Cosmetic Outcome of Cranioplasty After Decompressive Craniectomy—An Overlooked Aspect

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BACKGROUND: **Cranioplasty (CP) is an obligatory surgery after decompressive craniectomy (DC). The primary objective is to protect the brain from external injury and prevent syndrome of trephined. In a government hospital, such cases pose a significant burden to a trauma center. Because of this reason, cosmetic outcome is never taken into account for the CP. We present results of CP performed at our hospital.**

METHODS: **This is a retrospective review of the cases of CP performed over the past 3 years at our hospital. The cosmetic outcome was divided into 3 grades: 1—good symmetrical, 2—irregularities, 2a—elevated and 2b depressed, and 3—bad cosmetic outcome requiring reoperation.**

RESULTS: **A total of 133 patients with acute brain injury underwent CP during the study period. The outcome was good in 74 (55.6%) and bad, requiring reoperation, in 2 (1.5%) cases. Various types of the CP materials like autologous bone flap, titanium mesh, and customized titanium plates were used. Methods of fixation were threads or miniplates and screws. In univariate analysis, cerebral venous thrombosis as an indication for DC, use of autologous bone flap, and fixation with thread were associated with poor outcome. However, in multivariate analysis only the method of implant fixation was associated with poor outcome. It was found that if screws and plates are used for fixation of bone flap, the chances of bad outcome are reduced by 74.6%.**

CONCLUSIONS: **The cosmetic outcome is overlooked for CP. The bone flap fixation has to be rigid for a good outcome.**

INTRODUCTION

Decompressive craniectomy (DC) is a rescue measure for treatment of raised intracranial pressure resulting from malignant cerebral edema due to acquired brain injury.[1,2] DC is a life-saving surgery, and survivors require a cranioplasty (CP) to cover the defect produced by the DC. The CP is an obligatory surgery after DC. The indications of CP are reconstruction and protection, cosmesis, prevention and treatment of the syndrome of trephined, and possible neurologic recovery.[3] Major concerns before considering CP are residual brain swelling, risk of infection, and hydrocephalus.[4,5] In a high-volume government hospital, such cases pose a burden on the existing waiting list of patients who require surgery for life-threatening neurosurgical disorders. Because of this reason, cosmetic outcome after the CP was formerly of minor concern. We present a review of the cosmetic outcome of the CP performed at our institute.

MATERIALS AND METHODS

This is a retrospective study. All patients who underwent CP after DC for acute brain injury during the period from July 2015 to July 2018 were included. Data were collected from case files and radiologic images of patients. DCs were done by residents using a craniotome. All CPs were done by the chief resident of neurosurgery. CPs were done in emergency department and trauma center and not as an elective procedure in elective operating rooms. CPs were done in between trauma and emergency cases whenever the operating room slot was available. The autologous skull flaps stored in the anterior abdominal wall or in a deep freezer were fixed using nonabsorbable sutures or miniplates and screws. The contoured titanium meshes were fixed using screws. The custom-made 3-dimensional titanium implants were fixed

Key words
- Bone flap
- Cosmetic outcome
- Cranioplasty
- Decompressive craniectomy

Abbreviations and Acronyms
CP: Cranioplasty
CVT: Cerebral venous thrombosis
DC: Decompressive craniectomy
VP: Ventriculoperitoneal

