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Outcomes and Associated Complications of Cranioplasty following Craniectomy in Brunei Darussalam

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Abstract

Objective Cranioplasty, commonly performed after decompressive craniectomy, is associated with significant complications. We aim to characterize the outcomes and complications post cranioplasty performed in Brunei Darussalam.

Methods and Materials We conducted a nationwide retrospective study of the patients who underwent cranioplasty. Patients who underwent cranioplasty by the Neurosurgical Department from January 2014 to June 2019 were included. Patients were excluded if they did not have a minimum of 30-days follow-up or the initial cranioplasty was performed elsewhere. Outcomes including complications post cranioplasty and 30-day and 1-year failure rates were assessed. All statistical analyses were performed with SPSS version 20 (IBM Corporation, Armonk, New York, USA). The χ^2 test, Student's *t*-test, and the Mann–Whitney *U* test were performed for nominal, normally, and non-normally distributed variables, respectively. Multivariate logistic regression was used to assess predictors for complications and cranioplasty failure.

Results Seventy-seven patients with a median age of 48 (interquartile range, 37–61) years were included. Most cranioplasties used autologous bone (70/77, 90.9%). Infection and overall complication rates were 3.9% and 15.6%, respectively. Cranioplasty failure (defined as removal or revision of cranioplasty) rate was 9.1%. Previous cranial site infection post craniectomy was associated with cranioplasty failure (odds ratio: 12.2, 95% confidence interval [1.3, 114.0], $p = 0.028$).

Conclusions Cranioplasty is generally associated with significant complications, including reoperation for implant failure. We highlighted that autologous bone cranioplasties can be performed with an acceptable low rate of infection, making it a viable first option for implant material.

Keywords
- cranioplasty
- complication
- failure
- autologous bone

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Key Messages

Autologous bone cranioplasty can be performed with an acceptable low rate of infection, making it a viable first option for implant material for cranioplasty.

Introduction

Reconstruction of the cranial defect (cranioplasty) is a common elective procedure for patients who have undergone decompressive craniectomies in the settings of trauma, intracranial hemorrhages of various causes and malignant cerebral infarcts. In addition to providing protection to the underlying brain and restoring cosmesis, cranioplasty has also been reported to improve neurological function, particularly, in patients with syndrome of the trephined.[1] Although the procedure can be considered one of the least technically demanding in the field of neurosurgical procedures, it is also associated with significant complications. Reported complication rates range from 3.3% to 40.8% with high infection rates being one of the main concerns.[2–4]

Autografts to xenografts and bone substitutes, including polymethylmethacrylate (PMMA), hydroxyapatite, calcium phosphate, porous polyethylene, titanium, and polyetheretherketone (PEEK) have been used for the reconstruction of cranial defects.[1] To date, there are no guidelines or established best practices in relation to the choice of material used. The preferred method of cranioplasty in our institution involves the use of autologous bone as it is readily available and its benefit of potential growth and integration into recipient bone without graft rejection. PMMA and titanium mesh are also used when the patient's bone is not suitable for reimplantation. In this study, we aim to characterize the outcomes and associated complications of patients who underwent cranioplasty in Brunei Darussalam.

Subjects and Methods

A retrospective study of patients who underwent cranioplasty within the Neurosurgical Department from January 2014 and June 2019 was performed. Our department administers nationwide neurosurgical care for a population of 433,000 through two centers (Raja Isteri Pengiran Anak Saleha Hospital and Pantai Jerudong Specialist Centre). Approval for this study was obtained from our local authority, the Medical and Health Research and Ethics Committee, Ministry of Health.

Study subjects included all patients who underwent cranioplasty according to the Department of Neurosurgery registry. Data for 87 patients were collected but 10 patients were excluded from the final analysis as they did not have a minimum of 30 days follow-up (foreigners repatriated to their home countries postsurgery) or the initial cranioplasty was performed elsewhere. Data collected included age at the time of cranioplasty; sex; significant past medical history; indications for craniectomy, side of craniectomy, complications post craniectomy, Glasgow Outcome Score (GOS) post craniectomy, type of cranioplasty implant, side of cranioplasty, cranioplasty size, and time interval from craniectomy to cranioplasty. Outcomes including complications post cranioplasty and failure rates at 30 days and 1 year were assessed. Cranial site infection was defined as infection involving the skin and subcutaneous tissue of the incision site, such as skin crusting, skin redness, or inflammation of the overlying skin, or cranial infection involving deep soft tissue, spaces, and/or brain, such as intracranial infection, meningitis, or epidural abscess, or a wound infection that progressed. Exposed implant was defined as exposure or extrusion of implant due to erosion of the skin, without infection or with negative culture. Implant infection was defined as infection of the implant as a progression of a wound infection with positive culture. Cranioplasty failure was defined as revision or removal of a patient's implant.

