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Clinical Study

Complications of post-craniectomy cranioplasty: Risk factor analysis and implications for treatment planning

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ABSTRACT

The aim of this study was to review all post-craniectomy cranioplasties performed in a single institution, with an emphasis on procedure-related complications and risk factor analysis. Post-craniectomy cranioplasty is known to be associated with significant complications. Previous studies on predictors of complications have yielded conflicting results. We conducted a retrospective study on prospectively collected data on all cranioplasties done between 1 January 2003 and 31 December 2012. Multivariate analysis was performed to interrogate potential risk factors predisposing to procedure-related complications. Of the 162 procedures, the overall complication rate was 16.7%. Infection and flap depression occurred in 13 (8%) and five patients (3.1%), respectively. These led to reoperations in 12 patients. The presence of a ventriculoperitoneal shunt during cranioplasty was the only significant factor associated with a higher rate of infection (28.6% *versus* 9.7%, $p = 0.001$) and flap depression (14.3% *versus* 3.3%, $p = 0.03$). Indications for the initial craniectomy, choice of graft materials and the time interval between craniectomy and cranioplasty had no significant association with complications. The presence of ventriculoperitoneal shunt at the time of cranioplasty is a significant risk factor for cranioplasty complications. Early cranioplasty is safe. Whether temporizing lumbar or external ventricular drainage is a better alternative to shunting in patients who are drainage-dependent at the time of cranioplasty remain to be determined.

1. Introduction

Decompressive craniectomy (DC) is performed increasingly in patients with refractory intracranial hypertension resulting from traumatic brain injury or cerebrovascular diseases [1–3]. The resultant skull defect prompts subsequent cranioplasty for cosmesis, mechanical protection and potential improvement in intracranial haemodynamics [4,5].

Post-DC cranioplasty, however, is known to be associated with complication rates as high as 40% [4,6–9]. Infection is a particular concern and may result in additional morbidities and mortalities, prolonged hospital stays and increased costs [10,11]. Information on predisposing factors is therefore critical for better treatment planning but previous studies have yielded controversial findings [4,10–13]. For instance, Thavarajah et al. found early cranioplasty to be associated with infection [14] while others considered that it may reduce the risk of flap contamination [11]. Similar controversies exist in the choice between autograft and prosthetic flaps [9], as well as the optimal method of bone flap storage [15]. Our study aimed to review all post-DC cranioplasties performed in a single institution with a view to identify complications and their predisposing factors.

2. Methods

2.1. Study design

We conducted a retrospective study of prospectively collected data on consecutive post-DC cranioplasties performed at a University Teaching Hospital between 1 January 2003 and 31 December 2012. Univariate and multivariate analyses were completed to explore factors associated with complications.

2.2. Clinical management

All procedures were performed as elective operations in neurologically stable patients whose intracranial hypertension had resolved and who were free from local or systemic infection. During the study period there was no specific protocol for the

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timing of cranioplasty (early *versus* late). Autologous bone graft was used whenever available. Bone flaps were cryo-preserved in the hospital bone bank after DC and were immersed in povidone-iodine solution for 30 minutes before replacement. When no bone graft was available, for example, when a patient was transferred from other institutions, acrylic or titanium plate was used. Prophylactic intravenous cefazolin (2 g) was given on induction.

2.3. Data collection and statistical analysis

The complications investigated included death, cranioplasty infection, flap depression, new onset of neurological deficit and other unanticipated events. Infection was defined as osteomyelitis of the bone flap and/or central nervous system infections. Flap depression was defined as clinically evident depression over the cranioplasty site which persisted for over 3 months. Neurological deficit was defined as any new onset of focal neurological deficit, or seizure in patients who had no prior attacks following DC. Other complications included new onset of headache, urinary incontinence without other identifiable cause and wound problems such as dehiscence and delayed exposure of implants.

