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Impact of Craniectomy Size on Outcomes in Traumatic Brain Injury: A Retrospective Study at Shohadaye-Haftome-Tir Hospital, Tehran, Iran (2019–2021)

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Abstract

Background: Decompressive craniectomy is a widely accepted life-saving therapeutic approach for treating refractory raised intracranial pressure in traumatic brain injury. Research on the optimal size for craniectomy has yielded mixed results, and currently, there is no consensus on the appropriate size. The present study aims to investigate the effect of craniectomy size on the outcome of traumatic brain injury patients.

Methods: In this cross-sectional retrospective analysis, all patients who underwent decompressive craniectomy for the management of refractory raised intracranial pressure following traumatic brain injury from March 2019 to 2022 were surveyed. For craniectomy size assessment, the first postoperative CT scan was evaluated, recording the largest superior-inferior and anterior-posterior diameters of the craniectomy. The primary outcome of interest was hospital discharge status or mortality, while the secondary outcome focused on GOS scores three months post-discharge. The collected data were analyzed using SPSS software and using Fisher's Exact and T-tests, and Pearson's correlation coefficient with a significance threshold set at $P<0.05$.

Results: One hundred twenty-two patients were analyzed. The most common underlying cause of head trauma was a motor vehicle accident (72% of patients). The mean age of patients was 27.44 ± 12.42 years, and more than 70% of the patients were younger than 25 years of age. 79.9% of the patients were male. Thirty-two patients (26.22%) died during hospitalization. The mean GCS of patients at admission was 8.58 ± 4.08, and in patients who died, GCS was lower than in surviving patients ($P<0.0001$). The largest craniectomy size was 80.40 ± 18.95 mm in the superior-inferior direction and 95.57 ± 23.67 mm in the anterior-posterior direction. The craniectomy size of patients was significantly different in surviving and deceased patients. Moreover, in patients who died, the craniectomy size was smaller than in patients who survived. No significant correlation was observed between the largest anteroposterior size (r=0.024, $P=0.858$) and the largest superior-inferior diameter ($P=0.217$ and $P=0.065$) with GOS.

Conclusion: Larger sizes of craniectomy and bilateral surgery are associated with a greater reduction of intracranial pressure and a reduction in patient death, and the death rate of patients with a low GCS is also higher.

Keywords: Decompressive Craniectomy, Craniectomy Size, Intracranial Pressure, GCS, GOS

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↑What is "already known" in this topic:
Decompressive craniectomy is a life-saving treatment for refractory elevated intracranial pressure (ICP) in traumatic brain injury (TBI) patients. Some studies suggest that craniectomies larger than 15 cm yield better outcomes compared to those smaller than 8 cm. Recent guidelines also recommend performing larger craniectomies for patients with refractory elevated ICP.

→What this article adds:
The results of the present study indicate that a larger size and bilateral decompressive craniectomy are associated with reduced mortality and improved outcomes in TBI patients. Additionally, a significant association was observed between the GCS and disease outcome.

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Introduction

Severe traumatic brain injury (TBI) presents significant challenges to healthcare systems worldwide due to prolonged recovery periods and the need for long-term care. Any intervention that improves recovery rates and facilitates quicker returns to daily activities can help reduce healthcare costs and preserve patients' functional capabilities (1).

Increased intracranial pressure (ICP) and decreased cerebral perfusion pressure (CPP) are critical factors that contribute to secondary brain injury, leading to poorer clinical outcomes. Elevated ICP is associated with higher mortality rates and is a major indicator of severe TBI. Clinical guidelines universally emphasize the urgent need for managing raised ICP in TBI patients. Thus, timely intervention to lower ICP is essential, as any delay in treatment can worsen a patient's prognosis (1-3).