All statistical analyses were performed with SPSS version 20 (IBM Corporation, Armonk, New York, USA). The χ^2 test, Student's *t*-test, and the Mann–Whitney *U* test were performed for nominal, normally, and non-normally distributed variables, respectively. Potential predictors of complications and failure were screened using univariate analyses. Variables that fulfilled the cut-off of *p*-value of 0.1 or lower in the univariate analyses were entered into a multivariate logistic regression with backward stepwise elimination. In the final model, predictors for complications and cranioplasty failure were identified based on *p*-value less than 0.05. Odds ratios (ORs) and 95% confidence intervals (CIs) were calculated for these models.

Results

Patient Demographics and Characteristics

Our cohort consisted of 77 patients (52 men) with a median age of 48 (interquartile range [IQR], 37–61) years who underwent cranioplasty post craniectomy. The majority of the patients had craniectomies for the treatment of intracerebral hemorrhage (44/77, 57.1%) and cerebral malignant infarct swelling (22/77, 28.6%). The demographic and clinical variables are summarized in ►**Table 1**.

Cranioplasty Characteristics

A total of 77 cranioplasties were performed on the 77 patients, where the median size of the cranial defect was 85.0 cm^2 (►**Table 1**). Autologous bone, which was preserved from the patient's craniectomy, was used in most of the cases (70/77, 90.9%). Other implant materials used included PMMA (4/77, 5.2%) and titanium (3/77, 3.9%). The median time from craniectomy to cranioplasty was 63 (IQR, 41–92) days.

Cranioplasty Complications and Failure

The overall complication rate for cranioplasty was 15.6% (12/77). Implant infection and exposed implants occurred in 3.9% (3/77) and 2.6% (2/77) of patients, respectively. All three cranioplasty infections occurred in the autologous bone group, resulting in an infection rate of 4.3% (3/70) for autologous bone cranioplasty. Other complications included dislodged implant (1/77, 1.2%), bone resorption (1/77, 1.2%), superficial hematoma (1/77, 1.2%), extradural hematoma

Table 1 Patient demographics and characteristics

	Overall ($N = 77$)	Implant non-failure ($n = 70$)	Implant failure ($n = 7$)	*p*-Value
Male gender, *n* (%)	52 (67.5)	47 (67.1)	5 (71.4)	0.817
Median age, years (IQR)	48 (37–61)	48 (37–58)	52 (38–69)	0.357
Co-morbidities, *n* (%)				
Hypertension	57 (74.0)	52 (74.3)	5 (71.4)	0.869
Hyperlipidemia	29 (37.7)	25 (35.7)	4 (57.1)	0.265
Diabetes mellitus	17 (22.1)	14 (20.0)	3 (42.9)	0.164
Antiplatelet use	8 (10.4)	6 (8.6)	2 (28.6)	0.098
Anticoagulant use	5 (6.5)	5 (7.1)	0 (0)	0.465
Indication for craniectomy, *n* (%)				
ICH	44 (57.1)	40 (57.1)	4 (57.1)	1.000
Infarct	22 (28.6)	19 (27.1)	3 (42.9)	0.380
Infection	1 (1.3)	1 (1.4)	0 (0)	0.750
Trauma	8 (10.4)	8 (11.4)	0 (0)	0.345
Tumor	2 (2.6)	2 (2.9)	0 (0)	0.650
Side of craniectomy, *n* (%)				
Right	40 (51.9)	38 (54.3)	2 (28.6)	0.194
Left	36 (46.8)	31 (44.3)	5 (71.4)	0.170
Bilateral	1 (1.3)	1 (1.4)	0 (0)	0.750
Complications post craniectomy, *n* (%)				
None	68 (88.3)	63 (90.0)	5 (71.4)	0.145
Cranial site infection	4 (5.2)	2 (2.9)	2 (28.6)	0.003*
Reoperation on same site	4 (5.2)	4 (5.7)	0 (0)	0.516
Hydrocephalus requiring VPS	1 (1.3)	1 (1.4)	0 (0)	0.750
GOS post craniectomy, *n* (%)				
2	11 (14.3)	11 (15.7)	0 (0)	0.257
3	20 (26.0)	17 (24.3)	3 (42.9)	0.285
4	26 (33.8)	24 (34.3)	2 (28.6)	0.761
5	20 (26.0)	18 (25.7)	2 (28.6)	0.869
Implant, *n* (%)				
Autologous bone	70 (90.9)	64 (91.4)	6 (85.7)	0.616
PMMA	4 (5.2)	3 (4.3)	1 (14.3)	0.256
Titanium	3 (3.9)	3 (4.3)	0 (0)	0.576
Median size of cranial defect, cm^2 (IQR)	85.0 (53.4–96.3)	79.9 (51.5–96.0)	95.5 (66.8–103.8)	0.234
Median time from craniectomy to cranioplasty, days (IQR)	63 (41–92)	62 (41–92)	47 (32–88)	0.518
Median follow-up, months (IQR)	24 (13–38)	24 (13–37)	33 (4–46)	0.352

Abbreviations: GOS, Glasgow Outcome Score; IQR, interquartile range; ICH, intracerebral hemorrhage; PMMA, polymethylmethacrylate; VPS, ventriculo-peritoneal shunt.

