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Research Article

Posttraumatic Hydrocephalus Following Decompressive Craniectomy in Traumatic Brain Injury: Proportion and Risk Factors

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Abstract

Background Posttraumatic hydrocephalus (PTH) is an important cause of morbidity after decompressive craniectomy (DC) following traumatic brain injury (TBI). Early diagnosis and treatment of PTH can prevent further neurological compromise in patients who are recovering from TBI.

Objective The aim of this study was to assess the proportion of patients who develop hydrocephalus after undergoing DC and to identify the factors associated with PTH requiring surgical treatment in patients undergoing DC for TBI.

Methods Data of patients undergoing DC for TBI in the Trauma Neurosurgery Unit, Medical College Hospital, Trivandrum, between June and December 2020 were collected prospectively.

Results A total of 48 patients who underwent DC were studied. Six (12.5%) patients developed PTH. The patients were divided into two groups: PTH (patients who developed hydrocephalus) and non-PTH (patients who did not develop hydrocephalus). Age, sex, mode of injury, severity of injury, and preoperative radiological findings were not associated with the development of PTH. A distance of craniectomy margin from the midline of less than 2.5 cm was found to be statistically significant. No statistical difference was found in the outcome among the PTH and non-PTH groups.

Conclusion Craniectomy with a superior limit too close to the midline can predispose patients undergoing DC to the development of hydrocephalus. We therefore suggest performing wide DCs with the superior limit greater than 25 mm from the midline.

Keywords
- decompressive craniectomy
- GCS
- posttraumatic hydrocephalus
- risk factors
- severe traumatic brain injury

Introduction

Decompressive craniectomy (DC) is one of the most common surgical procedures done in a neurotrauma setup. Although the number of survivors of severe traumatic brain injury (TBI) has increased as a result of this procedure, morbidity is still high. The complications of this procedure are numerous, of which cerebrospinal fluid (CSF) circulation disorders are the most debilitating in an otherwise improving patient.

The incidence of hydrocephalus after DC varies in different studies. The incidence ranges from 6 to 54%.[1–4] This differing incidence rate may be due to differing definition of hydrocephalus and other exclusion criterias.[5]

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Posttraumatic hydrocephalus (PTH) is one of the most common complications and failure to recognize this condition and lack of appropriate treatment may result in adverse outcomes and delayed recovery.[6] In some cases, permanent neurological deficits may ensue.

The purpose of this study was to identify factors associated with PTH following DC and the outcomes.

Methods

This was a prospective cohort study that included all patients undergoing DC in the Trauma Neurosurgery Unit, Medical College Hospital, Trivandrum, from June to December 2020.

The sample size required is 47.

Statistical Analysis

SPSS (Statistical Package for Social Sciences) version 20 (IBM SPASS statistics; IBM Corp., Armonk, NY, United States, released 2011) was used to perform the statistical analysis.

- Inferential statistics like the following were used in the study:
- Chi-squared test was applied for categorical variables.
- Mann–Whitney *U* test was applied to find the statistical difference between the groups for quantitative variables (age and Glasgow coma scale [GCS]).
- The level of significance was set at 5%.

Inclusion Criteria

- Posttraumatic patients undergoing DC for TBI.
- Patients who survive for more than 7 days postoperatively.

Exclusion Criteria

- Patients younger than 18 and older than 65 years.
- Patients with a past neurological history leading to dilated ventricles or hydrocephalus, which is present on initial computed tomography (CT) scans.
- Patients with uncontrolled comorbidities (diabetes mellitus [DM], hypertension [HTN]).

Data Collection

Patient data, including the patient's age and gender, were collected as part of the demographic details. The primary cause of injury was documented.

Clinical examination findings, including GCS scores at admission and pupil reactivity, were documented. Pupillary reactivity and symmetry were noted with special attention to unilateral fixed pupil (anisocoria).

Pre-op CT findings were noted, including the status of basal cistern (effaced or not), extent of midline shift (>10 mm or 5–10 mm), and the presence of traumatic subarachnoid hemorrhage (tSAH; according to Fischer's grading with the presence of thick SAH, i.e., >3 mm or absent), intraventricular hemorrhage (IVH), subdural hemorrhage (SDH), epidural hemorrhage (EDH), and contusion-associated hemorrhage.

