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Comparison of the Timing of Cranioplasty Surgery After Decompressive Craniectomy

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Abstract

BACKGROUND/AIMS: We aimed to compare and evaluate the results of cranioplasty (CP) performed in the early period (within the first 1 month) and in the late period (from the 90th day onwards) in patients who had previously undergone decompressive craniectomy.

MATERIALS AND METHODS: A total of 138 patients who underwent CP in our hospital between 2016 and 2022 were included in this study. The patients were grouped as follows based on the interval between their craniectomy and CP: group 1, within the first 30 days; group 2, 31-90 days; group 3, 91-180 days; group 4, 181-360 days; and group 5, day 361 or later.

RESULTS: Our study included 94 men and 44 women who had undergone CP between 2016 and 2022. While groups 2 (p=0.011), 3 (p=0.040) and 4 (p=0.037) had statistically significant differences in comorbidities, group 5 (p=0.17) did not. The difference in infection developments (p=0.010) and their diagnosis (p=0.040) was statistically significant only between group 1 and group 4. In group 4, the number of patients with SVO was higher than that in the other groups. The duration of hospitalization was 20.13±19.42 days in group 1 and 28.39±30.96 in the other groups (p=0.137). Bone reabsorption was 2.91±7.59, 8.12±8.20, 11.37±10.07, 9.65±11.33, and 6.66±10.73 days in groups 1, 2, 3, 4 and 5, respectively. The midline shift was 1.87±2.018 and 0.51±1.19 in those patients with a craniectomy area >100 cm^2 and <100 cm^2 area, respectively. This difference was statistically significant (p=0.001).

CONCLUSION: By performing CP in the early period, early mobilization of the patient can be ensured and the risk of developing complications can be minimized.

Keywords: Cerebral edema, cranioplasty, decompressive craniectomy

INTRODUCTION

Cranioplasty (CP) is a cosmetic surgery which enhances neurological recovery by preserving the patient's neural tissues and balancing intracranial pressure, which normalizes the cerebrospinal fluid (CSF) and blood circulation.[1-5]

Decompressive craniotomy is frequently used in patients with raised intracranial pressure who cannot be treated medically at the point of connecting to life.[3] It is frequently performed in patients with traumatic brain injury, cerebral infarction, subarachnoid hemorrhage, intracranial hematoma, encephalitis, sinus thrombosis, postoperative tumor or aneurysm.

The complication rate following CP is high (0.9-40.4%),[4] and these complications include bone resorption (BR), seizures, hydrocephalus, bleeding, and infection.[1,4,6]

The recommended timing of performing CP differs in the literature; thus, there is no consensus. However, it is generally recommended that it be performed approximately 90 days after craniectomy.[3,4,7-13] Factors such as the patient's age, general condition, the presence of systemic

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diseases, infection, surgical site condition, and etiology affect the timing of CP.[14]

There is no consensus regarding the timing of performing CP. We aimed to compare and evaluate the results of CPs performed in the early period (within the first 1 month) with those performed in the late period (on or after the 90th day) in patients who had previously undergone decompressive craniectomy.

MATERIALS AND METHODS

Patient Selection

A total of 138 patients who underwent CP at our hospital between 2016 and 2022 were included in this study. The patients were divided into the following groups based on the interval between their craniectomy and CP: group 1, first 30 days; group 2, 31-90 days; group 3, 91-180 days; group 4, 181-360 days; and group 5, day 361 or later. The following data were retrospectively examined: the timing of the CP, the patient's age, diagnosis, the duration of their surgery, the materials used in CP, their preoperative and postoperative Glasgow Coma Scores (GCS), the bone tissue resorption percentages of the patients, seizures, hydrocephalus, postoperative bleeding, fluid or air collection, wound infection, reoperations and durations.

Surgical Procedure

In all patients, preoperative antibiotics were administered prophylactically and continued postoperatively until drain removal. Bone flap resorption was calculated based on the percentage reduction in flap area (% BR) by comparing the preoperative craniotomy defect with the post-CP bone flap area via computed tomography (CT). Field calculations were performed using OsiriX MD.

Autogenous bone flaps were hidden in the abdomen or lateral thigh. According to the pre-op resorption status, the titanium plate was completed with methyl methacrylate (MMA) and stabilized with a self-tapping screw or non-absorbable silk suture. The patient underwent cranial CT examination.

Ethical Approval

This study was approved by the University of Health Sciences Türkiye, Haseki Training and Research Hospital Ethics Committee (approval number: 224-2022, date: 21.12.2022). Written informed consent was obtained from the patient and/or their relatives before being included this retrospective study.

