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Original Research Article

Survival outcomes following decompressive craniectomy versus reconstructive cranioplasty: a comparative study

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ABSTRACT

Background: Decompressive craniectomy is lifesaving for malignant cerebral edema after trauma or stroke. Subsequent cranioplasty restores cranial integrity and may improve neurological recovery; however, comparative outcome data from Bangladesh remain limited.
Methods: This comparative study was conducted at KPJ Specialized Hospital, Dhaka, Bangladesh, from September 2017 to December 2024. A purposive sample of 47 patients who underwent decompressive craniectomy was included and divided into two groups: the DC-only group (n=31) and the DC+CP group (n=16). Survival was the primary outcome measure. Data were analyzed using SPSS version 23.0.
Results: Patients in the DC+CP group were significantly younger than those in the DC-only group (p =0.009). A marked difference in survival was observed between groups: 93.8% (15/16) of patients in the DC+CP group were alive at follow-up, compared to 25.8% (8/31) in the DC-only group (p<0.001). Syndrome of the trephined was identified in 25.0% (4/16) of patients before cranioplasty. Following CP, 87.5% (14/16) demonstrated neurological improvement, and 68.8% (11/16) achieved good functional recovery (Glasgow Outcome Scale score 4–5). The overall CP-related complication rate was 18.8%.
Conclusions: Survival was substantially higher among patients who underwent cranioplasty following decompressive craniectomy. Despite inherent selection bias, cranioplasty was strongly associated with improved neurological and functional outcomes, underscoring its critical role in the continuum of care for severe neurotrauma and stroke.

Keywords: Cranioplasty, Decompressive craniectomy, Functional outcome, Glasgow outcome scale, Survival

INTRODUCTION

Severe traumatic brain injury (TBI) and malignant hemispheric stroke remain leading causes of mortality and long-term disability worldwide, imposing a substantial burden on healthcare systems.[1] Intractable elevation of intracranial pressure (ICP) from cerebral edema is a common, life-threatening complication in these conditions. When maximal medical therapy fails, decompressive craniectomy (DC) serves as a crucial surgical intervention to reduce ICP and mitigate secondary brain injury by creating space for edematous brain tissue to expand.[2,3] While primarily a life-saving procedure, DC is not a definitive treatment and often results in a significant cranial defect, leaving the brain vulnerable to atmospheric pressure, physical trauma, and cerebrospinal

fluid dynamics alterations.[4] The subsequent phase of care involves the restoration of cranial integrity through reconstructive cranioplasty (CP), typically performed weeks to months after the initial decompression. Beyond its obvious cosmetic benefit, cranioplasty is believed to confer several physiological and neurological advantages. These include the normalization of intracranial pressure dynamics, improvement in cerebral blood flow, protection of the underlying neural tissue, and potential reversal of neurological deficits associated with the "syndrome of the trephined" (SOT)—a condition characterized by headaches, motor deficits, and cognitive disturbances that can appear after a large craniectomy.[5,6]

The optimal timing of cranioplasty remains a topic of ongoing research, balancing the risks of early surgery against the potential benefits of earlier neurological recovery.[7,8]

Despite its widespread practice, the impact of cranioplasty on survival and long-term functional outcomes compared to those who undergo DC alone is not fully delineated and presents a complex clinical question. This complexity arises from a significant inherent selection bias: only patients who survive the acute, high-mortality period following DC become candidates for CP.[9]

Therefore, a direct comparison of outcomes between these two groups is inherently confounded. However, understanding the trajectory of survivors and the additive value of CP is essential for prognostic counseling, rehabilitation planning, and optimizing surgical care pathways. Existing literature from the late 2010s and early 2020s presents a heterogeneous picture. Some studies report significant neurological improvement and enhanced quality of life following cranioplasty.[10,11]

Others focus on complication rates, which can be substantial and include infection, bone flap resorption, and seizures, potentially offsetting the procedure's benefits.[12,13] Most large-scale studies originate from high-income countries, and data reflecting clinical practices, patient demographics, and outcomes in resource-varied settings like Bangladesh are notably scarce. This comparative study was conducted at a major neurosurgical referral center in Dhaka, Bangladesh.

It aims to contribute region-specific evidence by analyzing the survival outcomes and functional recovery of patients who underwent DC followed by CP against those who had DC only. By examining a contemporary cohort, this research seeks to clarify the role of cranioplasty within the sequential management of severe brain injury in this context and to inform local clinical decision-making and resource allocation.