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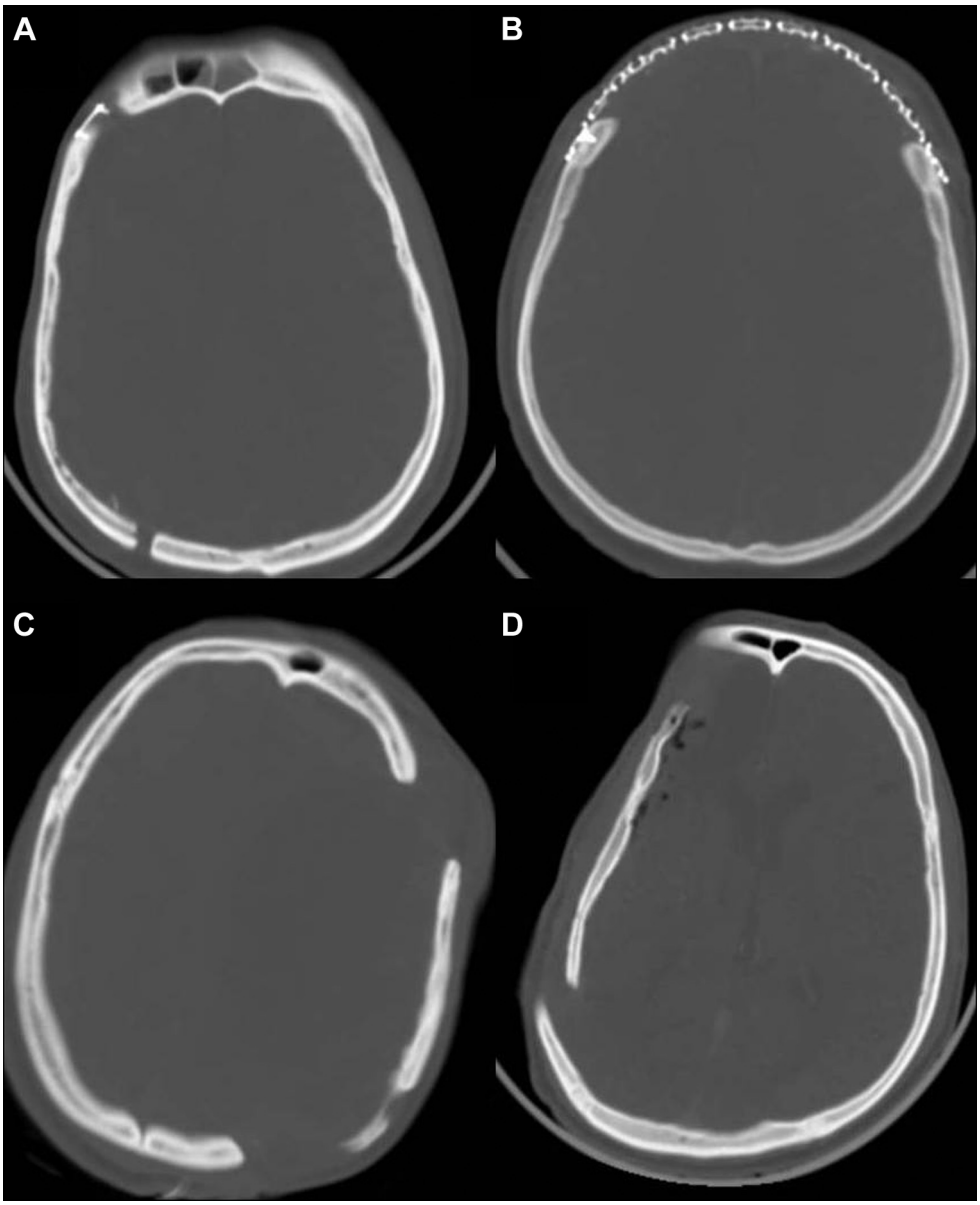

Figure 1. Postoperative computed tomography axial images showing types of cosmetic outcome. (**A**) Grade I with autologous bone flap. (**B**) Grade I with titanium mesh. (**C**) Grade IIa showing elevated bone flap. (**D**) Grade IIb showing sunken bone flap.

using screws. The bone flap/titanium meshes were not anchored with temporalis muscle/fascia or pericranium. Cosmetic outcomes of these patients were analyzed by applying the following grading system (Figures 1 and 2):

I: Bilateral smooth symmetry without felt or seen irregularity

II: Irregularities present

a: Elevated bone flap

b: Sunken bone flap

III: Bad cosmetic outcome requiring reoperation

For analysis, grade I was grouped into good outcome and grades II and III were grouped into bad outcome.

The assessment was based on clinical examination and postoperative radiology. Patients were assessed in person. The patients' descriptions of their own cosmetic results were not taken into account. The scale was administered in the first few cases by 2 authors, D.S. and D.S. (resident and consultant), until the resident became familiar with the scale. The outcome was then assessed by

Figure 2. Clinical photographs of patients with poor cosmetic outcome. (**A**) Grade IIa showing elevation at cranioplasty site. (**B**) Grade IIb showing depression at cranioplasty site.

only 1 of the authors (D.S.), who is a chief resident of neurosurgery. Possible variables that can influence outcome were analyzed. These were age, gender, functional status at time of CP, timing of CP, indication for DC, type of CP, methods of fixation, and ventriculoperitoneal (VP) shunt. The cost factor was not considered for analysis.

