1 million loose life each year due to TBI.[2] The total cost of treatment and rehabilitation is phenomenal for the developing societies.

Decompressive craniectomy (DC) is considered a part of the tiered therapeutic protocol for the management of intracranial hypertension due to severe TBI (sTBI). It has become a popular choice among the clinicians and is often used to treat diffuse cerebral edema and intracranial hematomas. Despite DC, a number of patients die, and others suffer from severe neurological disability. The survivors present to the hospital for cranioplasty, i.e., repair of bony defect with autologous or synthetic substitutes (titanium mesh/polyethylether ketone PEEK cage/Ceramics).

We conducted this observational study to assess functional outcome as measured by Glasgow outcome scale-extended (GOSE) in patients at the time of cranioplasty following DC due to sTBI. As a secondary outcome, the correlation between various factors at hospital admission/stay and functional outcome at the time of cranioplasty was obtained.

Materials and Methods

Approval from Institutional Ethics Committee for conduction of study was

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obtained. The study was conducted at Jai Prakash Narain Apex Trauma centre (JPNATC), All India Institute of Medical Sciences, New Delhi, India over a period of 2 years (2013–2015). After getting consent for the conduct of study and publication of data from the patient or nearest relative, patients (15–65 years) posted for cranioplasty following DC due to sTBI were prospectively enrolled. Patients with coexisting spine injury, major trauma leading to nonfunctional limbs, psychiatric patients, unattended patients, and nonconsenting patients were excluded. Demographic, clinical data, and GOSE were noted at the time of admission for cranioplasty from the patient or nearest relative or both. Retrospective data noted from hospital records included admission Marshalls grading, Glasgow coma score (GCS), motor response, mean arterial pressure (MAP), and timing of DC following sTBI. For the ease of analysis, we used Marshall grading for categorizing head injured. One patient can have more than one type of lesions such as patients with subdural hemorrhage may have subarachnoid hemorrhage (SAH) or an epidural hemorrhage along with brain contusions. Marshall grading categorizes TBI patients into six categories based on findings of noncontrast computed tomography (CT) scan of the brain, status of the mesencephalic cisterns, the degree of midline shift, and the presence or absence of one or more surgical mass [Appendix 1].[3] Other variables noted included, duration of hospital stay, GCS at discharge, duration between DC, and cranioplasty (days).

GOSE score between 5 and 8 was considered as good outcome and GOSE 2–4 was considered as poor outcome.

Statistical analysis

Data were analyzed using STATA 14 (StataCorp. 2015. Stata Statistical Software: Release 14. College Station, TX: StataCorp LP). Categorical data are expressed as frequency and percentage. Quantitative data are expressed as mean and standard deviation. Association between categorical variables was compared using Chi-square/Fisher's exact test. Univariate and multivariate logistic regression analysis was performed to estimate unadjusted and adjusted odd's ratio. P <0.05 was considered statistically significant.

Results

This was a prospective observational cohort study to see the functional outcome in patients posted for cranioplasty following DC due to TBI. A total of 85 patients (71 males and 14 females) were enrolled over a period of 2 years. As a secondary objective correlation between various factors at admission and during the hospital stay with functional outcome was seen. The data at the time of hospital admission due to initial head injury were noted retrospectively [Table 1].The mean age of the patients was 33.42 ± 12.70 years. The median GCS at the time of admission due to head injury, discharge and at the time of cranioplasty was 8 (interquartile range [IQR] 3–15), 10 (IQR 4–15), and 15 (IQR 7–15), respectively. A total of 85% patients had a full GCS score at the time of cranioplasty. However, only 31 patients (36%) had good functional outcome (GOSE 5–8), 54 patients (64%) had poor functional outcome (GOSE 1–4).

The retrospective data (variables at the time of admission due to TBI) are shown in [Table 1]. The mean MAP at admission was 97.23 ± 13.97 mmHg. According to Marshall CT scan grading, majority of the patients (91%) were grade II and IV. There was no patient in Marshall category I and V. Diffuse injury II, III, and IV was seen in 35, 14, and 28 patients, respectively. Nonevacuated mass lesion >25 mm ≥ (Marshall Grade V) was seen in 8 patients. A total of 35 patients had subdural hematoma, 9 had extradural hematoma, SAH was seen in 20 patients, intracerebral contusion was present in 50 patients whereas skull fracture was detected in 15 patients. DC was done within 6–24 h in 54% patients, within 6 h in 15% patients, and >24 h in remainder of the patients. Timing between injury and DC did not correlate with outcome. The median duration of hospital stay was 32 days (range 5–105). Tracheostomy was done in 53 out of 85 patients. On an average, cranioplasty was done 163.6 days (IQR 38–1000) following DC. Delayed cranioplasty (>2 months) postcraniectomy was