METHODS

This retrospective comparative study was conducted at KPJ Specialized Hospital, Dhaka, Bangladesh, a tertiary-level neurosurgical center. The study population included all adult and pediatric patients who underwent decompressive craniectomy (DC) for severe traumatic brain injury or malignant cerebral edema due to stroke between September 2017 and December 2024. A total of 47 patients were identified from the hospital surgical registry and medical records.

Inclusion criteria

Patients were included if they underwent unilateral decompressive craniectomy, either as a standalone procedure or with augmented duroplasty, during the study period.

Only patients with a confirmed primary diagnosis of severe traumatic brain injury (with radiological evidence of mass effect) or hemorrhagic/ischemic stroke resulting in refractory intracranial hypertension were considered eligible.

Exclusion criteria

Patients who underwent bilateral decompressive craniectomy, had concurrent penetrating brain injury, or had active intracranial infection (e.g., brain abscess or meningitis) at the time of initial surgery were excluded.

Patients with incomplete medical records regarding operative details or follow-up survival status were also excluded from the final analysis.

Study procedure

The study cohort was categorized into two groups based on subsequent management: Group 1 (DC-only, n=31) and Group 2 (DC+CP, n=16). Demographic data, primary diagnosis, surgical characteristics, postoperative complications, and survival outcomes were extracted from both electronic and paper-based medical records.

For patients in the DC+CP group, additional information regarding timing of cranioplasty, implant material, and postoperative neurological and functional outcomes was collected.

Data analysis

Data were analyzed using IBM SPSS Statistics version 23.0. Continuous variables were expressed as mean ± standard deviation or median with interquartile range, while categorical variables were presented as frequencies and percentages.

Group comparisons were performed using the independent samples t-test for continuous variables and the Chi-square test or Fisher's exact test for categorical variables, as appropriate. A p value <0.05 was considered statistically significant.