Categorical and continuous variables are presented in percentage and mean, respectively. Chi square test, univariate analysis, and multivariate logistic regression analysis were used. A P value of <0.05 was considered as statistically significant.

RESULTS

A total 380 patients underwent DC during the study, out of which 133 (91 [68.4%], male) underwent CP and were available for follow-up. The median age of the patients was 35 years (range 2–60 years), and median timing of CP was 6 months (range 1–48 months). Hemicranioplasty was done in 117 (88%). The most common indication for the DC requiring CP was traumatic brain injury in 86 (64.7%) cases. Other indications of the DC were cortical venous thrombosis (CVT) and arterial infarct. Autologous bone flap stored in the anterior abdominal wall was the most common CP material used in 103 (77.4%) cases. The VP shunt was done before CP in 16 (12.8%) cases (Table 1). Good cosmetic outcome was seen in 74 (55.6%) patients, and poor cosmetic outcome in 59 (44.4%) cases. Two patients with bad cosmetic outcome required reoperation for fixation (Table 2). The common complications after CP were seizures in 24 (18%) cases and infection in 13 (9.8%) cases.

Univariate analysis was performed to find out the effect of different parameters like age, timing of CP after DC, indications of DC, type of CP, methods of fixation of bone flap/implant, and VP shunt on cosmetic outcome. Univariate analysis revealed that indications of DC, type of CP, and methods of fixation had statistically significant correlation with cosmetic outcome, whereas age, timing of CP, and VP shunt before CP had no statistically significant correlation with cosmetic outcome. Patients who underwent CP after the DC for CVT had the worst cosmetic outcome. Patients who had custom-made titanium plates had the best cosmetic outcome. When the bone flap was fixed with miniplates and screws, the cosmetic outcome was best (Table 3). However, in multivariate logistic regression analysis only the method of fixation of bone flap had a statistically significant relationship with cosmetic outcome ($P = 0.049$). In multivariate analysis it was found that if screws and plates are used for fixation of bone flap, the chances of a bad outcome are reduced by 74.6%.

DISCUSSION

DC is one of the most commonly performed neurosurgical procedures worldwide. Cushing in the early 20th century described the procedure for management of increased intracranial pressure.[6] DCs performed by Cushing were much smaller than current DCs, and the CP was never taken into account by him. After that the DC became the cornerstone for management of severe brain edema due to brain injury refractory to medical therapies.[7] The bone defect caused by DC causes significant changes in the dynamics of local cerebral blood flow, as well as cerebral metabolic rate of oxygen and glucose consumption, which affect normal brain function and metabolism.[8] CP after DC with autologous bone flap stored in either the abdomen or a deep freezer is practiced worldwide.[9] With an increase in indications of DC, there is a proportionately increased need for CP.[10]

Table 1. Clinical and Surgical Variables (Number = 133)

Variables	Number (Percentage)
Gender	
Male	91 (68.4%)
Female	42 (31.6%)
Cranioplasty site	
Hemicranioplasty	117 (88%)
Bifrontal	16 (12%)
Indications for decompressive craniectomy	
Traumatic brain injury	86 (64.7%)
Cerebral venous thrombosis	28 (21.1%)
Arterial infarct	19 (14.3%)
Cranioplasty types	
Autologous bone flap	103 (77.4%)
Titanium mesh	28 (21.1%)
Customized patient-specific titanium plate	2 (1.5%)
Methods of fixation	
Screws and plates	119 (89%)
Threads	14 (10.5%)
Functional status at time of cranioplasty	
Good recovery	75 (56.4%)
Moderate disability	42 (31.6%)
Severe disability	14 (10.5%)
Vegetative state	2 (1.5%)
Ventriculoperitoneal shunt before cranioplasty	
Yes	16 (12.8%)
No	117 (87.2%)

Table 2. Cosmetic Outcome and Complication of Cranioplasty

Cosmetic Outcome	
Grade 1: Good Symmetry	74 (55.6%)
Grade 2: Irregularities	
a. Elevated	40 (30.1%)
b. Depressed	17 (12.8%)
Grade 3: Bad, Requiring Resurgery	2 (1.5%)
Site of irregularity	
Temporal	22 (16.5%)
Other	35 (25.6%)
Complications	
Hemorrhage	2 (1.5%)
Infection	13 (9.8%)
Seizures	24 (18%)