All the patients underwent the standard unilateral wide fronto-temporo-parietal DC with Lax duraplasty with synthetic graft with the size of the craniectomy defect being at least 15 cm (anteroposterior [AP]). Bone flap was placed in the abdomen for further cranioplasty purposes. Postoperative serial CT scans was obtained. Initial CT was obtained within 48 to 72 hours and the extent of the superior craniectomy margin (divided into <2.5 or >2.5 cm) from midline was recorded along with the presence of interhemispheric hygroma, following which serial CT scans were obtained at 10 to 14 days and at 1 month (as per the department protocol) or if there was deterioration of neurological status including a decrease in cognitive status, urinary incontinence, gait disturbance, or general decrease in conscious levels as determined by the GCS score.

For the purposes of this study, PTH is defined as radiological evidence of ventricular dilatation, with a modified frontal horn index ≥33%[7] associated with obliterated CSF spaces, third ventricular enlargement, and periventricular lucencies on serial CT along with clinical deterioration as evidenced by a decrease in consciousness determined by GCS score, urinary incontinence, gait disturbance, and the need for a CSF diversion procedure (external ventricular drain [EVD] or ventriculoperitoneal [VP] shunt). In our setup, medium-pressure Chhabra VP shunt was used. Patients were followed up for 1 month and outcome was recorded in terms of Glasgow outcome scale (5-point GOS). Outcome was graded as unfavorable if the GOS was 1 to 3, while a GOS of 4 to 5 was considered a favorable outcome.

Results

Forty-eight patients were included in the study. Six patients developed PTH. The proportion of patients who developed PTH following DC was 12.5%. Five of the PTH patients underwent VP shunt placement. One patient underwent external ventriculostomy as an emergency procedure. VP shunt placement could not be done due to respiratory complications and the patient died. One patient who underwent VP shunting post-DC died due to respiratory complications with persistent vegetative state.

The patients were divided into two groups: PTH (patients who developed hydrocephalus) and non-PTH (patients who did not develop hydrocephalus). The distribution of patients and treatment characteristics were compared, as detailed in ►**Table 1**.

The age of the patients included in the study ranged from 19 to 65 years. The most common age group among the non-PTH group was 46 to 55 years and among the PTH group, it was 36 to 45 years, but no statistical significance was obtained between the two groups ($p = 0.803$). The patients in the study group were mostly males and no difference was elicited between the PTH and non-PTH groups. The most common mode of injury was Road Traffic Accident (RTA) (68.8%), but no statistical significance was elicited. Patients who underwent DC had an initial GCS score ranging from 4 to 14. No statistical difference was found between the two groups in terms of the GCS score at presentation ($p = 0.62$). Two patients (33.3%) presented with anisocoria in the PTH group, while 18 patients had anisocoria in the non-PTH

Table 1 Demographic, clinical, and imaging data for 48 patients undergoing DC after severe TBI

		Hydrocephalus (PTH)		*p*-value
Variable	Total	Yes	No	
No. of patients	48	6	42	
Median age (y)		44	42.5	0.803
Sex, *n* (%)				
Male	39 (81.3)	5 (10.4)	34 (70.8)	0.88
Female	9 (18.8)	1 (2.1)	8 (16.7)	
Median GCS		6	6	0.62
SDH, *n* (%)				
Yes	42 (87.5)	6 (12.5)	36 (75)	0.32
No	6 (12.5)	0 (0)	6 (12.5)	
EDH, *n* (%)				
Yes	9 (18.8)	2 (4.2)	7 (14.6)	0.32
No	39 (81.3)	4 (8.3)	35 (72.9)	
SAH, *n* (%)				
Yes	23 (47.9)	3 (6.3)	20 (41.7)	0.91
No	25 (52.1)	3 (6.3)	22 (45.8)	
IVH, *n* (%)				
Yes	6 (12.5)	1 (2.1)	5 (10.4)	0.74
No	42 (87.5)	5 (10.4)	37 (77.1)	
Contusion associated hemorrhage, *n* (%)				
Yes	39 (81.3)	5 (10.4)	34 (70.8)	0.88
No	9 (18.8)	1 (2.1)	8 (16.7)	
Basal cisterns (compressed), *n* (%)				
Yes	29 (60.4)	4 (8.3)	25 (52.1)	0.73
No	19 (39.6)	2 (4.2)	17 (35.4)	
MLS, *n* (%)				
> 10 mm	24 (50.0)	2 (4.2)	22 (45.8)	0.38
5–10 mm	24 (50.0)	4 (8.3)	20 (41.7)	