Table 1: Demographic and physiological variables of the patients at the time of admission for TBI

Variables	Subgroups	Number (%)
Age (years)	≤30	45 (52.94)
	>30	40 (47.06)
Sex	Male	71 (83.53)
	Female	14 (16.47)
Marshall grading	Grade II TO IV	77 (90.59)
	Grade V-VI	8 (9.41)
MAP (mmHg)	≥ 90	65 (76.47)
	<90	20 (23.53)
Timing of DC (hrs)	< 6	13 (15.30)
	6-24	46 (54.11)
	>24	26 (30.59)
Tracheostomized	No	32 (37.65)
	Yes	53 (62.35)
Hospital stay (days)	1-14	36 (42.35)
	≥15	49 (57.65)
Duration between DC & cranioplasty (days)	≤60	9 (10.59)
	> 60	76 (89.41)
Motor response (adm)	1-2	16 (18.82)
	3-4	16 (18.82)
	5-6	53 (62.35
GCS (adm)	≤ 8	50 (58.82)
	9-12	19 (22.35)
	13-15	16 (18.82)
GCS discharge	≤ 8	26 (30.59)
	9-12	27 (31.76)
	13-15	32 (37.64)

more common in patients with poor GOSE. Patient's characteristics at the time of sTBI (age, sex, MAP, GCS, and Marshall grading of CT scan), during hospital stay (timing of DC, tracheostomy, and duration of hospital stay), at discharge (GCS), and at the time of cranioplasty (duration between DC and cranioplasty, GOSE) are tabulated.

There was no significant association between age, sex, Marshall grading, GCS, motor response at the admission, timing of DC and duration between DC and cranioplasty, with functional outcome [Table 2]. On univariate analysis, tracheostomy (P = 0.00), duration of the hospital stay (P = 0.002), MAP at the admission (P = 0.01), and GCS at the discharge (P = 0.01) correlated with the outcome [Table 1]. On multivariate analysis, MAP at the admission (odds ratio [OR] [95% confidence interval {CI}]; 0.07 [0.01–0.40]) and tracheostomy (OR [95% CI]; 15 [1.45–162.9]) were found to be independent predictors of functional outcome [Table 3].

Discussion

DC is considered a salvage surgery for TBI patients; however, it is associated with high morbidity and mortality.[4,5] We planned this study to see the functional outcome in patients posted for cranioplasty following DC due to sTBI. We chose this group of patients since cranioplasty is considered as surrogate of good outcome among the patients who survived after DC. In our study, up to 64% of the survivors following DC had a poor outcome. Brain trauma foundation guidelines propose a large frontotemporoparietal DC to reduce mortality and improved neurologic outcome in patients with sTBI (Level II A).[6] However, there are not many studies favoring DC, our study adds to this existing knowledge as the patients who survived could not lead an independent life. The functional outcome of patients following DC was not encouraging.[7,8] Despite of the best available care in a specialized trauma care unit, the burden of TBI is significant. Thus, the major challenge in management of head injury is prevention, prehospital care and rehabilitation in developing countries.

Admission variables such as age, GCS, MAP, pupillary response, and CT findings have often been used alone or in combination to prognosticate and predict outcome in patients with TBI.[9,10] We tried to correlate these variables with outcome in patients presenting to us for cranioplasty following DC. In addition to admission variables, duration of injury to decompressive surgery, tracheostomy, duration of hospital stay, and GCS at discharge were also analyzed.

Table 2: Table showing the association between clinical variables and outcome of patients