ICP may rise in the immediate hours following injury or over the next few days. The first-line treatment for severe cerebral edema involves medical management, including positioning the patient with the head elevated at 30°, maintaining normovolemia, controlling agitation and sedation (using Propofol at 2–4 mg/kg/h), managing seizures, using neuromuscular blockade, and administering hyperosmolar agents like Mannitol or hypertonic saline. Additionally, mechanical ventilation is critical to maintain oxygenation and regulate $Paco_2$ levels between 35–40 mm Hg. For cases of refractory elevated ICP, decompressive craniectomy (DC) has proven to be a life-saving procedure. This involves removing a bone flap and opening the dura to relieve pressure, thus creating more space for the swollen brain and reducing the risk of herniation (4-9).

While the potential benefits of craniectomy are well-established, research on the ideal size for the craniectomy has shown mixed results. Studies by Jiang et al. and Qiu et al. suggest that craniectomies larger than 15 cm yield better outcomes compared to those smaller than 8 cm (10, 11). Recent guidelines recommend larger craniectomies for patients with refractory ICP. However, practical challenges in emergency settings and variations in patient head size complicate the use of a fixed craniectomy size. Although larger craniectomies are correlated with improved outcomes, definitive evidence for the optimal size that balances effective decompression with favorable outcomes—without incurring increased surgical risks—remains lacking (12).

This study aims to investigate the impact of craniectomy size on the outcomes of patients with severe TBI who have undergone decompressive craniectomy.

Methods

This cross-sectional retrospective analysis focuses on patients who underwent decompressive craniectomy for the management of refractory raised ICP following traumatic brain injury. The study includes data from March 2019 to 2022 at a teaching hospital affiliated with Iran University of Medical Sciences.

Emergency surgery was performed on patients with severe cerebral edema and ongoing central herniation (with or without uncal herniation), either immediately upon hospital admission or within a few days if their cerebral edema did not respond to maximal medical interventions.

Data were collected from patient records, including age, sex, mechanisms of injury, Glasgow Coma Scale (GCS) scores at admission and discharge, type of surgery (unilateral or bilateral), and mortality rates. Preoperative and postoperative CT scans were reviewed to assess the nature of the injury and to measure the largest craniectomy size.

Craniectomy size was determined from the first postoperative CT scan, recording the maximum superior-inferior (SI) and anterior-posterior (AP) diameters. The primary outcome was hospital discharge status (alive or deceased), while the secondary outcome was the Glasgow Outcome Scale (GOS) scores at three months post-discharge.

Inclusion criteria

Patients diagnosed with traumatic brain injury who underwent decompressive craniectomy for ICP management were included.

Exclusion criteria

Patients younger than 18 years, those with penetrating brain injuries, individuals who underwent non-brain-related surgery, those who did not provide consent, those who died before a postoperative CT scan could be performed (thus precluding craniectomy size assessment), patients with insufficient medical data, those lost to follow-up, and individuals with a history of pre-existing brain pathologies were excluded.

Statistical analyses were performed using SPSS software. Descriptive statistics are presented as means ± standard deviations and percentages. Comparisons between living and deceased patients were performed using Fisher's Exact and t-tests. Pearson's correlation coefficient was used to assess the relationship between GOS scores and craniectomy size, with significance set at $P < 0.05$.

Results

Following the application of inclusion and exclusion criteria, 122 patients were included in the final analysis. The most common cause of head trauma was motor vehicle accidents (72%). The mean age of the patients was 27.44±12.42 years, with more than 70% of patients being younger than 25 years. Of the patients, 79.9% were male. A total of 32 patients (26.2%) died during hospitalization. There was no significant relationship between gender and outcome (P>0.05).

The results also showed no significant difference between the ages of deceased and surviving patients (P>0.05). Bilateral decompressive craniectomy was performed in 27 patients (22.13%). The type of surgery was bilateral in 28.8% of the surviving patients and 12.5% of the deceased patients (P=0.036).