Abbreviations: DC, decompressive craniectomy; EDH, epidural hemorrhage; GCS, Glasgow coma scale; IVH, intraventricular hemorrhage; MLS, midline shift; SAH, subarachnoid hemorrhage; SDH, subdural hematoma; TBI, traumatic brain injury.

group as illustrated in ►**Fig. 1**. There was no significant difference between the two groups ($p = 0.65$).

The most common CT finding was acute SDH (42 patients), followed by contusion-associated hemorrhage (39 patients). IVH was an uncommon finding, which presented in six patients. Midline shift was found to be greater than 10 mm in 24 patients, while it was 5 to 10 mm in 24 patients. None of the pre-op CT findings had statistical significance.

Interhemispheric hygroma (IIH) was present in three patients (50%) in the PTH group, while it was present in nine patients (21.4%) in the non-PTH group, as shown in ►**Table 2**. However, no statistical significance was elicited ($p = 0.13$). The graph in ►**Fig. 2** shows a distance of less than 2.5 cm of craniectomy margin from midline, which was observed in 5 patients (83.33%) in the PTH group and in 10 patients (23.8%) in the non-PTH group. A p-value of 0.003 was obtained; hence, it was statistically significant.

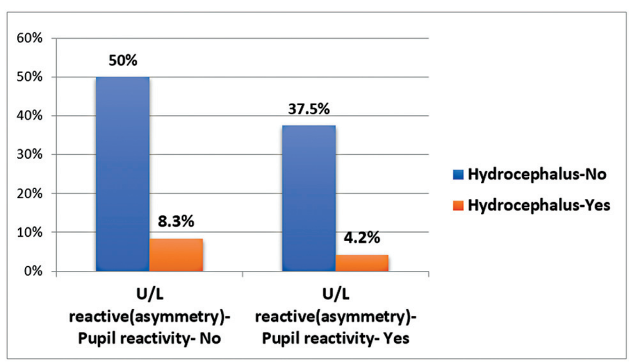

Fig. 1 Distribution of the subjects based on unilateral (U/L) pupillary reactivity (asymmetry).

Fifteen patients had a favorable outcome (GOS of 4 and 5) in the study group, while 16 patients died (33.33%). Five patients were categorized to be in persistent vegetative state

Table 2 Distribution of the post-op computed tomography (CT) findings

Post-op CT findings			Hydrocephalus (PTH)		Total	Chi-squared value	p-value
			No	Yes			
Interhemispheric hygroma	No	Count	33	3	36	2.28	0.13
		%	68.8	6.3	75.0		
	Yes	Count	9	3	12		
		%	18.8	6.3	25.0		
Craniectomy margin from midline	< 2.5 cm	Count	10	5	15	8.65	0.003[a]
		%	20.8	10.4	31.3		
	> 2.5 cm	Count	32	1	33		
		%	66.7	2.1	68.8		

[a]Significant.