Statistical Analysis

Statistical analysis was performed using SPSS (v 20.0; SPSS Inc., Chicago, IL, USA). Descriptive data are expressed as frequencies, cross-table, rates, arithmetic means, and standard deviations. Data were analyzed using Student's t-test and correlation. The groups were compared with the test variables using the Independent samples t-test. A p-value of <0.05 was considered statistically significant.

RESULTS

In our study, 138 patients who underwent CP between 2016 and 2022 were included. The patients were grouped based on the interval between their craniectomy and CP, and 5 groups were formed. The groups were compared among themselves, and group 1 and all other groups were compared. The demographic characteristics and first diagnoses of the patients are shown in Table 1. The preoperative time, material used, BR, preoperative and postoperative GCS, cranial defect area, postoperative hematoma formation or collection, development of epileptic seizure or hydrocephalus, infection, risk of reoperation, midline shift, comorbidity, and pneumocephalus in CP were compared between the groups. When group 1 was compared with all the other groups, significant differences were found in terms of age, preoperative time, BR, preoperative GCS, and midline peeling due to sunken skin flap (Table 2). In group 1, the CP area was smaller (p=0.00), the incidence of comorbidities (p=0.012) and Trephened syndrome development (p=0.001) was lower, and the presence of air in chamber postoperatively (p=0.009) was lower than in the other groups; with these differences being statistically significant. No statistically significant difference was found between the first group and the other groups in terms of sex, postoperative bleeding, collection, reoperation rate and time, and post-CP incidences of seizure or the need for ventriculoperitoneal shunt, when compared using the Independent t-test.

Postoperatively, air was present in 106 patients, which was found to be significant only in group 2 (p=0.013). In terms of comorbidities, there was a statistically significant difference between groups 2 (p=0.011), 3 (p=0.040), and 4 (p=0.037). No statistically significant difference was found in group 5 (p=0.17).

Infection was less common in group 1 and more common in group 4; this difference was statistically significant (p=0.010). The incidence of cerebrovascular disease was found to be higher in those patients in group 4 than in the patients in the other groups. However, there was no statistically significant difference among the other groups.

Table 1. Demographic features and diagnoses of the patients

Cranioplasty groups	Male	Female	Comorbidity							Diagnosis				
			DM	HT	CAD	HT and DM	HT and CVH	HT, DM, CVH	None	CVD	T	PT	PA	ICH
Group 1	25	11	0	6	3	1	0	0	26	1	14	14	0	7
Group 2	19	13	1	9	4	5	0	0	13	11	8	7	0	6
Group 3	24	5	1	8	4	3	0	0	13	5	8	3	1	12
Group 4	16	13	0	7	0	4	3	0	15	7	11	7	2	2
Group 5	10	2	0	1	0	2	0	1	8	2	6	4	0	0
Total	94	44	2	31	11	15	3	1	75	26	47	35	3	27

DM: Diabetes mellitus, HT: Hypertension, CAD: Coronary artery disease, CVD: Cerebrovascular diseases, T: Trauma, PT: Postoperative tumor, PA: Postoperative aneurysm, ICH: Intracranial hemorrhage.

Autogenous grafts, MMA, titanium mesh, and bone matrix were used for the CP. Group 1 included patients with post-traumatic open wounds, collapse fractures, and multiple-part fractures, and patients with tumors were common. Therefore, the MMA graft was used more than the other materials. Autogenous grafts were used more often in group 2 than in the other groups, and this difference was statistically significant (p=0.017) (Table 3).

Seven patients with very early-stage CP underwent reoperation. Four were re-operated on due to infection; MRSA growth was observed in one patient and *Escherichia coli* in another. Two patients underwent surgery because of bleeding in the hostel, and one patient was operated on due to the early development of extra-axial collections and seizures.

Of the 27 patients who underwent reoperation, 19 developed a collection. Of these 19 patients, five underwent CP soon after the craniectomy; this was not statistically significant. Postoperatively, 38 patients developed bleeding in the hospital, and 12 of them underwent reoperation. In the very early period, two patients underwent reoperation. This was not statistically significant.

The two groups based on bone flap areas (<100 cm^2 and ≥100 cm^2) were compared with each other. BR and midline slip were higher and length of stay was longer in the group with a bone flap <100 cm^2 than in the group with a bone flap <100 cm^2 (Table 4).