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The mean GCS at admission was 8.58 ± 4.08, with significantly lower GCS scores in patients who died (P<0.001). The largest craniectomy size was 80.40±18.95 mm in the superior-inferior direction and 95.57±23.67 mm in the anterior-posterior direction. Significant differences in craniectomy size were observed between surviving and deceased patients, with deceased patients having smaller craniectomy sizes (P=0.002 for superior-inferior direction, P=0.031 for anterior-posterior direction).

However, no significant correlation was found between GOS and craniectomy size in surviving patients (P=0.217 for superior-inferior diameter, P=0.858 for anterior-posterior diameter).

Discussion

Raised ICP is a common and serious complication of TBI, often resulting in increased mortality, morbidity, and disability. Decompressive craniectomy is a therapeutic procedure aimed at reducing ICP, which improves cerebral compliance, cerebral blood flow, and cerebral oxygenation. However, its results in treating these patients are controversial. In some studies, this treatment has been associated with increased survival. While the study by Kurzbuch et al. was unable to determine what ideal craniectomy size could be performed to reduce complications and produce the best functional outcome (13-21).

In this study, 22 patients with a mean age of 27.44±12.42 years were studied, more than 70% of whom were younger than 24 years old. 79.5% of patients were male, and in 22.3% of patients, bilateral decompressive craniectomy was performed. A total of 32 patients (26.2%) died.

The present study demonstrated that bilateral decompressive craniectomy surgery reduced the risk of death by better controlling intracranial pressure. Similarly, Whitfield et al. concluded that bilateral decompressive craniectomy significantly reduced posttraumatic intracranial pressure and improved cerebral perfusion pressure dynamics (22).

Another finding of the present study was the impact of GCS and GOS on patient outcome. While GCS was lower in patients who died, there was no significant association between GOS and craniectomy size in patients who survived. In a study by Schur et al., patients were divided into small and large groups based on craniectomy size. They reported no significant difference in mean GOS between the two groups (23). The most important finding of the present work is the significant association of craniectomy size with disease outcome, as patients who survived had larger craniectomy sizes in both the anterior-posterior and superior-inferior dimensions.

A review of the literature also shows that some researchers have emphasized that large craniectomy is associated with better outcomes compared with conventional and smaller craniectomies. In the study by Sedney et al., it was shown that in patients who had a craniectomy of less than 10 cm, all patients (100%) died. While larger craniectomy size was significantly associated with reduced mortality, it was also associated with increased complications (24). Similarly, in another study, Qiu et al. reported a significant reduction in mortality in patients who underwent large craniectomy compared with patients who underwent standard craniectomy (11). In another study by Koo et al., the optimal craniectomy size in patients with increased intracranial pressure who underwent surgery was determined to be 13.4 cm. It was also emphasized that large craniectomy resulted in significantly lower mortality and a high rate of favorable outcomes compared with small craniectomy. However, large craniectomy was associated with higher bleeding (25).

There is currently no evidence for the optimal size of craniectomy, and different craniectomy sizes have been reported in different studies. However, current guidelines for the management of patients with traumatic brain injury recommend that the craniectomy size should not be smaller than 12 × 15 cm or 15 cm in diameter, and a review of studies suggests that increasing the size of craniectomy is associated with better clinical outcomes (25, 26).

Limitations

The primary limitation of this study was the loss of some patients to follow-up, which may have impacted long-term outcome assessment.

Also, the lack of ICP monitoring is another limitation of the study.

Conclusion

The results of the current study indicate that larger size and bilateral decompressive craniectomy are associated with reduced mortality and improved outcomes in TBI patients. Although a significant relationship between craniectomy size and patient outcome was observed, further studies are necessary to confirm these findings and determine the optimal craniectomy size for various TBI cases.

Authors' Contributions

The authors contributed equally to this work.

Ethical Considerations

This study adhered to the Declaration of Helsinki, and informed consent was obtained from the first-degree relatives of patients. The study was approved by the Ethics Committee of Iran University of Medical Sciences under code IR.IUMS.FMD.REC.1402.004.

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Conflict of Interests

The authors declare that they have no competing interests.

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