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Original Article

Factors associated with post traumatic hydrocephalus following decompressive craniectomy: A single-center experience

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ABSTRACT

Background: A decompressive craniectomy (DC) is a surgical procedure sometimes utilized to manage refractory intracranial hypertension following severe traumatic brain injury (sTBI). The previous studies have established a relationship between DC and post traumatic hydrocephalus (PTH). This study aimed to identify the factors responsible for developing shunt-amenable PTH in patients who underwent DC following sTBI.

Methods: A review of a prospectively collected database of all patients admitted with severe TBI in a tertiary neurosurgical center in North-west England between January 2012 and May 2022 was performed. PTH was defined as evidence of progressive ventricular dilatation, clinical deterioration, and/or the eventual need for cerebrospinal fluid diversion (i.e., a ventriculoperitoneal shunt). Statistical analysis was carried out using IBM SPSS versus 28.0.1.

Results: Sixty-five patients met the eligibility criteria and were included in the study. The mean age of the PTH group was 31.38 ± 14.67, while the mean age of the non-PTH group was slightly higher at 39.96 ± 14.85. No statistically significant difference was observed between the two groups' mechanisms of traumatic injury (P = 0.945). Of the predictors investigated, cerebellar hematoma (and contusions) was significantly associated with PTH (P = 0.006).

Conclusion: This study concludes that cerebellar hematoma (and contusions) are associated with developing PTH in patients undergoing DC.

Keywords: Brain trauma, Severe traumatic brain injury, Trauma, Traumatic brain injury, Ventriculoperitoneal shunt

INTRODUCTION

A decompressive craniectomy (DC) is a surgical procedure that is sometimes deployed to manage refractory intracranial hypertension following severe traumatic brain injury (sTBI).[11] There are several complications following the procedure, including malignant brain edema, subgaleal/subdural cerebrospinal fluid (CSF) effusion, atrophy of the temporal muscle, postoperative acute subgaleal/subdural hematoma, syndrome of the trephined, soft tissue oedema, seizures, hemorrhagic progression of brain contusion, skin necrosis, and post traumatic hydrocephalus (PTH).[10] PTH is a significant complication following brain trauma.[7] It could result from an obstruction of the flow of the CSF or its malabsorption of it; the exact etiology has not been clearly defined in the literature. However, if it is not appropriately managed, it can lead to restrictions in rehabilitation prognosis, increased length of stay, poorer functional outcomes, and other complications.[9]

The previous studies have established a relationship between DC and PTH.[1,2,6,8,14,17] Some papers have aimed to identify the factors responsible for the development of PTH in cohorts of patients who had DC for TBI, with some identified factors being the presence of interhemispheric hygroma, subarachnoid hemorrhage, delayed cranioplasty, younger age, and the severity of TBI.[12,13] Few studies have comprehensively investigated the association between the pattern of intracranial injury and the development of PTH in specific cohorts of patients who had a subsequent DC following brain trauma. In this study, we aim to identify the factors responsible for developing shunt-amenable PTH in patients who underwent DC following sTBI.

MATERIALS AND METHODS

Study population

An audit of a prospectively collected database of all patients admitted with severe TBI in a tertiary neurosurgical center in North-west England was carried out. The project was registered with the Northern Care Alliance Research and Innovation. This included data collected by the local Trauma and Research Network (TARN) from January 2012 to May 2022. We included all patients who had a DC as part of the management of severe TBI. Our exclusion criteria included: Patients who died in the 1st week, patients with incomplete data entries, patients who did not have a DC, and patients who had hydrocephalus before the sTBI. All patients were managed according to the local institutional protocol. Raised intracranial pressure was managed per the measures delineated by the Brain Trauma Foundation Guidelines. As this was a retrospective chart audit, and the data were completely anonymized, patient consent and ethical approval were not required.

Data collection

Datasets were extracted from the local TARN database. This database contains a dataset of prospectively recorded variables covering demographics plus injury-related physiological, investigation, treatment, and outcome parameters that are collated using a standard web-based case record form by the local TARN hospital audit coordinators. Injury descriptions from imaging, operative, and necropsy reports are submitted by TARN coordinators.

Clinical and demographic variables that were extracted from the database included the Glasgow coma scale (GCS) at admission, date of injury, status at 30 days (dead or alive), date of death, no of days from injury to death, date of birth, age, sex, mechanism of injury, DC intervention, type of DC, date of DC, shunt insertion, date of shunt insertion, type of shunt, no of days between injury and shunt insertion, presence of intracranial infection, external ventricular drain (EVD) insertion, the pattern of intracranial injury, and the Glasgow outcome score (GOS). In line with TARN protocol, the GOS was assessed at discharge or death, whichever came first.

