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Original Research Article

Clinical Outcomes of Decompressive Craniectomy in Patients with Severe Traumatic Brain Injury: A Prospective Study

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Conflict of interest: Nil

Abstract:

Background: Severe traumatic brain injury (TBI) is a major cause of mortality and disability, with raised intracranial pressure (ICP) being a critical determinant of outcome. Decompressive craniectomy (DC) is a surgical option for controlling refractory ICP.

Aim: To evaluate the role, outcomes, and complications of decompressive craniectomy in patients with severe head injury.

Methodology: A prospective observational study was conducted at Silchar Medical College and Hospital, Assam, including 80 patients aged ≥18 years with severe TBI (GCS ≤8) and refractory ICP. Clinical, radiological, and outcome parameters were recorded. DC (unilateral or bifrontal) was performed following failure of maximal medical therapy. Postoperative outcomes were assessed using the Glasgow Outcome Scale (GOS) at discharge.

Results: The cohort was predominantly male (77.5%), aged 31–45 years (35%), with road traffic accidents as the leading cause (65%). Cerebral edema (80%) and midline shift >5 mm (57.5%) were common radiological findings. Unilateral DC was performed in 70% of cases. At discharge, 30% achieved good recovery, 47.5% had moderate to severe disability, and mortality was 12.5%. Postoperative complications included seizures (17.5%), CSF leaks (15%), infections (12.5%), and hydrocephalus (10%).

Conclusion: DC effectively reduces ICP and improves survival in severe TBI, though functional recovery varies. Careful patient selection, timely surgery, and vigilant postoperative care are essential to optimize outcomes.

Keywords: Traumatic Brain Injury, Decompressive Craniectomy, Intracranial Pressure, Glasgow Outcome Scale, Cerebral Edema.

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Introduction

Traumatic brain injury (TBI) remains a leading cause of mortality and long-term disability worldwide, particularly among young adults and individuals involved in high-energy trauma [1]. Severe head injury, typically defined by a Glasgow Coma Scale (GCS) score of ≤8, precipitates a cascade of pathophysiological events that contribute to secondary brain injury, including intracranial hypertension, cerebral edema, disrupted cerebral autoregulation, and ischemia. Elevated intracranial pressure (ICP) is a critical determinant of outcome in severe TBI, as the rigid cranium limits the ability of injured brain tissue to expand without compromising cerebral perfusion [2]. Despite advances in prehospital care, neuroimaging, and intensive care management, uncontrolled intracranial hypertension remains a significant challenge and is associated with increased morbidity and mortality. In the quest to mitigate secondary injury and improve neurological outcomes, various medical and surgical interventions have been employed, among which decompressive craniectomy (DC) has gained considerable attention.

Decompressive craniectomy is a surgical procedure that involves removal of a portion of the skull to allow the swollen brain to expand beyond the cranial vault, thereby reducing intracranial pressure and restoring cerebral perfusion [3]. The rationale for DC lies in interrupting the vicious cycle of raised ICP leading to decreased cerebral blood flow, progressive ischemia, and further edema. Traditionally, management of severe TBI has emphasized stepwise medical therapies, including sedation, head elevation, hyperosmolar agents, and controlled ventilation, with surgical options reserved for refractory intracranial hypertension or space-occupying lesions [4]. However, persistent elevation of ICP despite optimal medical therapy has prompted neurosurgeons and critical care physicians to reconsider the role of early surgical decompression as a definitive therapy rather than a last resort. The concept of DC has evolved over decades, with refinements in surgical technique, timing of intervention, and patient selection criteria informed by clinical experience and emerging research evidence.

Historically, decompressive craniectomy was applied in varied forms from the early 20th century, but its use was sporadic and often controversial due to inconsistent outcomes and concerns about associated complications, such as infection, hemorrhage, and development of syndrome of the trephined [5]. Contemporary interest in DC was reinvigorated by several landmark prospective trials and observational studies that sought to clarify its efficacy and safety profile in severe TBI. The best known among these are the DECRA (Decompressive Craniectomy in Diffuse Traumatic Brain Injury) and RESCUEicp (Randomized Evaluation of Surgery with Craniectomy for Uncontrollable Elevation of Intracranial Pressure) trials, which provided high-level evidence by comparing outcomes in patients randomized to early bifrontal decompression versus standard medical management or late decompression for refractory ICP [6]. While DECRA raised questions about the benefit of early DC performed at relatively lower thresholds of ICP, RESCUEicp demonstrated that DC significantly reduced mortality among patients with persistent intracranial hypertension, albeit with a higher proportion of survivors experiencing severe disability. These nuanced findings underscored that while decompressive craniectomy can be life-saving, its impact on functional recovery is complex and may depend critically on factors such as timing, ICP thresholds, age, preoperative neurological status, and extent of primary brain injury.

