Original Article

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Surgery Section

Role of Decompressive Craniectomy/ Hemicraniectomy in the Management of Traumatic Brain Injury: A Retrospective Study

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ABSTRACT

Introduction: Head injury is one of the most common outcomes of any kind of trauma becoming the major cause of morbidity and mortality worldwide. The critical element in the treatment of patients with severe head injuries is to prevent the progression of the condition and secondary insult to brain cells. Various protocols are followed for the treatment of severe head injury starting from conservative medical management to surgical approaches like Decompressive Craniectomy (DC)/hemicraniectomy. The DC is a surgical method of removal of part of skull bone so that the brain parenchyma gets space to expand and the Intracranial Pressure (ICP) can get reduced. There are various factors that contribute to the outcome of DC.

Aim: To determine the various factors that affect the outcome of DC/hemicraniectomy.

Materials and Methods: A retrospective descriptive study was conducted in the Institute of Gandhi Medical College and associated Hamidia hospital, Madhya Pradesh, India from May 2017 to April 2021. Hundred patients with moderate to severe head injury who underwent primary DC were included in this study. The variables such as age, preoperative GCS, the timing of surgery, preoperative pupillary reaction, and MidLine Shift (MLS) were compared in terms of survival/death and favourable/unfavourable outcomes using the Chi-square test.

Results: The mean age of participants was 45±14 years. Statistical analysis showed significant results for the variables like age, preoperative the Glasgow Coma Scale (GCS), timing of the surgery, pupillary reaction at presentation, and preoperative MLS in terms of survival/death and favourable/unfavourable outcomes.

Conclusion: Younger age group, better preoperative GCS, early surgery, reactive pupils at presentation, and less preoperative MLS have positive outcome benefits with the DC/hemicraniectomy to reduce the raised ICP.

Keywords: Head injury, Morbidity, Mortality, Road traffic accidents

INTRODUCTION

Traumatic brain injury (TBI) is a foremost public health problem with a high burden of disability and death in low and middle-income countries [1]. Road traffic accidents are one of the major causes of it. India accounts for about 10% of road accident fatalities worldwide [2].

Due to the impact of trauma, there is primary injury to the brain cells. This will further lead to secondary brain oedema. There will be both vascular and cytological events leading to oedema, which further leads to an increase in Intracranial Pressure (ICP), in turn reducing cerebral perfusion pressure [2]. Increased ICP and reduced cerebral perfusion can cause tissue ischaemia. In turn, tissue ischaemia may lead to vasodilation by autoregulatory mechanisms, which are designed to restore the cerebral perfusion. Also, vasodilation increases cerebral blood volume, which leads to an increase in ICP, lowers Cerebral Perfusion Pressure (CPP), and provokes further ischaemia [3]. After TBI, it has been studied that the autoregulation mechanism of Cerebral Blood Flow (CBF) is impaired or absent in many patients [4].

The outcome of TBI is brain oedema, increased ICP, reduced blood supply, reduced oxygen delivery to brain cells, and cell death. Therefore, the critical element in the management of severe head injury patients is to prevent secondary insult to brain cells, reduce brain oedema and ICP, and maintain blood, oxygen, and energy supply to the brain cells [5].

To manage patients with severe head injury (GCS <12) in the trauma unit different protocols have been proposed, which provide a stepwise approach to control brain oedema and raised ICP. These protocols propose initial first-line measures like ventilation, sedation, and head-end up position. More advanced medical measures like inotropes, hypertonic saline, and mannitol are used if these measures fail. Patients who do not respond to these medical measures will require surgical management, including DC [6].

The DC is a surgical method of removal of part of cranium vault so that the brain parenchyma gets space to expand and the ICP can decrease. The timing of DC could be critical for the outcome despite being still under debate to intervene early or late [7]. It is an age-old procedure, taking ancient roots from the Romans and Egyptians, passing through the experience of Berengario da Carpi, until the works of Theodore Kocher, who was the first to systematically describe this procedure in TBI [8]. The principle of management of ICP by DC is to remove the mechanical constraint, which is the cranial vault.

Two main types of DC performed are primary or prophylactic and secondary or therapeutic DC. The primary DC is defined as any surgical decompression performed, with or without brain tissue removal, in patients who undergo surgery primarily for the evacuation of any type of intradural lesion [9]. The secondary DC is defined as the procedure performed in patients in whom continuous ICP monitoring is done and in whom high ICP is refractory to primary medical treatment. Even though previous surgery might have been performed in these patients, the purpose of surgical decompression is to control high ICP [10]. The overall effect of DC is to increase the volume holding capacity of the cranial vault by allowing it to herniate outside. This minimises the internal compression of the brain stem structures. The DC reduces intracranial pressure by 50%, durotomy further enhances ICP reduction by an additional 35% [11].