Definition of the outcome

PTH was defined as evidence of progressive ventricular dilatation, clinical deterioration and/or the need for CSF diversion (e.g., a ventriculoperitoneal shunt). This definition has been used and established in the previous studies.[6] The indications for shunt insertion were guided by local practices, including improvement in symptoms and consciousness level following large volume lumbar puncture, improvement of symptoms and consciousness following the insertion of an EVD, progressive increase in ventricular size with decreased consciousness, marked ventricular dilation with clinical deterioration following removal of EVD, and improvement in symptoms following significant subgaleal CSF collection drainage.

Statistical analysis

Statistical analysis was carried out using IBM SPSS versus 28.0.1. Continuous variables were represented with mean and standard deviations, while categorical variables were expressed as absolute frequencies and percentages. Ordinal variables were represented as medians and IQR. The sample was divided into the PTH and non-PTH groups; statistical analysis was conducted between the two groups to explore statistically significant relationships between different predictors. The student's *t*-test was used to evaluate the statistical significance between the mean ages of the PTH group and the non-PTH group. The Wilcoxon Sign-rank test was used to compare the GCS scores and Fisher's exact test was utilized for the categorical variables. $P < 0.05$ was considered statistically significant with a 95% confidence interval.

RESULTS

Of the 806 patients reviewed, 65 met the eligibility criteria and were included in the study (PTH group – 8, the non-PTH group – 57). The mean age of the PTH group was 31.38 ± 14.67, while the mean age of the non-PTH group was slightly higher at 39.96 ± 14.85. There were significantly more males in both groups. There was no statistically significant difference between both groups' age and sex. At 30 days, there was a 12.5% of mortality rate in the PTH group as opposed to 19.3% in the non-PTH group ($P = 0.542$). The median of the GCS scores was the same (5). No statistically significant difference was observed between the two groups' mechanisms of traumatic injury (MOI) (P = 0.945). Although a higher percentage of the PTH group (50%) had EVD inserted, it did not reach statistical significance (P = 0.059). Similarly, there was no statistically significant difference between the GOS of the two groups. The summary is shown in Table 1.

The pattern of intracranial injury was extensively investigated. The different types of injury sustained included the base of skull fracture, brainstem hemorrhage, brainstem compression, cerebellum hematoma, cerebrum hematoma, extradural hematoma, pneumocephalus, intraventricular hemorrhage, skull vault fracture, subarachnoid hemorrhage, orbit fracture, and subdural hemorrhage. Of all the predictors, only cerebellar hematoma (and contusions) had a significant association with PTH (P = 0.006). The summary is shown in Table 2.

The clinical features of patients who had cerebellar contusions and PTH are also featured in Table 3.

DISCUSSION

This study primarily focused on identifying clinical predictors of PTH in patients who underwent DC following sTBI. Although DC is a life-saving procedure, identifying the incidence and clinical predictors of PTH in this subset of patients can help inform the counseling and decision-making process. Moreso, it will inform the prognosis during the subsequent neurorehabilitation. Following examination of the factors that could be associated, only the presence of cerebellar contusions demonstrated a statistically significant relationship (P = 0.006). No significant association between the other predictors tested; these included age, sex, the outcome at 30 days, intracranial infection, EVD insertion, MOI, admitting GCS score, and GOS.

Table 1: Demography and associated factors.

Variable	PTH (12%)	Non-PTH (88%)	*P*-value
Age	31.38±14.67	39.96±14.85	0.130
Sex			0.673
Male	7 (88%)	50 (87.7%)	
Female	1 (13%)	7 (14%)	
Alive at 30 days	7 (88%)	46 (81%)	0.542
GCS score	5 (3–7)	5 (3–7)	0.614
MOI			0.945
Blow (s) without weapon	1 (13%)	14 (25%)	
Falls <2 m	3 (38%)	17 (30%)	
Falls more than 2 m	1 (13%)	7 (14%)	
Shooting	0	1 (2%)	
Stabbing	0	1 (2%)	
Other	0	2 (4%)	
Intracranial Infection	3 (38%)	7 (12%)	0.098
EVD Insertion	4 (50%)	10 (18%)	0.059
Glasgow outcome scale			0.631
Death	1 (13%)	11 (19%)	
Prolonged disorder of consciousness	1 (13%)	3 (5%)	
Severe Disability	4 (50%)	15 (26%)	
Moderate Disability	0	7 (12%)	
Good Recovery	2 (25%)	20 (35%)	