The aim of the CP after DC is to protect the brain from external trauma, to achieve a natural appearance and prevent syndrome of the trephined.[10-16] However, in high-volume trauma centers, the CP is performed in between other emergency neurosurgical procedures. CPs are done in emergency and trauma operating rooms. Though the CP is an elective procedure, it is not done in elective operating rooms due to a long waiting list of other elective neurosurgical procedures that require sophisticated equipment. Because CPs require the same simple instruments and equipment as trauma cases do, CPs are done in trauma operating rooms. Patients who require CPs compete with other patients who require emergency neurosurgical procedures. Patients who require a CP undergo surgery quickly so as to minimally use the operating room time; hence they are not given enough priority, resulting in overlooking the aspect of cosmetic outcome of the CP. Earlier, we studied the complications of CP.[10] The complications in the present series are reduced as compared with our previous series.[10] As the complications have come down and neurologic outcomes have improved, we felt a need to look at the cosmetic outcome of the CP.

The cosmetic outcome is not addressed in many studies. A review of materials used for the CP did not address the cosmetic outcome.[17] Cosmetic results are probably rarely reported in the literature, as there is the general conviction that cosmetic results after CP, especially in patients with unfavorable neurologic outcome, are less important than improvement of brain functions and functional outcome. A scientifically validated method of evaluation of cosmetic results that may be generalizable and objective is not available. Earlier studies have used patients' or parents' satisfaction as an outcome tool for assessment of the cosmetic outcome after the CP.[18,19] The patients' or parents' judgment is not always available reliably due to the neurologic inability of some patients or their refusal to provide an opinion. One objective scale, the Rostock Functional and Cosmetic Cranioplasty Score, which takes into account scar/skin, fitting of the CP, symmetry, and function, needs to be validated externally.[20]

Bad cosmetic results have been recorded from 1.5%–8.7% of cases in various series.[19,21-23] In the present study we proposed our cosmetic outcome scale on the basis of our patients' complaints. Nearly half of our patients had a poor cosmetic outcome. However, only 2 out of 133 (1.5%) patients required reoperation for poor cosmetic outcome. Almost all of the patients who had a poor outcome (grade 2) had socially acceptable appearances, and some irregularities could be easily covered with hair. The irregular modeling of acrylic may result in an inadequate prosthesis; in case of titanium mesh there may be failure to contour; in case of autologous bone, the resorption may cause the sinking of the flap; and in every case malposition or dislodgement of an implant can result in a poor cosmetic outcome. We studied various factors resulting in poor cosmetic outcome, which are discussed as follows.

DC after CVT is not common. Patients who underwent DC for CVT at our institute presented in poor neurologic status due to malignant cerebral hemorrhagic infarction, and early DC was done as a life-saving measure. If the CP was performed after DC for CVT, the

Table 3. Univariate Analysis of Factors Affecting Outcome

Variables	Good Outcome (n = 74) (55.6%)	Bad Outcome (n = 59) (44.4%)	*P* Value
Age			
≤40 years	46 (52.3%)	42 (47.7%)	0.274
>40 years	28 (62.2%)	17 (37.8%)	
Timing of cranioplasty			
0–3 months	20 (66.7%)	10 (33.3%)	
4–6 months	15 (60%)	10 (40%)	0.262
>6 months	39 (50%)	39 (50%)	
Diagnosis			
Trauma	54 (62.8%)	32 (37.2%)	
CVT	10 (35.7%)	18 (64.3%)	**0.042**
Infarct	10 (52.6%)	09 (47.4%)	
Type of cranioplasty			
Autologous	50 (48.5%)	53 (51.5%)	
Titanium	22 (78.6%)	06 (21.4%)	**0.008**
Customized	02 (100%)	0 (0.0%)	
Methods of fixation			
Screws and plates	71 (59.7%)	48 (40.3%)	**0.009**
Thread	03 (21.4%)	11 (78.6%)	
VP shunt			
Yes	08 (50.0%)	08 (50.0%)	0.628
No	66 (56.4%)	51 (43.6%)	

Significant *P* values are typed in bold.
CVT, cerebral venous thrombosis; VP, ventriculoperitoneal.