Variables	Subgroups	GOSE		P
		Poor outcome (1-4)	Good outcome (5-8)	
Age (years)	≤ 30	29 (64.44)	16 (35.56)	0.853
	> 30	25 (62.50)	15 (37.50)	
Sex	Male	47 (66.20)	24 (33.80)	0.250
	Female	7 (50.00)	7 (50.00)	
Marshall grading	Grade II TO IV	47 (61.04)	30 (38.96)	0.248
	Grade V-VI	7 (87.50)	1 (12.50)	
MAP (mmHg)	≥ 90	46 (70.77)	19 (29.23)	0.012
	< 90	8 (40.00)	12 (60.00)	
Timing of DC (hrs)	< 6	5 (38.46)	8 (61.54)	0.05
	6-24	34 (69.39)	12 (30.61)	
	>24	15 (65.22)	11 (34.78)	
Tracheostomized	No	12 (37.50)	20 (62.50)	0.000
	Yes	42 (79.25)	11 (20.75)	
Hospital stay (days)	1-14	16 (44.44)	20 (55.56)	0.002
	≥15	38 (77.55)	11 (22.45)	
Duration between DC & cranioplasty (days)	≤60	5 (55.56)	4 (44.44)	0.718
	>60	49 (64.47)	27 (35.53)	
Motor response (adm)	1-2	14 (87.50)	2 (12.50)	0.079
	3-4	10 (62.50)	6 (37.50)	
	5-6	30 (56.60)	23 (43.40)	
GCS (adm)	≤ 8	35 (70.00)	15 (30.00)	0.326
	9-12	10 (52.63)	9 (47.37)	
	13-15	9 (56.25)	7 (43.75)	
GCS discharge	≤ 8	21 (80.77)	5 (19.23)	0.010
	9-12	19 (70.37)	8 (29.63)	
	13-15	14 (43.75)	18 (56.25)	

Table 3: Univariate and Multivariate logistic regression between clinical variables and outcome of the patients

Variables	Subgroups	GOSE		OR (95% C.I.)	
		Bad (1-4) %	Good (5-8) %	Unadjusted	Adjusted
Age (years)	≤30	29 (64.44)	16 (35.56)	0.91 (0.37,2.22)	1.14 (0.32,4.08)
	> 30	25 (62.50)	15 (37.50)	1.0	1.0
Sex	Male	47 (66.20)	24 (33.80)	1.95 (0.61, 6.23)	0.75 (0.15,3.74)
	Female	7 (50.00)	7 (50.00)	1.0	1.0
Marshall grading	Grade II TO IV	47 (61.04)	30 (38.96)	0.22 (0.02, 1.91)	0.69 (0.42, 1.13)
	Grade V-VI	7 (87.50)	1 (12.50)	1.0	1.0
MAP	≥ 90	46 (70.77)	19 (29.23)	0.27 (0.09, 0.78)	0.07 (0.01, 0.40)
	< 90	8 (40.00)	12 (60.00)	1.0	1.0
Timing of DC (hrs)	< 6	5 (38.46)	8 (61.54)	1	1
	6-24	34 (69.39)	12 (30.61)	0.22 (0.06-0.80)	0.13 (0.22, 0.79)
	>24	15 (65.22)	11 (34.78)	0.45 (0.11-1.78)	0.69 (0.19,4.10)
Tracheostomy	No	12 (37.50)	20 (62.50)	6.36 (2.3-16.89)	15 (1.45,162.9)
	Yes	42 (79.25)	11 (20.75)	1.0	1.0
Hospital stay (days)	1-15	23 (52.57)	21 (47.73)	2.83 (1.12, 7.14)	1.48 (0.36, 5.99)
	>15	31 (75.61)	10 (24.39)	1.0	1.0
Hospital stay (days)	1-14	16 (44.44)	20 (55.56)	4.31 (1.68,11.04)	2.96 (0.61,14.4)
	≥15	38 (77.55)	11 (22.45)	1	1.0
Duration between DC & cranioplasty (days)	≤60	5 (55.56)	4 (44.44)	1.45 (0.36,5.86)	0.79 (0.12,5.28)
	>60	49 (64.47)	27 (35.53)	1.0	1.0
Hospital readmission	Yes	7 (77.78)	2 (22.22)	1.0	1.0
	No	47 (61.84)	29 (38.16)	2.15 (0.41,11.11)	3.80(0.17,85.52)
Motor response (adm)	1-2	14 (87.50)	2 (12.50)	1.0	1.0
	3-4	10 (62.50)	6 (37.50)	4.2 (0.69, 25.26)	6.7 (0.40,109.8)
	5-6	30 (56.60)	23 (43.40)	5.3 (1.10, 26.00)	7.7 (0.72, 83.31)
GCS (adm)	≤8	35 (70.00)	15 (30.00)	1.0	1.0
	9-12	10 (52.63)	9 (47.37)	2.1 (0.70, 6.21)	0.28 (0.04,2.05)
	13-15	9 (56.25)	7 (43.75)	1.8 (0.57, 5.78)	0.26 (0.03,2.17)
GCS discharge	≤8	21 (80.77)	5 (19.23)	1.0	1.0
	9-12	19 (70.37)	8 (29.63)	1.76 (0.49, 6.34)	1.62 (0.20,12.63)
	13-15	14 (43.75)	18 (56.25)	5.4 (1.62, 17.92)	0.53 (0.03, 10.13)