GCS: Glasgow coma scale, EVD: External ventricular drain, MOI: Mechanisms of traumatic injury, PTH: Post traumatic hydrocephalus, Number in bracket represents the sample size with the defined chatacteristic, GCS score is presented in median (interquatile range)

Our findings somewhat contrast with other studies investigating this subject. Several significant factors associated with PTH in patients who had DC identified in the literature include admitting GCS <6, intraventricular hemorrhage on the first CT scan, a requirement of bilateral DC,[4] interhemispheric subdural hygromas, younger age,[16] craniectomy size,[1,5] and repeated operations.[1] A potential explanation for these differences could be variations in sample size and research methodology across the different studies. However, our study found an association with cerebellar contusions/intracerebral hemorrhage. Traumatic cerebellar contusions and hematomas are relatively uncommon.[15] When they do occur, they become risk factors for developing hydrocephalus, often due to the compression of posterior fossa CSF structures. The posterior fossa is a small intracranial compartment compared to the anterior and middle cranial fossa,[3] which makes compression of the fourth ventricle or cerebral aqueduct an established risk.

Decompressive craniectomies are known to alter the CSF dynamics,[10] and this surgery, in combination with the increased risk of hydrocephalus in patients with cerebellar contusions/hematomas, could work synergistically to cause PTH, especially when the contusions may not be large enough to independently cause hydrocephalus. The development of PTH is unpleasant and can significantly impact the length and success of the rehabilitation process of patients. Thus, early identification of possible associated factors, such as cerebellar hemorrhage, could prove useful during the long-term management of patients who have undergone DC to manage their intracranial injuries.[8] More research is necessary to identify the extent to which cerebellar contusions predispose patients who have had DC to PTH.

We experienced some limitations while conducting this investigation. Our definition of the outcome was primarily those who had undergone shunt insertion due to clinically relevant PTH. This could have reduced the number of people said to have PTH in our study. The sample size of this study is also small, which makes our findings to be less generalizable. Further investigation with a larger sample size may be beneficial in validating the findings of this study.

Table 2: Pattern of intracranial injury and their association to PTH.

Injury type	PTH (8)	non-PTH (57)	*P*-value	Injury type	PTH (8)	Non-PTH (57)	*P*-value
Base of Skull Fracture	75%(6)	56%(32)	0.452	Pneumocephalus	50%(4)	19%(11)	0.075
Brainstem hemorrhage	13%(1)	11%(6)	1.0	Intraventricular haemorrhage	38%(3)	23%(13)	0.395
Brainstem compression	50%(4)	33%(19)	0.439	Skull vault fracture	75%(6)	68%(39)	1.0
Cerebellum hematoma	**50%(4)**	**7%(4)**	**0.006**	Subarachnoid haemorrhage	100%(8)	72%(41)	0.184
Cerebrum hematoma	88%(7)	100%(57)	0.123	Orbit fracture	13%(1)	9%(5)	0.561
Extradural hematoma	25%(2)	21%(12)	1.0	Subdural haemorrhage	75%(6)	89%(51)	0.254

PTH: Post traumatic hydrocephalus, Number in bracket represents the sample size with the defined chatacteristic, Text in bold shows statistical significance

Table 3: Features of patients who had cerebellar contusions and post traumatic hydrocephalus.

Age/Sex	MOI	Indication for shunt placement	Admitting GCS score	No. of days between injury and shunt insertion
52/M	Fall <2 m	Marked ventricular dilation and deterioration following removal of EVD	3	47
56/F	Fall <2 m	Improvement in symptoms following drainage of large subgaleal CSF collection.	7	43
32/M	Fall more than 2 m	Progressive increase in ventricular size with decreased consciousness	3	145
24/M	Vehicle incident/collision.	Improvement of symptoms and consciousness following insertion of an EVD.	8	84

CSF: Cerebrospinal fluid, EVD: External ventricular drain, MOI: Mechanisms of traumatic injury, GCS: Glasgow coma scale

Despite comprehensive data collection, we could not collect data on other factors, including the size of the craniectomy, the distance of the medial edge of the craniectomy from the midline, the length of ICU admission, and the duration of intubation and ventilation. Although we intended to conduct a multivariable analysis of the statistically significant factors in this study, this was not feasible due to the restricted statistical significance of the data. Despite the limitations, we believe that this study will be a valuable addition to the growing body of work on PTH.

CONCLUSION

This series concludes that cerebellar hematoma (and contusions) is associated with developing PTH in patients undergoing DC. This is an important finding for neurosurgeons when considering decompressive craniectomies as a management modality in patients with sTBI.

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Declaration of patient consent

Patients' consent not required as patients' identities were not disclosed or compromised.

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Conflicts of interest

There are no conflicts of interest.

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