proportion of bad outcome was high. Cerebral edema takes much longer to subside after CVT due to chronic brain swelling. These patients have a brain bulge at the time of CP, resulting in poor fixation of bone flap and a bad cosmetic outcome. We have done perioperative placement of lumbar drains in these patients to control brain swelling. We did not wait for brain swelling to subside before cranioplasty, as the CP is a prerequisite before transferring to a rehabilitation facility. The best outcome was seen with customized implants, followed by titanium mesh and autologous bone flap. The outcome was better when miniplates and screws were used to fix an autologous bone flap. The autologous bone flap tends to resorp over time when placed in the anterior abdominal wall. The smaller bone flap results in a sunken flap in spite of fixation resulting in a bad outcome. If the bone flap can be fixed with miniplates and screws, the sinking of flap can be prevented and cosmetic outcome can be improved. The timing of CP after DC and placement of a VP shunt before the CP had no bearing on cosmetic outcome. However, in multivariate logistic regression analysis the only method of fixation had a statistically significant relationship with cosmetic outcome. The use of miniplates and screws reduced the chances of a bad outcome by 74.6%. The poor cosmetic outcomes seen in our present study are mainly due to the unavailability of implants. The autologous bone flap and fixation with thread does not cost anything to a patient, whereas the cost of an implant, a miniplate, and screws for fixation is immense and must be borne by the patient. Currently none of the government health schemes in our country cover the cost of cranial implants.

The factors resulting in poor cosmetic outcome have not been addressed in previous studies. In 1 study of CP in children from a developing county, the parents rated the cosmetic outcomes of the CP; 72.2% were satisfied and 27.8% were dissatisfied with the cosmetic outcome of the CP. In this study the bone flaps were stored in a deep freezer and fixed with threads at the time of replacement during the CP. The time interval between DC and CP, indication for the DC, site of the CP, and area of skull defect were not significantly associated with the cosmetic outcome of the CP.[18] Contrary to this study, in our present study we found that fixation with thread resulted in a bad outcome. Among the methods used for the CP, the best outcomes have been reported with patient-specific customized implants, though the cost of implant is high.[24,25]

In resource-constrained settings the following options can be exercised to improve the cosmetic outcome of the CPs:

1) Using Gigli saw and beveling the bone flap at the time of craniotomy. The beveled bone flap sits well on the skull defect and obviates the need for rigid fixation using miniplates and screws.
2) Anchoring the bone flap or titanium mesh with temporalis muscle/fascia and pericranium. This may prevent sinking of the bone flap.
3) Using stainless steel wires to fix the bone flap instead of titanium miniplates and screws. We used steel wires earlier to fix the bone flap but had many patients who complained of a pricking sensation from wire and occasionally extrusion of wires.
4) Filling the gap between bone flap and skull with osteointegrative bone cement. This may prevent resorption but needs to be studied.
5) Performing hinge or expansile craniotomy (floating bone flap) instead of DC to avoid a second operation for the CP.

Limitations and Future Prospects

The major limitation of our study was that it was a retrospective study including only 133 patients. Not all of the patients who underwent the DC were followed up due to attrition. The sampling was convenient but not consecutive as all patients who survived after DC did not return for CP. The cosmetic outcome was assessed only in the patients who came for routine follow-up. Our results are not easily transferrable to all neurosurgical units, particularly those that are well resourced, but the general principles are of relevance. A large prospective study is required to evaluate the various factors responsible for bad cosmetic outcome. Two registries, the United Kingdom and German Cranial Reconstruction Registries, are prospective, multicenter, open registries that will look for cosmetic, besides functional, outcome after CP.[26,27]

CONCLUSION

In a large-volume trauma center, because of the long waiting list and financial constraints, the cosmetic outcome after CP is generally overlooked. The poor cosmetic outcome may affect the social lives of patients who recover neurologically and are ready to go back to work. The cosmetic outcome should also be considered when performing the CP. The CP should not be taken lightly just to fill the skull defect. Poor cosmetic outcome may be due to rushed surgery. If CPs are done electively by consultants with similar dedication and perfection as surgery for craniosynostosis, the cosmetic result can be improved. In patients with good neurologic outcomes, especially young people with socially active lives, the cosmetic result should be 1 of the most important goals to be achieved with the CP. The insurance company and the government funding agency should provide for the cost of the implants required for CP. When available, patient-specific implants should be used for the best cosmetic outcome.

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