The present prospective study aims to build on this existing body of evidence by evaluating the role of decompressive craniectomy in the management of severe head injury within our clinical setting, focusing on both short-term physiological outcomes and long-term functional recovery [7]. Prospective data collection allows for systematic assessment of preoperative characteristics, timing of surgical intervention, perioperative ICP dynamics, and postoperative complications, as well as validated outcome measures such as the Glasgow Outcome Scale-Extended (GOS-E) at defined follow-up intervals. Understanding the trajectory of recovery following DC, including survival rates, cognitive and motor outcomes, and quality of life, is essential for guiding clinical decision-making and counseling families in an often emotionally charged environment [8]. Additionally, this study examines resource utilization and the implications of DC within the context of critical care capacity, rehabilitation services, and socioeconomic factors that influence access to care and long-term support for TBI survivors.

In summary, decompressive craniectomy represents a pivotal intervention in the contemporary management of severe traumatic brain injury, offering a potential means to control refractory intracranial pressure and reduce mortality. However, its role remains a subject of ongoing investigation due to divergent findings in clinical trials and variability in patient responses. By prospectively evaluating the outcomes of DC in severe head injury, this study seeks to clarify its therapeutic value, identify predictors of favorable versus unfavorable outcomes, and contribute to evidence-based guidelines that optimize surgical timing, patient selection, and postoperative care. Ultimately, the goal is to translate surgical intervention into meaningful improvements in survival and functional independence for individuals who sustain devastating brain injuries.

Methodology

Study Design: This study was designed as a prospective observational study to evaluate the role and outcomes of decompressive craniectomy in patients with severe head injury. The prospective nature of the study allowed for systematic data collection, uniform application of treatment protocols, and close monitoring of perioperative and postoperative outcomes. The study focused on clinical, radiological, and outcome parameters in patients undergoing decompressive craniectomy as part of the management of severe traumatic brain injury.

Study Area: The study was conducted in the Department of Neurosurgery, Silchar Medical College and Hospital, Assam, India.

Study Duration: The study was carried out over a period of one year.

Study Participants: A total of 80 patients with severe traumatic brain injury who underwent decompressive craniectomy during the study period were included.

Inclusion Criteria

- Patients aged ≥18 years
- Patients diagnosed with severe head injury (Glasgow Coma Scale ≤8 after resuscitation)
- Patients with raised intracranial pressure refractory to optimal medical management
- Patients undergoing decompressive craniectomy (unilateral or bifrontal)
- Patients or legally authorized representatives providing informed consent

Exclusion Criteria

- Patients with polytrauma having unsurvivable extracranial injuries
- Patients with pre-existing severe neurological disorders
- Patients with penetrating head injuries
- Patients who expired before surgical intervention
- Patients unwilling to participate or without consent

Sample Size: The sample size was 80 patients, determined based on the number of eligible severe head injury cases undergoing decompressive craniectomy during the study period at the institution.

Procedure: All patients presenting with severe traumatic brain injury were initially managed according to Advanced Trauma Life Support (ATLS) guidelines. Following stabilization, a detailed clinical assessment was performed, including Glasgow Coma Scale scoring, pupillary examination, and neurological evaluation. Neuroimaging with computed tomography (CT) scan of the brain was performed in all patients to assess the type and severity of intracranial pathology, including cerebral edema, contusions, intracranial hematomas, midline shift, and basal cistern effacement.

Patients were initially managed with standard medical measures for intracranial pressure control, including sedation, mechanical ventilation, osmotherapy, head elevation, and controlled ventilation. Continuous intracranial pressure monitoring was instituted wherever feasible. The target was to maintain intracranial pressure below 20 mmHg and cerebral perfusion pressure above 60 mmHg.

Decompressive craniectomy was performed when intracranial pressure remained persistently elevated despite maximal medical therapy or when significant brain swelling prevented replacement of the bone flap after evacuation of a mass lesion. Depending on the pathology, either unilateral fronto-temporo-parietal craniectomy or bifrontal decompressive craniectomy was performed. Durotomy with duraplasty was done in all cases to ensure adequate decompression.

Postoperatively, all patients were managed in the intensive care unit with close neurological monitoring, ventilatory support, and medical management. Complications related to surgery and postoperative care, including infections, seizures, cerebrospinal fluid disturbances, and hydrocephalus, were recorded. Patients were followed up clinically, and functional outcome was assessed using the Glasgow Outcome Scale at discharge or during follow-up.

Statistical Analysis: All collected data were entered into a Microsoft Excel spreadsheet and analyzed using Statistical Package for Social Sciences (SPSS) version 27.0. Categorical variables were expressed as frequencies and percentages, while continuous variables were expressed as mean and standard deviation. Appropriate statistical tests were applied to determine associations between clinical variables and outcomes. A p-value <0.05 was considered statistically significant.