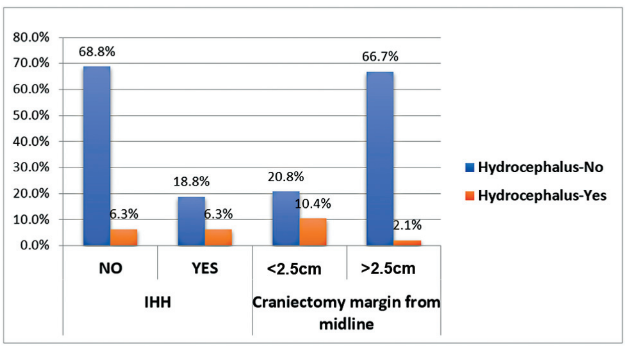

Fig. 2 Distribution of the post-op computed tomography (CT) findings.

and 12 patients had severe disability. Seventeen patients were alive and had an unfavorable outcome (GOS of 2 and 3). However, no statistical difference was found in the outcome of the PTH and non-PTH groups ($p = 0.906$).

Discussion

Our study found the incidence of PTH to be 12.5%, which is less than that reported in many other studies.[3,8] Age, sex, mode of injury, and severity of injury were not associated with the development of PTH. The median GCS at admission in both the PTH and non-PTH groups was 6, which indicates that the patients who underwent DC had severe TBI. There was no significant difference between the two groups. De Bonis et al[9] and Vedantam et al[10] also recently reported similar findings. Unilateral pupillary reactivity (anisocoria) was also not an associated finding in our study. In our study, severe injury was not associated with the development of PTH following DC.

None of the preoperative radiological findings were associated with increased incidence of post-DC PTH in our study. Kaen et al[11] in their study of 73 patients undergoing DC found that SAH (92%), brain edema (75%), and brain contusions (67%) were common findings; IVH, however, was less common. None of them had statistical significance in the causation. This is comparable to the findings in the present study.

Interhemispheric hygroma was present in 50% of the patients who developed PTH compared to 21.4% in the non-PTH group. However, our analysis showed no statistical significance between the two groups. This was different from the study conducted by Nasi et al[10] where IIH was associated with the development of PTH. However, Kaen et al[11] also observed the appearance of PTH after the resolution of these hygromas. Most of the collections were transient. Further studies are required with more patients to arrive at a significant conclusion.

Distance of craniectomy from midline was less than 2.5 cm in 15 patients and too medial a craniectomy was perform in five of six patients in the PTH group. This was statistically significant. De Bonis et al[12] reported that 9 of 26 patients who underwent DC developed PTH, of which 8 (89%) patients had undergone a craniotomy with the superior limit of less than 25 mm from the midline. The theory they proposed was that when the craniectomy margin is too close to the midline, the compression over the veins is reduced and during the diastolic phase, there is an increase in venous outflow, which in turn produces an increase in extracellular fluid absorption and a decrease in the volume of the brain parenchyma, which causes ventricular enlargement. Takeuchi et al reported an increase in the incidence of hydrocephalus when the craniectomy margin is too close to the midline in patients of malignant cerebral infarction.[9] The current results are similar and support their theories.

The overall mortality rate in our study was 33.3% (16 of 48 patients). An unfavorable outcome was found in 33 of 48 patients (68.7%), while 15 patients presented with good outcome. There was no statistical significance between the outcome of both PTH and non-PTH groups. This was comparable to studies conducted by Vedantam et al.[8]

Limitations

Further follow-up is warranted in the current study to determine the final outcome and to determine whether PTH can be prevented or resolved with early cranioplasty, thus supporting the aforementioned hypothesis. The major limitation of our study was the limited number of patients and difficult long-term follow-up due to the COVID-19 pandemic.

Conclusion

PTH is a common and devastating complication that may occur following DC for TBI. In our series, the proportion of patients developing PTH was 12.5%. Age, sex, mode of injury, severity of injury, preoperative radiological findings, and postoperative interhemispheric collections were not associated with the development of PTH. Craniectomy margin less than 2.5 cm from the midline lead to a significantly increased incidence of PTH. We therefore suggest performing wide decompressive craniectomies, with the superior limit greater than 2.5 cm to avoid additional procedures pertaining to the management of PTH. However, the outcome at 1 month in the PTH and non-PTH groups did not show any significant difference. Further studies are required to quantify long-term outcomes and to find other modalities of treatment for these complications, if required.

Note
Informed consent was obtained from all the participants of the study as per the WHO guidelines.

Conflict of Interest
None declared.

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