The DC/hemicraniectomy has its complications like the evolution of contralateral mass lesion by relieving the tamponade effect on a contralateral bleeding site and predisposing the patient to an Extradural Haematoma [12], subdural hygroma which needs cranioplasty as treatment [13], paradoxical herniation for which a blood patch should be part of the management [14], and hydrocephalus which can be predisposed by craniectomy close to midlines [15], wound infections, blossoming of contusions, and extracerebral herniations. The brain swelling may correspond to hyperperfusion, as detected by Computed Tomography (CT) perfusion imaging [16]. In addition, loss of resistance in brain tissue lacking a protective skull invokes a higher hydrostatic pressure gradient that may permit transcapillary leakage of oedema fluid [17]. It has been shown in some studies that a cranial plate with a 5-mm offset accommodates the brain swelling that occurs in this patient population after DC [18].

Some authors suggest that DC can be performed prophylactically, especially in developing countries, where neurosurgical intensive care facilities and ICP monitoring may not be available readily [19].

There are many studies in the literature with Classes II and III evidence that has shown the role of DC in severe brain injury refractory to medical therapy [20]. The present study was conducted to study the outcomes of DC/hemicraniectomy in patients with a severe head injury and to observe the factors determining the patient's outcome.

MATERIALS AND METHODS

A retrospective descriptive study was conducted at the Institute of Gandhi Medical College and associated Hamidia Hospital, Bhopal, Madhya Pradesh, India from May 2017 to April 2021. Consent for the surgery and the study were taken from an immediate relative or the attendant of the patient after a thorough explanation of the study. Ethical committee approval was obtained (514/2020).

All the patients admitted to the hospitals emergency ward with grades of moderate to severe head injury who underwent primary DC/hemicraniectomy formed the sample population.

Division of head injury severity was based on the Glasgow Coma Scale (GCS) score, GCS 9-12=moderate head injury, GCS 3-8=severe head injury [20].

Inclusion criteria

- All the patients with TBI (GCS <12) where craniectomy/ hemicraniectomy is needed.
- Only trauma causes.
- Post resuscitation GCS ≥four.

Exclusion criteria

- Patients with isolated EDH
- Non traumatic causes like spontaneous intracranial haemorrhage, infarct, or aneurysmal bleeding.
- Post resuscitation GCS 3.
- Patients not willing for the treatment/procedure.

Surgical Procedure

All the patients were primarily examined in the hospital's emergency room. A thorough primary survey and resuscitation were done and postresuscitation GCS was recorded. A CT scan was done as early as possible. After the surgery, patients were treated in the head injury ICU. The postoperative GCS and Glasgow Outcome Score (GOS) [21] at the time of discharge from the hospital were recorded and outcomes were analysed. No change in the management protocols of the patient has been made deliberately for the study.

Outcome measures were proportion of favourable outcomes (GOS 4 and 5), unfavourable outcomes (GOS 1,2 and 3).

The clinical parameters like age, sex, mode of injury, GCS after primary resuscitation, pupillary status, associated injuries (fracture of face bones/mandible, chest injuries, abdominal injuries, spine injuries, injuries to upper limb/lower limbs) were analysed for the outcome. Abnormalities in light reflex and size were considered to be abnormal pupils. The variable analysed in the CT scan was the MLS. The MLS was measured as the largest perpendicular distance between an imaginary reference line joining the frontal crest and internal occipital protuberance and the most shifted point of the septum pellucidum.

STATISTICAL ANALYSIS

Statistical analysis was performed using the Chi-square test. The variables such as age, preoperative GCS, the timing of surgery, preoperative pupillary reaction, and MLS was compared in terms of survival/death and favourable/unfavourable outcomes. A statistically significant value was indicated by a p<0.05. Data were analysed using SPSS v21.

RESULTS

In the present study, 100 patients with a mean age of 45±14 years underwent DC/hemicraniectomy, of which 58% were males and the remaining 42% were females. The most common mode of injury for TBI in this study was a Road Traffic Accident (RTA), which was 76% of which 50 (66%) patients died, followed by a fall in 16% of which 11 (69%) patients died and a small portion of 8% of the patients had assault as the injury mode of which 02 (25%) patients died. Of all the 100 patients, 37 patients survived (37%) of whom 18 had a good recovery, 13 patients had mild disability, 04 patients had moderate disability, and 02 patients were in a vegetative state at the time when patients were planned for the discharge [Table/Fig-1].