(1/77, 1.2%), and seizures (3/77, 3.9%). The complication of exposed implant occurred as early as 29 days and as late as 21 months post cranioplasty. There were no mortalities related to cranioplasty. The overall cranioplasty failure rate was 9.1% (7/77). The 30-day and 1-year failure rates were 3.9% (3/77) and 5.2% (4/77), respectively.

Factors Affecting Cranioplasty Complications and Failure

Multivariate analysis did not show any factors that were associated with cranioplasty complication. However, previous cranial site infection post craniectomy was associated with cranioplasty failure (OR 12.2, 95% CI [1.3, 114.0], $p = 0.028$).

Organisms Isolated from Exposed/Infected Implants

Methicillin resistant *Staphylococcus aureus* was the most common organism grown from the exposed/infected implants. Other organisms included *Staphyloccoccus aureus*, coagulase-negative staphylococci and *Klebsiella pneumoniae*.

Discussion

In this study, the combined cranioplasty complication rate of 15.6% is comparable to prior findings in the literature involving the use of autologous bone, PMMA, and titanium.[5–9] This supports the current view that cranioplasty, although not a technically demanding procedure, is associated with higher rates of postoperative complications compared with other elective cranial surgeries.[10]

The overall infection rate reported in this study was 3.9%. Van de Vijfeijken et al reported an overall complication rate of 5.6% across all types of materials in their systematic review.[11] The infection rate of 4.3% in our heterogenous cohort of patients who underwent autologous bone cranioplasty was also reported. Previous studies in autologous bone cranioplasty have shown variable infection rates, ranging from 0% to 25.9%.[10,12–19] However, pooled data analysis showed the infection rate of autologous bone was 8% and it did not exhibit an increase in infection rates compared with synthetic materials (hand-molded PMMA and prefabricated PMMA, 12%; PEEK, 5%; hydroxyapatite, 6%; and titanium, 8%).[20] This is important to lower- to middle-income countries, where autologous bone cranioplasty remains the most viable option to lower healthcare cost.

Seven out of 77 cranioplasties had complications (infection, implant exposure, implant dislodgement, and resorption), which required either removal or revision surgeries resulting in an implant failure rate of 9.1%. Implant exposure remains an issue in cranioplasty. Among the different materials, titanium has been found to be strongly associated with the highest rate of wound complication.[20,21] Titanium-related implant exposure was reported to occur as a result of an inflammatory process, particularly in patients with metal hypersensivity,[22] whereas implant exposure in autologous bone is usually a result of mechanical skin erosion by fixation implants.[7] In addition, scalp atrophy can worsen over time and contribute to the thinning of the previously operated scalp flap over the implant. Therefore, survivability of the cranioplasty implant can decrease over time (►**Fig. 1**), and the long-term follow-up to detect this potentially slowly progressing complication is vital.

Bone resorption is a well-known complication exclusive to autologous bone cranioplasty. It has been reported to occur in 7.2% to 50% of autologous bone cranioplasty.[1] Factors increasing the risk of bone resorption include multiple fractures, bone fragmentation, large craniectomy defect, younger age, and the presence of ventriculoperitoneal shunts.[23–25] The low rate of resorption (1.3%) in this study was an unexpected finding. This complication is likely to be under-reported in our cranioplasty cohort. As bone resorption is a non-linear process that may require reoperation to replace the implant, regular and long-term outpatient follow-up to assess for mechanical stability is recommended.

Our study found that previous cranial site infection post craniectomies was associated with cranioplasty failure. Time interval between craniectomy and cranioplasty was shown to not affect complication and failure outcomes in our cohort of patients. Schuss et al reported that early cranioplasty, the