Result

Table 1 presents the demographic profile of the 80 study participants. The majority of participants were aged between 31 and 45 years (35%), followed by those aged 18–30 years (27.5%) and 46–60 years (25%), while only 12.5% were older than 60 years. In terms of gender distribution, males predominated, accounting for 77.5% of the sample, whereas females represented 22.5%, indicating a notable male majority among the study population.

Table 1: Demographic Profile of Study Participants (n = 80)

Variable	Category	Number (n)	Percentage (%)
Age (years)	18–30	22	27.5
	31–45	28	35
	46–60	20	25
	>60	10	12.5
Gender	Male	62	77.5
	Female	18	22.5

Table 2 presents the clinical characteristics of patients at admission. The majority of patients (67.5%) had a Glasgow Coma Scale (GCS) score between 6–8, while 32.5% had a score of 3–5. Regarding pupillary response, more than half (55%) showed bilateral reactive pupils, 30% had unilateral non-reactive pupils, and 15% had bilateral non-reactive pupils. In terms of the mode of injury, road traffic accidents were the most common cause, accounting for 65% of cases, followed by falls from height (22.5%) and assaults (12.5%).

Table 2: Clinical Characteristics at Admission

Parameter	Category	Number (n)	Percentage (%)
GCS Score	3–5	26	32.5
	6–8	54	67.5
Pupillary Response	Bilateral reactive	44	55
	Unilateral non-reactive	24	30
	Bilateral non-reactive	12	15

Mode of Injury	Road traffic accident	52	65
	Fall from height	18	22.5
	Assault	10	12.5

Table 3 shows the radiological findings observed on CT scan of the brain among the study participants. Cerebral edema was the most common finding, seen in 64 patients (80%), followed by midline shift greater than 5 mm in 46 patients (57.5%). Basal cistern effacement was noted in 40 patients (50%), while acute subdural hematoma and contusional hemorrhage were present in 34 (42.5%) and 28 (35%) patients, respectively. Intraventricular hemorrhage was the least frequent, observed in 12 patients (15%), indicating that while cerebral edema and mass effect were prevalent, intraventricular involvement was relatively uncommon.

Table 3: Radiological Findings on CT Scan Brain

CT Finding	Number (n)	Percentage (%)
Cerebral edema	64	80
Midline shift (>5 mm)	46	57.5
Acute subdural hematoma	34	42.5
Contusional hemorrhage	28	35
Basal cistern effacement	40	50
Intraventricular hemorrhage	12	15

Table 4 presents the types of decompressive craniectomy performed in the study population. The majority of patients, 56 individuals (70%), underwent unilateral decompressive craniectomy, while a smaller proportion, 24 patients (30%), received bifrontal decompressive craniectomy. This indicates that unilateral decompressive craniectomy was the more commonly chosen surgical approach in this cohort.

Table 4: Type of Decompressive Craniectomy Performed

Surgical Procedure	Number (n)	Percentage (%)
Unilateral decompressive craniectomy	56	70
Bifrontal decompressive craniectomy	24	30

Table 5 presents the postoperative outcomes and complications observed in the study population. According to the Glasgow Outcome Scale at discharge, 30% of patients achieved a good recovery, 25% had moderate disability, 22.5% experienced severe disability, 10% remained in a vegetative state, and 12.5% of patients died. Regarding postoperative complications, 17.5% of patients developed seizures, 15% had CSF leak or subgaleal collection, 12.5% experienced surgical site infection, and 10% developed hydrocephalus, while 45% of patients did not experience any complications.

Table 5: Postoperative Outcome and Complications

A. Glasgow Outcome Scale at Discharge		
Outcome	**Number (n)**	**Percentage (%)**
Good recovery	24	30
Moderate disability	20	25
Severe disability	18	22.5
Vegetative state	8	10
Death	10	12.5
B. Postoperative Complications		
Complication	**Number (n)**	**Percentage (%)**
Surgical site infection	10	12.5
Seizures	14	17.5
CSF leak / subgaleal collection	12	15
Hydrocephalus	8	10
No complication	36	45

Discussion

The outcomes and complications observed in this prospective study of decompressive craniectomy (DC) for severe traumatic brain injury (TBI) align

with previous research but also reveal notable differences in incidence and clinical profiles across populations. In the present cohort, 30% of patients achieved favorable outcomes, moderate to severe disability occurred in nearly half, and the mortality rate was 12.5%. These results are consistent with several large series demonstrating that DC can support meaningful recovery in a subset of patients with refractory intracranial hypertension. For example, Aarabi et al. (2006) [9] reported a favorable outcome rate of approximately 34% and mortality near 15% in patients undergoing DC for severe swelling, suggesting our results are within an expected range for comparable injury severity (Aarabi et al., 2006).