Table 2. Comparison of the characteristics of the groups formed based on the timing of cranioplasty

	Group 1, (n=30)	Group 2, (n=32)	Group 3, (n=29)	Group 4, (n=29)	Group 5, (n=12)
Age	34.91±20.62 (p=0.002)	47.12±18.28 (p=0.012)	49.79±16.10 (p=0.002)	42.37±15.67 (p=0.113)	43.33±16.80 (p=0.208)
Pre-op time	11.38±13.01 (p=0.000)	73.87±30.18 (p=0.00)	146.75±35.08 (p=0.00)	270.00±74.35 (p=0.00)	1015.83±895.80 (p=0.00)
Bone resorption	2.91±7.59 (p=0.001)	8.12±8.20 (p=0.008)	11.37±10.07 (p=0.000)	9.65±11.33 (p=0.006)	6.66±10.73 (p=0.190)
Pre-op GCS	4.61±0.64 (p=0.001)	4.03±0.89 (p=0.003)	4.13±0.83 (p=0.012)	4.13±0.74 (p=0.008)	4.08±0.90 (p=0.032)
Post-op GCS	4.69±0.52 (p=0.141)	4.50±0.62 (p=0.167)	4.55±0.63 (p=0.393)	4.58±0.50 (p=0.402)	4.41±0.66 (p=0.145)
Midline shift	0.30±0.66 (p=0.001)	1.18±1.46 (p=0.002)	1.65±1.73 (p=0.000)	1.06±2.05 (p=0.040)	1.83±2.75 (p=0.03)
Hospitalization period (days)	20.13±19.42 (p=0.137)	29.28±32.75 (p=0.161)	25.17±24.01 (p=0.354)	31.55±35.80 (p=0.106)	26.16±31.45 (p=0.43)

Pre-op: Preoperative, Post-op: Postoperative, GCS: Glasgow Coma Score.

Table 3. Materials used for cranioplasty

	CP material					Total
	Autogenous	MMA	Titanium	MMA or titanium with autogenous	Bone matrix	
Group 1	22	11	1	1	1	36
Group 2	29	2	1	0	0	32
Group 3	21	3	1	4	0	29
Group 4	14	11	1	2	1	29
Group 5	3	6	1	2	0	12

CP: Cranioplasty, MMA: Methyl methacrylate.

Table 4. Comparison of groups based on the craniectomy area width (α<100 cm^2 and α≥100 cm^2)

	(α<100 cm^2), (n=80)	(α≥100 cm^2), (n=58)	p
Age	41.50±19.45	46.10±16.74	0.113
Pre-op time	196.15±463.23	195.82±191.87	0.996
Bone resorption	4.68±8.16	11.72±10.45	0.001
Pre-op GCS	4.53±0.61	3.81±0.86	0.001
Post-op GCS	4.71±0.50	4.37±0.61	0.001
Midline shift	0.51±1.19	1.87±2.018	0.001
Hospitalization period	18.45±19.15	36.98±35.37	0.001
Reoperation time	18.12±22.3	4.16±3.25	0.149
Duration (classification)	2.35±1.40	3.01±1.05	0.003

Pre-op: Preoperative, Post-op: Postoperative, GCS: Glasgow Coma Score.

DISCUSSION

Although CP appears to be a simple procedure, complication rates are high (10.9-50%).[11,15] In addition to easy dissection, the other advantages in early-stage CP include lower blood loss and a shorter surgical time.[4,8,11] In addition, it can provide early normalization of cerebral blood flow.[16] Furthermore, better neurological recovery and fewer complications are observed.[2,9,11] Studies have demonstrated a high complication rate due to the risk of hydrocephalus in the early postoperative period and increased length of stay.[6,10] Especially with the prolongation of the interval between decompressive craniectomy and CP, the risk of seizure and midline shift may increase. Other studies have demonstrated that there is no difference in complications between CP being performed in the early and late periods.[7,13] It is recommended that CP be performed at the earliest between the 15th and 30th days.[3] After the CSF dynamics and blood circulation are normalized after CP, neurocognitive functions improve.[2,5,7,16] Although there was no statistically significant difference in the preoperative GCS and postoperative GCS in our study group, the GCS was better in both the early and late groups. With early surgery, the risk of developing midline shift and Trephened syndrome reduces due to CPs effect on cerebral blood flow and CSF circulation.