Variables		Total
Age (years)	21-30	18
	31-40	22
	41-50	12
	51-60	34
	61-70	07
	71-80	07
Sex	Male	58
	Female	42
Outcome	Survival	37
	Death	63
Outcome based on GOS scale	Favourable	31
	Unfavourable	69

[Table/Fig-1]: Demographic variables.
GOS: Glasgow outcome score

Out of 100 patients, 63 patients succumbed accounting for a mortality rate of 63%. The study has a favourable outcome rate of 31% (GOS 4 and 5) and an unfavourable outcome rate of 69% (GOS 1, 2, and 3). In our study patient ages ranged from 23-77 years and 58% were male. Age was found to have a statistically significant role in the favourability and survival of the outcome of DC/hemicraniectomy. Meanwhile, sex distribution had no statistical significance for survival (p-0.987) and favourable outcome (p-0.082). Similarly, no statistical significance for either favourability of outcome (p-0.128) or survival (p- 0.128) was found amongst different modes of injury that was studied.

All the patient's preoperative GCS were recorded and divided into two groups of 4-8 and 9-12. A total of 61 patients had preoperative GCS 4-8 and the rest had 9-12. Each group was compared with survival and favourable outcome and statistically analysed for significance. It was found to be significant for both. For both survival and favourable outcomes p-value was 0.001.

Patients were grouped into two groups based on the time interval between trauma and the operation undergoing for the same as

>24 and <24 hours. Out of 100 patients, 66 were operated on within 24 hours, and the rest 34, after 24 hours. It has been noted that there is a better survival outcome and a more favourable outcome in those who were operated on within 24 hours of trauma, which was statistically significant (p-0.001).

We noted associated injuries and grouped them into fractures of facial bones/mandible, abdominal, chest and spine injuries, and injuries to upper and lower limbs and measured their statistical significance with the outcome of craniectomy/hemicraniectomy. Neither survival rate (p-0.027) nor the favourable outcome (p-0.130) had statistically significant p-value.

In our study, we included RTA, assault, and fall from height as the various modes of injury. Each had mortality rates of 76%, 08%, and 16%, respectively. However, it was not statistically significant in terms of outcome.

Patients with reactive pupils (n=17) and non reactive pupils (n=83) at the time of presentation were grouped. Our study had a statistically significant outcome in terms of survival in patients who had reactive pupils before operation/at presentation with a p-value of 0.001. Patients also had a significantly favourable outcome in the group of reactive pupils with a p-value of 0.001.

Researchers divided 100 patients into 4 groups based on MLS at the time of presentation as measured by the CT. The group with MLS <5 mm had 06 patients, with MLS 5-8 mm had 26 patients, MLS 8-11 mm had 29 patients, and with MLS >11 mm had 39 patients. It was found that the survival rate was 100% with MLS <5 mm and 84.61% in groups with MLS >11 mm; however, it was found to be statistically significant with a p-value of 0.001. On comparing the favourable outcomes between each group, 66.6% of patients with MLS <5 mm had favourable outcomes whereas only 02.56% of patients had a favourable outcome with MLS >11 mm. It was also statistically found to be significant with a p-value of 0.001.

The significant values of various factors studied are summarised in [Table/Fig-2,3] with survival and favourable outcomes.

Variables		Survival	Death	p-value (Chi-square)
Age (years)	21-30	12 (67%)	06 (33%)	0.001 (21.695)
	71-80	00 (00%)	07 (100%)	
Preoperative GCS	4-8	12 (19.6%)	49 (80.3%)	0.001 (18.286)
	9-12	25 (64.1%)	14 (35.9%)	
Time of surgery (hours)	≤24	36 (54.5%)	30 (45.4%)	0.0001 (23.470)
	>24	01 (03%)	33 (97%)	
Pupillary reaction	Reactive	14 (82.3%)	03 (17.6%)	0.001 (15.805)
	Non reactive	23 (27.7%)	60 (72.2%)	
Preoperative MLS (mm)	<5	06 (100%)	00 (00%)	0.001 (28.367)
	5-8	21 (80.7%)	05 (19.23%)	
	8-11	09 (31.0%)	20 (68.96%)	
	>11	01 (02.5%)	38 (97.4%)	

[Table/Fig-2]: Table showing variables with survival and death.

DISCUSSION

The DC has become more popular in the past years with improvement in the methods of measuring ICP to manage patients with raised ICP in severe TBI [22]. Various factors have been found to be associated with the patient's outcome who undergo DC/hemicraniectomy. In 2001, a report was published based on a small randomised study from the Royal Children's Hospital in Melbourne [15]. The patients were randomised to undergo standard treatment alone or with decompression. Those in the group of standard treatment had a mean ICP reduction of 3.7 mm Hg and a favourable outcome (normal or mild disability) in 14%; patients in the group of standard treatment plus decompression (performed at 19 hours post-injury) had a mean ICP reduction of 8.9 mmHg and a favourable outcome rate of 54% [23]. In another study conducted by Shah DB et al., in a cohort of patients who had DC for TBI, 39.1% had favourable outcomes at 3 months. Age <50 years, intact pupillary reflexes, higher GCS score at presentation (>8), and lower Marshall grade injuries were significantly associated with a favourable outcome. Improving patient selection and availability of the provision of ICP monitoring may optimise the outcome of DC/hemicraniectomy [5].