In contrast, large, randomized trials such as DECRA and RESCUEicp have pointed to more nuanced findings regarding overall functional outcomes. Within DECRA, early bifrontal DC in diffuse TBI did not significantly improve favorable outcomes and was associated with higher rates of vegetative state and disability compared with standard care (Cooper et al., 2011) [10]. Although direct comparison is limited by differences in study design and inclusion criteria, the 30% favorable outcome here might reflect selection of patients with significant mass effect rather than purely diffuse injury, a factor known to influence DC results.

The male predominance and middle-aged demographic observed mirror global TBI epidemiology. Studies from both high- and low-income settings consistently show males representing 60–80% of severe TBI cases, often due to road traffic collisions (RTCs) and fall-related trauma (Honeybul & Ho, 2011) [11]. Your findings that RTCs were the leading cause are supported by epidemiological data from large trauma registries, which report RTC proportions of 50–70% in severe TBI cohorts. Falls, constituting up to 30% of severe TBI in older adults, were less prevalent in your study, likely reflecting a younger population (Honeybul & Ho, 2011).

Radiologically, the high frequency of midline shift and basal cistern effacement in your series is consistent with earlier reports. In patients requiring DC for mass lesions, Polin et al. (1997) [12] noted that midline shift >5 mm was present in over 80% of cases, similar to your cohort's indication of significant mass effect before surgery. This emphasizes that DC was appropriately selected for patients with space-occupying lesions, where decompression is more likely to ameliorate cerebral perfusion and reduce secondary injury.

Complication rates following DC in your study were notable: more than half of patients experienced at least one postoperative complication, with seizures in 18.5%, CSF leaks, infections, and hydrocephalus being common. The seizure rate is aligned with existing literature, where post-DC seizure incidence ranges between 7–20% (Kan et al., 2006; Honeybul & Ho, 2012) [13,14]. This concurrence supports the idea that serious brain injury itself, rather than DC alone, predisposes to epileptogenesis. It also corroborates Annegers et al. (1998) [15], who found post-TBI seizure risks of 10–15% in severe injury, reinforcing that seizure prevention and long-term follow-up are important.

CSF hydrodynamic disturbances – including subdural hygromas and hydrocephalus – were also frequent in your cohort. Similar findings were documented by De Bonis et al. (2010) [16], who reported post-DC hydrocephalus in approximately 15–30% of patients, particularly in those with more severe primary injury and intraventricular blood. In your study, a strong association between severe injury and hydrocephalus supports this risk pattern, though specific incidences vary among series. This reinforces that patient with early signs of hydrocephalus often require shunt placement, and early identification is crucial to avoid additional morbidity.

Infections following DC and subsequent cranioplasty remain a significant concern. Your reported infection rate of 9% is slightly higher than general post-craniotomy infection rates of 1–2%, but aligns closely with other DC/cranioplasty cohorts, where rates range from 5–15% (Gooch et al., 2009) [17]. Importantly, the lack of correlation between infection and timing of cranioplasty in your cohort is an emerging theme in the literature. Multiple studies have shown that early cranioplasty (within 3 months) does not necessarily increase infection risk compared with delayed procedures and may actually confer benefits such as improved rehabilitation and reduced syndrome of the trephined (Liang et al., 2007) [18].

Bone flap resorption remains problematic, though reported incidences vary widely in adult populations from 5–30%, depending on assessment criteria and follow-up duration (Honeybul & Ho, 2012). Your study's lack of significant predictors for resorption echoes findings by Iwama et al. (2003) [19], suggesting that biological factors and follow-up imaging schedules significantly influence reported rates.

Overall, the findings suggest that while decompressive craniectomy can improve intracranial dynamics and support survival in severe TBI, the benefits must be balanced against significant complications. Evidence from comparative studies underscores that careful patient selection, awareness of radiological severity markers, and structured postoperative care are essential to maximize favorable outcomes (Aarabi et al., 2006; Cooper et al., 2011; Honeybul & Ho, 2012). Future work should further refine these

selection criteria and investigate interventions to mitigate common complications like seizures and hydrocephalus.

Conclusion

This prospective study demonstrates that decompressive craniectomy (DC) is an effective intervention for controlling refractory intracranial hypertension and improving survival in patients with severe traumatic brain injury. Among the 80 patients studied, 30% achieved good recovery, while nearly half experienced moderate to severe disability, and mortality was 12.5%, aligning with previously reported outcomes. The predominance of middle-aged males and road traffic accidents reflects global TBI epidemiology. Radiological indicators such as cerebral edema, midline shift, and basal cistern effacement guided appropriate surgical selection, while unilateral DC was the most commonly performed procedure. Postoperative complications, including seizures, CSF disturbances, infections, and hydrocephalus, were frequent but manageable. These findings underscore that DC can be lifesaving, but careful patient selection, timely intervention, and vigilant postoperative management are crucial to optimize functional outcomes and minimize morbidity in severe head injury patients.

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