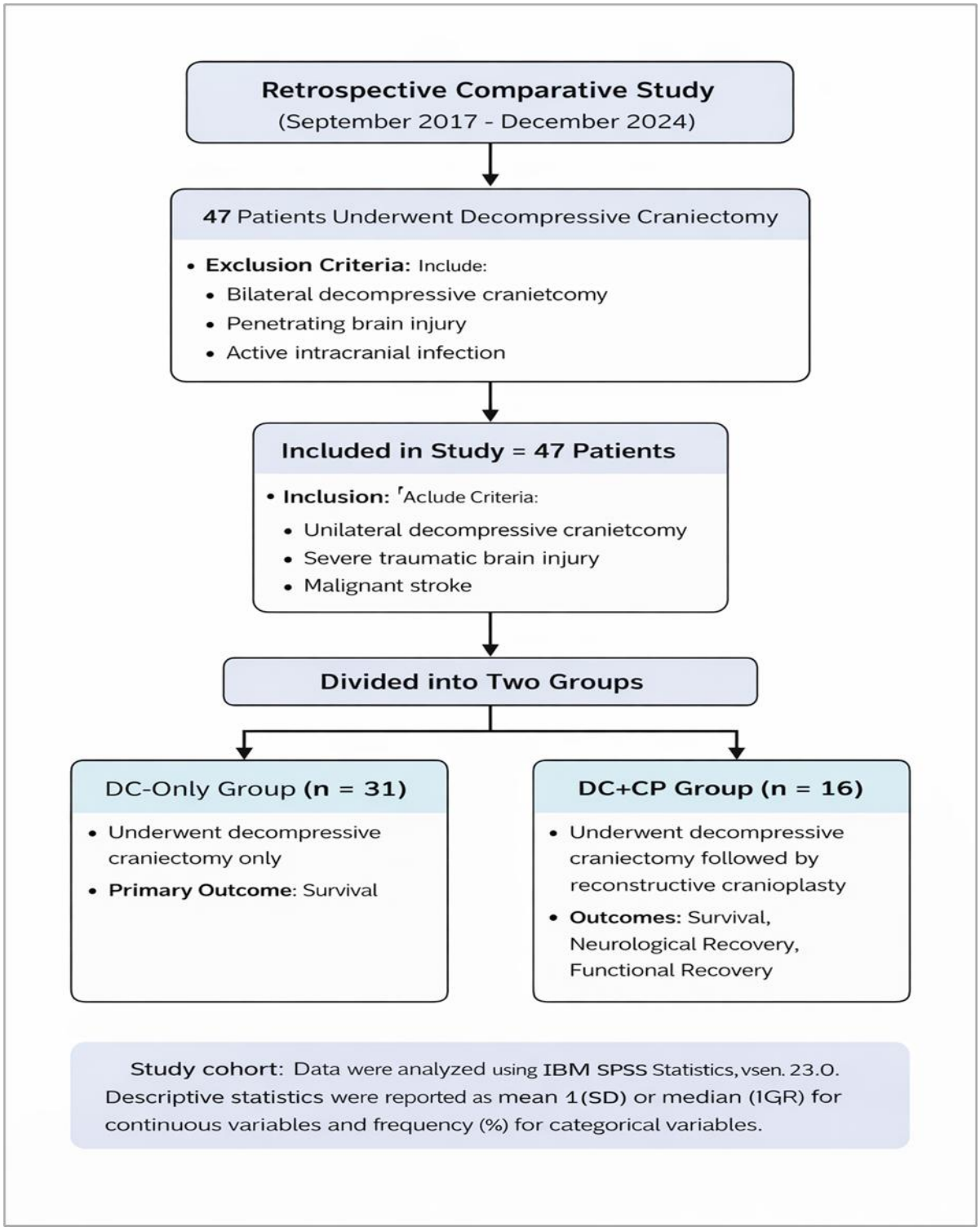

Figure 1: Flow diagram.

RESULTS

The total cohort comprised 47 patients who underwent decompressive craniectomy (DC). Of these, 16 patients (34.0%) progressed to reconstructive cranioplasty (CP) and constituted the DC+CP group, while 31 patients (66.0%) formed the DC-Only group. A significant age difference was noted: the DC+CP group was younger (35.9±13.5 years) than the DC-Only group (52.1±21.3 years; p=0.009). Indications for DC were comparable: Traumatic Brain Injury (TBI) was the most common cause (62.5% in DC+CP vs. 45.2% in DC-Only, p=0.26).

The median time from DC to CP was 5.8 months. Survival outcomes were starkly different. The overall survival rate was 48.9% (23/47). In the DC+CP group, survival was

93.8% (15/16), compared to only 25.8% (8/31) in the DC-Only group (p<0.001). Of the 24 deaths, 23 were in the DC-Only group, primarily from primary brain injury progression (47.8%) or systemic complications (34.8%).

Table 1: Baseline demographic and clinical characteristics.

Group	N	Age (years) mean±SD	Male N (%)	TBI N (%)
DC-only	31	52.1±21.3	21 (67.7)	14 (45.2)
DC+CP	16	35.9±13.5	13 (81.3)	10 (62.5)
P value		0.009	0.490	0.260

Age was analyzed with an independent samples t-test; Gender and TBI indication were analyzed with a chi-square test. DC: Decompressive Craniectomy; CP: Cranioplasty; TBI: Traumatic Brain Injury; SD: Standard Deviation.

Table 2: Surgical details and interim complications.

Detail	DC-only (n=31)	DC+CP (n=16)
DC with duroplasty, N (%)	11 (35.5)	16 (100)
Pre-CP SOT, N (%)	1 (3.2)	4 (25.0)
DC-to-CP interval (MOS), median (IQR)	-	5.8 (3.2-9.1)

SOT: Syndrome of the Trephined; IQR: Interquartile Range.

Table 3: Primary survival outcome.

Outcome	Total (n=47)	DC-only (n=31)	DC+CP (n=16)	P value
Alive, N (%)	23 (48.9)	8 (25.8)	15 (93.8)	<0.001
Deceased, N (%)	24 (51.1)	23 (74.2)	1 (6.2)	

P value derived from Fisher's Exact Test.

Complications before CP were noted, with Syndrome of the Trephined (SOT) identified in 25.0% (4/16) of future CP patients.

Table 4: Cranioplasty procedure and functional outcomes (n=16).

Measure	DC+CP group
	N (%)
Material: autologous	10 (62.5)
CP complication	3 (18.8)
Neuro-improvement	14 (87.5)
Good recovery (GOS 4-5)	11 (68.8)

GOS: Glasgow Outcome scale (Score 4: Moderate disability; Score 5: Good recovery)

Following CP, 87.5% (14/16) of the patients demonstrated subjective neurological improvement, with all SOT cases resolving. Good functional recovery (GOS 4-5) was achieved in 68.8% (11/16) of CP patients. The CP-specific complication rate was 18.8% (3/16), including one case each of infection, bone resorption, and seizure.