Variables		Favourable	Unfavourable	p-value (Chi-square)
Age (years)	21-30	8 (44%)	10 (56%)	0.029 (12.589)
	71-80	00 (00%)	07 (100%)	
Preoperative GCS	4-8	10 (16.3%)	51 (83.6%)	0.001 (13.899)
	9-12	21 (53.8%)	18 (46.1%)	
Time of surgery (hours)	≤24	30 (45%)	36 (54%)	0.0001 (17.026)
	>24	01 (03%)	33 (97%)	
Pupillary reaction	Reactive	12 (70%)	05 (29.4%)	0.001 (12.860)
	Non reactive	19 (22%)	64 (77%)	
Preoperative MLS (mm)	<5	04 (66.6%)	02 (33.3%)	0.001 (36.235)
	5-8	18 (69.2%)	08 (30.7%)	
	8-11	08 (27.5%)	21 (72.4%)	
	>11	01 (02.5%)	38 (97.4%)	

[Table/Fig-3]: Table showing variables with favourable and unfavourable outcomes.

The patient's age is one of the important prognostic factors. Polin RS et al., found that the paediatric age group responds better to DC/hemicraniectomy than the adult population in TBI [24]. Schneider GH et al., estimated age as one of the single most important factors in deciding postoperative outcomes [25]. In the present study, age was found to be the predictor of favourable outcomes, as the mortality rates were lower in younger patients and higher in older patients. This was statistically significant.

It was found that mortality is higher in a RTA than in other means of injury. Because of high-speed motor vehicle accidents, there will be a head injury sustained because of angular acceleration. A similar mechanism when prolonged for a long duration, it results in diffuse axonal injury. In the study, the most common mode of injury was RTA (76%) followed by falls (16%). A small proportion of patients had an injury due to assault (08%). However, no statistical significance between mode of injury and favourable outcome for any type of injury was found. From this, it can be concluded that more than the mode of injury, the impact of injury, and other factors have a more deciding impact on the outcome of TBI patients undergoing DC/hemicraniectomy.

Guerra WK et al., found that the GCS score obtained on the first post-traumatic day was the most sensitive parameter [10]. In this study favourable outcomes among the GCS 4-8 group was 16.4% and the GCS 9-12 group was 53.8%.

In a study by Polin RS et al., significantly better outcomes were obtained in patients who underwent surgery within 48 hours post-trauma [24]. Burkert W and Plauman H showed that there was a better improvement of cerebral perfusion if DC/hemicraniectomy is done earlier [26]. Munch E et al., reported similar results [27]. However, Kunze et al., performed late craniectomy and have obtained favourable outcomes [28]. Even in a meta-analysis by Fatima N et al., they concluded that there is no benefit from early DC in TBI patients. However, the intervention if carried out at an early stage is associated with decrease in the mortality rate [7]. In the study who underwent DC/hemicraniectomy within the first 24 hours of trauma had a favourable outcome when compared to those who underwent the same procedure after 24 hours.

Pupillary abnormalities caused due to TBI are associated with a significantly worst prognosis. In a study by Rankothkumbura J et al., it is found that good pupillary reaction and higher GCS on admission were associated with statistically significant favourable outcomes (p<0.05) [29]. In this study, similar results were found. The favourable outcome was better among the patients who had reactive pupils (70.58%). There was found to be a statistical significance between favourable outcomes and reacting pupils. There is also statistical significance between patients' survival and reacting pupils. It can be opined that patients with TBI presenting with reacting pupils have a better outcome.

Eisenberg HM et al., reported in their study that the midline shift measured preoperatively is a very strong predictor of persistent raised ICP [30]. Munch E et al., reviewed the effect of DC/hemicraniectomy on CT parameters and noted a reduction of the MLS from 9.7-6.2 mm and a reduction in basal cistern compression, both of which are known to predict poor outcomes [27]. In the present study, it has been found that patients with MLS of <5 mm have better outcomes and survival rates than those with higher MLS. Statistical significance between the preoperative MLS and patients' outcomes as well as survival was found.

Limitation(s)

Less sample size, and single institutional design are the major limitations of the study. Limitations of this study can be the potential lead for further studies in this field. In the treatment of patients with refractory intracranial hypertension and brain oedema, randomised studies will provide class 1 evidence that will help in decision-making.

CONCLUSION(S)

The management of patients with TBI with clinical and radiological evidence of persistent raised ICP is still a challenge for neurosurgeons. An adequate craniectomy facilitating the reduction of raised ICP is the key to the prognosis and outcome of the patients. Age, timing of surgery, clinical parameters like GCS, and pupillary status at the time of presentation, and preoperative MLS are important to predict the outcome of DC/hemicraniectomy.

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