GCS at admission is considered as one of the most important parameter to predict outcome in TBIs.[11,12] However, in our study, this parameter was not independently associated with the functional outcome. In recent years, GCS at admission seems to have lost its predictive value for outcome in patients with TBI. The predictive value of the GCS needs to be reviewed when building prognostic models.[13] Leitgeb *et al*. found GCS score at ICU discharge as a reasonable predictor of outcome at 1 year. Patients with a GCS score < 10 at ICU discharge are less likely to have favorable outcome.[14] In our study, 80% of patients with GCS at discharge ≤ 8, 70% of patients with GCS at discharge 9–12, and 43% of patients with GCS at discharge 13–15 had poor outcome. In univariate analysis, GCS at discharge correlated with the outcome, but it was not found to be an independent predictor of outcome in multivariate analysis.

On multivariate analysis, tracheostomy during hospital stay and hypertension at admission were associated with poor outcome. Up to 79% of patients of the tracheostomized patients had poor outcome as compared to 42% of the patients who were not tracheostomized. Tracheostomy was found to be independent predictor of functional outcome.[15] Although this study found that 79% patients of the tracheostomized patients had poor outcome as compared to 42% of the patients who were not tracheostomized. This association could be due to high requirement of tracheostomy in patients with poor outcome. In our study, all patients with poor GCS underwent early tracheostomy (within 5 days) to facilitate early weaning. Hence, we would like to emphasize that one should not interpret the result of this study as tracheostomy is associated with poor outcome.

The incidence of hypotension at admission was very low in our study. Our study included only adult patients with isolated TBI at the time of ICU admission. We found an association between hypertension at admission (MAP > 90 mmHg) and poor outcome. Trauma leads to sympathetic hyperactivity due to increased catecholamine secretion and aggravates brain damage caused by primary injury. This secondary insult leads to intracranial hypertension, cerebral blood flow dysregulation and cerebral ischemia. Deranged autoregulation also contributes to hypertension-induced cerebral hyperemia. Sellmann *et al*. described prehospital hypertension (>160 mm Hg) as an indicator for in hospital mortality in TBI patients.[16] Ley *et al*. identified high systolic blood pressure as a risk factor for delayed complications.[17] Few other studies found a correlation between prehospital hypertension and higher mortality in TBI patients.[18] In our study, mean MAP at admission was 97.23 (±13.97) mm Hg, indicating that many of the patients with isolated TBI patients presented with admission hypertension. Although there are guidelines regarding early management of hypotension, there are no fixed recommendation for identification and treatment of admission hypertension in TBI.

Despite of the best available care in a specialized trauma care unit, the burden of TBI is significant. CHIRAG study compared the early intensive care and ICU protocol adherence at JPNATC and Harborview Medical Center in the USA and found achieving early ICU adherence to guideline indicators was feasible and associated with significantly lower in-hospital mortality at JPNATC.[19] Thus, a major challenge in front of the developing nations is prevention, prehospital care and rehabilitation. To tackle burden of disabled population, rehabilitation services must be boosted in the developing nations.

Limitations

Study collected retrospective data at the time of initial admission during head injury. The prospective data (functional outcome) relied on a patient who came for cranioplasty. The time of presentation for cranioplasty was variable among the patients. Larger small sample size is required to see the association between patient variables and the outcome in the survivors of DC to find out which group of patients could be benefitted by DC. The present study aimed to assess the functional outcome in patients who survived following DC and impact of GCS and other physiological factors at the time of injury on functional outcome. It is a single point evaluation study and does not study the outcome of patients following cranioplasty.

Conclusion

Significant disability is seen among the survivors of DC. Tracheostomy and MAP at admission were found to be independently associated with the patient outcome. GCS at discharge seems to be a better predictor of outcome than admission GCS. However, these findings need to be tested in a larger group of patients.

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Conflicts of interest

There are no conflicts of interest.

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Appendix

Appendix 1: Marshall category I-VI

	Category	Definition
I	Diffuse injury I (no visible pathology)	No visible intracranial pathology seen on CT scan
II	Diffuse injury II	Cisterns are present with midline shift 0-5 mm and/or lesions densities present; no high or mixed density lesion >25 mm^3 may include bone fragments and foreign bodies
III	Diffuse injury III (swelling)	Cistern compressed or absent with midline shift 0-5 mm; no high or mixed density lesion >25 mm
IV	Diffuse injury IV (shift)	Midline shift >5 mm; no high or mixed density lesion >25 mm^3
V	Any lesion surgically removed	
VI	High or mixed density lesion >25 mm^3; not surgically evacuated	