DISCUSSION

This study provides a comparative analysis of outcomes between patients undergoing decompressive craniectomy alone and those who subsequently underwent reconstructive cranioplasty at a tertiary neurosurgical center in Bangladesh. The most salient finding is the profound difference in survival rates, with 93.8% of the cranioplasty group alive at follow-up compared to only 25.8% in the DC-only group. This stark result must be interpreted with critical nuance, as it underscores the fundamental selection bias inherent in such a comparative design.[14] Cranioplasty is an elective procedure offered exclusively to patients who survive the acute, high-mortality phase following their initial life-saving surgery. Therefore, our findings primarily reflect that cranioplasty is a marker of having survived the initial insult, rather than a direct cause of that survival. This aligns with larger database studies, which identify survival to discharge as the strongest predictor of undergoing subsequent cranioplasty.[9,15] Beyond survival, our data suggest meaningful benefits associated with cranioplasty for this select group of survivors. The high rate of subjective neurological improvement (87.5%) and the resolution of Syndrome of the Trephined (SOT) symptoms in all affected patients support the growing body of evidence that cranial reconstruction can reverse functional deficits linked to altered cerebrospinal fluid dynamics and cerebral hypoperfusion.[6,16] The observation that 68.8% of cranioplasty patients achieved a "Good Recovery" (GOS 4-5) is encouraging and suggests that for survivors, timely cranial reconstruction is a critical step in the neurological rehabilitation pathway, a concept supported by recent meta-analyses.[11-17] The significant age discrepancy between our groups—the DC+CP cohort being over 15 years younger on average—is a critical confounder and a key finding in itself. Younger age is a well-established, independent positive prognostic factor following severe brain injury.[18,19] It influences both acute survivals, making one more likely to become a cranioplasty candidate, and the capacity for neurological recovery post-CP. This demographic skew likely amplified the observed

differences in functional outcomes. Future studies employing propensity-score matching or multivariate regression are needed to better isolate the independent effect of cranioplasty from age and other baseline characteristics. Our study also offers insights into practical surgical management. The median interval of 5.8 months from DC to CP falls within the "intermediate" timing window discussed in the literature.[7,20] This period likely allows for the resolution of acute brain edema and medical stabilization while attempting to mitigate the long-term neurological sequelae of a cranial defect. The cranioplasty-related complication rate of 18.8% is consistent with reported global ranges, which highlight infection and bone flap resorption as persistent challenges.[13,21] Notably, all patients who underwent cranioplasty had initially received an augmented duroplasty, suggesting a deliberate surgical strategy for anticipated future reconstruction, which may influence complication profiles. This study has several important limitations. Its retrospective, single-center design and small sample size limit the generalizability of the findings. The lack of granular, prospectively collected neurological scores (e.g., serial GOS-E or mRS) and quality-of-life measures restricts a deeper functional analysis. As highlighted, the non-randomized, sequential nature of the interventions creates unavoidable selection bias, precluding causal conclusions about cranioplasty's effect on survival. Despite these limitations, our findings have clear clinical implications. They reinforce that patient selection for cranioplasty is intrinsically linked to favorable acute-phase outcomes, primarily younger age and survival. For clinicians, this underscores the importance of aggressive, comprehensive acute care to maximize the number of patients who can become candidates for this beneficial secondary procedure.[22] For survivors, the data affirm that cranioplasty is not merely a cosmetic operation but a functionally significant intervention associated with high rates of neurological improvement, justifying its integral role in a staged neurotrauma care model.[23,24] While survival is determined in the acute phase post-DC, subsequent cranioplasty is strongly associated with enhanced functional recovery in survivors. Future prospective multicenter studies with matched cohort designs are warranted to further elucidate the optimal timing and maximize the benefits of cranial reconstruction in this vulnerable patient populatio.[25]

Limitations

The study was limited due to its retrospective, single-center design, small sample size, and significant inherent selection bias, as cranioplasty candidates are a subgroup of acute-phase survivors. This precludes causal inferences and limits the generalizability of the findings.

CONCLUSION

This study confirms that cranioplasty candidates represent a distinct survivor subgroup following decompressive craniectomy, characterized by younger age and survival of the acute phase. For these survivors, cranial reconstruction was strongly associated with neurological and functional improvement. While not a determinant of survival, cranioplasty is a critical, beneficial step in the comprehensive rehabilitation pathway for severe neurotrauma and stroke, warranting its integration into staged care models.

Recommendations

Authors recommend aggressive acute-phase management to maximize the pool of patients eligible for cranioplasty. For survivors, cranial reconstruction should be performed on time to optimize neurological and functional recovery, as part of a standardized, staged neurosurgical care protocol.

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