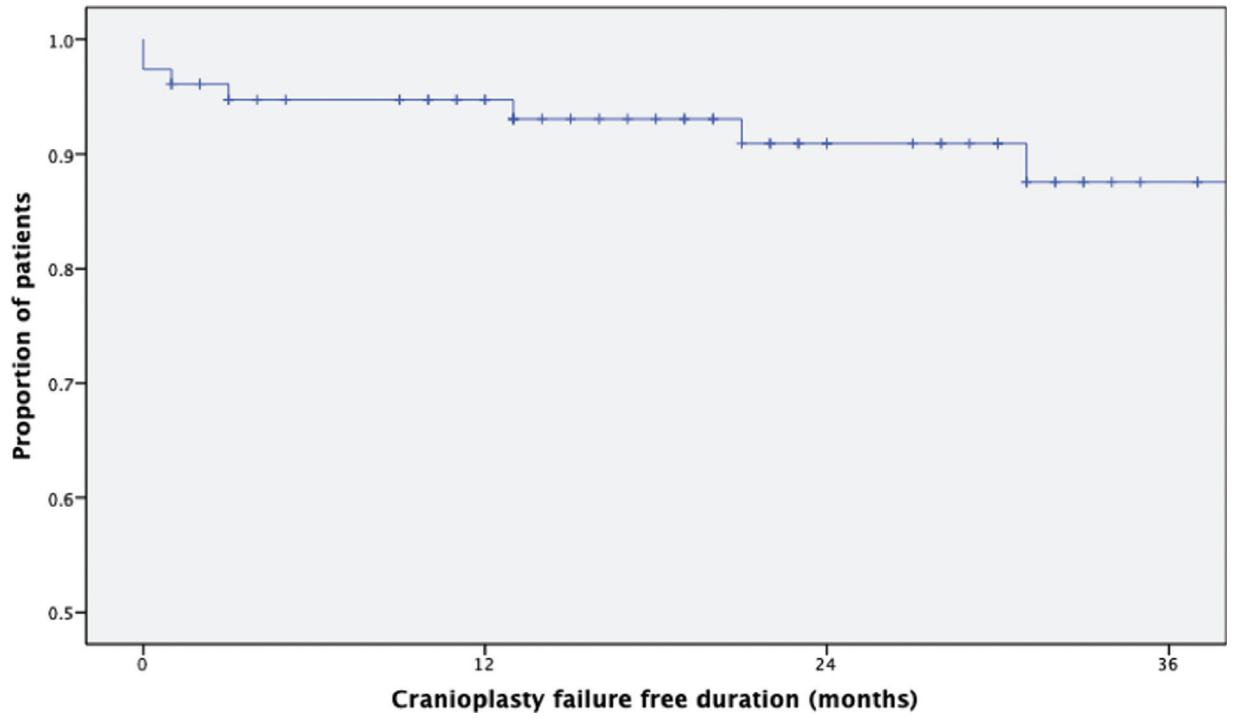

Fig. 1 Kaplan–Meier graph showing cranioplasty survival over time.

presence of ventriculoperitoneal shunt, and primary indication for decompressive craniectomy of intracerebral hemorrhage were significant associations for the occurrence of postoperative complications after cranioplasty.[26] Cranioplasty infection rates were also shown to be predicted by the occurrence of reoperation and indication of decompressive craniectomy for stroke.[27] However, there is currently limited evidence in the literature to consistently predict the risks of complications and failure.[28–35] Therefore, clinical judgement on a case-by-case basis is suggested.

In our practice, each patient is assessed clinically and radiologically for the resolution of cerebral edema and any active medical issues that may contradict the procedure, in particular infection, to ensure that cranioplasties may be performed as early as possible. Autologous bone that has been cryopreserved or stored in subcutaneous abdominal pockets are used as the first option due to our relatively low infection rate, ease of availability and it being economical as there is no further cost. Although cranioplasties are usually performed within 6 to 8 weeks from the craniectomy, we do not set a strict arbitrary time window as we found that the timing of cranioplasty did not affect the complication and failure rates. However, we tend not to perform surgery too early to allow healing of soft tissues adjacent to the craniectomy defect and avoid operating on a potentially contaminated wound, as well as, to maximize neurorehabilitation during the acute phase. At the same time, we also must balance these factors against the reduced viability of the bone flap after prolonged storage. Lastly, we believe that care taken in the initial craniectomy to ensure optimal wound healing and complication prevention, combined with meticulous surgical dissections and closure under non-tension during cranioplasty, should be taken into upmost consideration.

Limitations

This was a retrospective study and was subject to shortcomings commonly related to this format including loss of patient data and inadequate assessment on follow-up, particularly in the assessment for bone resorption. Moreover, these results represent only a single department experience. However, our standardized surgical approach and centralized nature of the neurosurgical service, which enables identification late complications, may outweigh our shortcomings.

Conclusion

Our study characterized the complication and failure rates and outcomes of patients who underwent cranioplasty in Brunei Darussalam. It highlighted that autologous bone cranioplasty can be performed with an acceptable low rate of infection, making it a viable first option for implant material. However, cranioplasty in general is associated with significant complications, including the necessity for reoperation for implant failure. There are currently no guidelines or established best practices so good clinical judgement on a case-by-case basis is important in influencing a positive outcome post cranioplasty.

Note
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None.

Conflict of Interest
None declared.

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