There may be signs of infection, hyperemia, swelling, temperature increase, and abscess in the surgical field after CP. There is a risk of infection, especially following trauma and decompression of the frontal sinus and in those patients with comorbidities and long hospital stays.[15] Although the infection rates following CP are reportedly 7-22%,[17] there was one study where this rate was as high as 33%.[16] In our study, infection was observed in 27 patients (19.56%); and it was observed in four patients (11.11%) in the very early period. In the first month, two patients following CP demonstrated microbial growth. One patients had MRSA growth and the other had *E. coli* growth.

The risk of post-CP seizures can be as high as 30.3%, but early surgery can reduce this risk.[12]

In our study, seven patients (5.07%) developed post-CP seizures. One patient (2.7%) developed a seizure in the very early period. Patients were more prone to seizures if they developed postoperative bleeding, fluid collection, or infection. Four patients underwent reoperation. Reoperation was performed in one patient in the very early group and in three patients in the late period.

There are studies reporting that it increases the risk of multiple skull fractures, age <30 years, large bone defects, post-traumatic hydrocephalus and shunt operations, low GCS, infection, prolonged interval prior to CP, and BR.[18] Especially in children, BR can reach up to 66.7%.[18] Studies indicate that BR is high in those patients aged <18 years and that the risk of reoperation is high.[11] Avascular necrosis in bone flaps reduces with osteoblastic/osteoclastic cell activity and regression of collagen matrix enzymes.[19] The rate of BR due to bone thinning, decreases in density, and osteolysis can be as high as 31.7%,[18] 46.3% in the study by Zhang et al.[20], or 46.3% in the study by Stieglitz et al.[21] Furthermore, it was higher in those with a greater melting point.[18-22]

In our study, the rate of BR was 2.91%±7.59% in the first 30 days and 9.31%±9.97% after the 31st day. The BR and short time-to-surgery were found to be statistically significant (p=0.001). Furthermore, in group 1, most of the patients had a CP defect <100 cm^2. In patients with a flap area >100 cm^2, the BR was statistically higher than in those with a flap area <100 cm^2 (p=0.00). The correlations between low GCS scores, the presence of comorbidities, long hospitalization, midline spur, postoperative bleeding, seizures, and the CP flap area were statistically significant. The BR was 5.76%±11.87% in those patients aged <19 years (n=13) and 7.84%±9.59% in those aged >19 years. Although the sample was small, the BR was lower in the younger group than in the older group (p=0.47). When the very early CP group was compared with the other groups, there was no statistically significant difference in terms of postoperative bleeding, collection or the rate of reoperation.

The rate of reoperation after CP is reportedly 1.4%-32%.[8] While the total number of patients who underwent reoperation was 27 (19.56%) in our study, 7 (19.44%) in the very early group underwent reoperation. The reoperation rates in our study are consistent with those in the literature. There was no significant difference between the groups.

When group 1 and all other CP groups were compared, group 1 had younger patients, fewer comorbidities, shorter time-to-CP, better preoperative and postoperative GCS, lower midline slip, CP area <100 cm^2, and lower BR.

If the bone flap area was >100 cm^2, the BR was greater. BR was found to be statistically associated with a low GCS score, the presence of comorbidities, longer hospitalization periods, midline shift, postoperative bleeding, and seizures. Although the BR rate was lower in patients aged <19 years, it was not statistically significant. However, our study sample was small.

Study Limitations

Our study was a retrospective study with a small sample size. Further studies with larger sample sizes are required to externally validate our findings.

CONCLUSION

In the early period of CP, lower age, fewer comorbidities, better GCS, lower brain edema and less midline shift are important factors. In the early period, protection of brain tissue from external factors and the normalization of CSF and blood flow with CP can ensure early mobilization of the patient and minimize the risk of developing complications.

MAIN POINTS

- The time between decompressive craniectomy and cranioplasty is important.
- The results of cranioplasty applied at a young age and in the early period are more successful.
- Performing cranioplasty in the early period can provide protection to the brain tissue from external factors. Normalization of cerebrospinal fluid and blood flow can provide early mobilization of the patient.

ETHICS

Ethics Committee Approval: This study was approved by the University of Health Sciences Türkiye, Haseki Training and Research Hospital Ethics Committee (approval number: 224-2022, date: 21.12.2022).

Informed Consent: Written informed consent was obtained from the patient and/or their relatives before being included this retrospective study.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: G.B., A.A., Concept: G.B., A.A., Design: G.B., A.A., Data Collection and/or Processing: G.B., A.A., Analysis and/or Interpretation: G.B., A.A., Literature Search: G.B., A.A., Writing: G.B., A.A.

DISCLOSURES

Conflict of Interest: No conflict of interest was declared by the authors.

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