Risk factor analysis was performed on variables including age, sex, comorbidities, indication for craniectomy, interval between DC and cranioplasty, and the presence of ventriculoperitoneal (VP) shunt during cranioplasty. Non-parametric variables and counts of complications were constructed into contingency tables with hypothesis testing by analysis of variance, Pearson's chi-squared test or Fisher's exact test. SPSS Statistics (version 21; IBM, Armonk, NY, USA) was used for analysis. Level of significance was set at $p < 0.05$.

3. Results

3.1. Patient demographics

Our study includes 162 patients with a mean age of 49.3 years (range, 8–93 years). The male to female ratio was 1.7 to one. Autologous bone flap was used in 106 patients (65.4%) and the rest were acrylic or titanium flaps. The mean interval between DC and cranioplasty was 162 days (range, 15–1140 days). The indications for craniectomy were cerebrovascular diseases in 43.8%, traumatic head injuries in 42%, infections in 9.3% and tumours in 4.9% of patients. The mean follow-up duration was 57.6 months (range, 6–125 months). Detailed demographics are described in Table 1.

3.2. Complications

The overall complication rate was 16.7%. Cranioplasty infection and flap depression occurred in 13 (8.0%) and five (3.1%) patients, respectively, leading to 12 (7.4%) reoperations. Five patients (3.1%) developed new neurological deficits including three with seizures and two with reduced conscious levels. Headache and urinary incontinence without other identifiable cause occurred in one patient each. Poor wound healing with delayed exposure of implants occurred in two patients.

3.3. Risk factor analysis

Risk factor analysis with multivariate logistic regression was performed (Table 2). Presence of a VP shunt during cranioplasty was associated with both infection (odds ratio 14.7; 95% confidence interval [CI] 3.02–78.5; $p = 0.001$) and flap depression (odds ratio 7.6; 95% CI 2.89–168.8; $p = 0.03$). Flap material and time interval since DC did not predict complications. Further analysis on selected risk factors is described in the following sections.

Table 1
Cranioplasty patient demographics

Characteristics (parametric)		
Age (years)		
Mean ± SD	49.3 ± 15.3	
Interval between craniectomy and cranioplasty (days)		
Mean ± SD	162 ± 170.5	
Characteristics (non-parametric)	Frequency (n)	Percentage (%)
Sex		
Male	102	63.0
Female	60	37.0
Comorbidities		
Hypertension	27	16.7
Diabetes mellitus	10	6.2
Indications for craniectomy		
Cerebrovascular disease	71	43.8
Traumatic head injury	68	42.0
Infection	15	9.3
Tumor	8	4.9
Material of flap		
Autologous	106	65.4
Prosthetic	56	34.6
VP shunt during cranioplasty		
Present	21	13.0
Absent	141	87.0

SD = standard deviation, VP = ventriculoperitoneal.

3.4. Presence of VP shunt during cranioplasty

A comparison between patients with (n = 21) and without (n = 141) VP shunt *in situ* during cranioplasty showed that the former group had a significantly higher rate of infection (28.6% *versus* 9.7%; $p = 0.001$) and flap depression (14.3% *versus* 3.3%; $p = 0.03$). This was found to be an independent risk factor on multivariate analysis (Table 2). Amongst the six patients with shunts during cranioplasty and later complicated by infection, one was successfully treated with intravenous antibiotics only. The remaining five patients required temporary externalisation with a ventricular drain and subsequent revision cranioplasty. Of note was that only three of these five patients were found to be shunt-dependent after the resolution of infection. None of the patients who were shunt-free at the time of cranioplasty required subsequent cerebrospinal fluid (CSF) diversion.

3.5. Indications for the initial craniectomy

A high infective complication rate (20%) was found in patients who underwent DC due to infection. Despite a significantly longer interval between craniectomy and cranioplasty in these patients and those who underwent craniectomy for other pathologies (mean 274 days *versus* 159 days, respectively; $p = 0.01$), the infective complication rate was higher in the former group (20% *versus* 6.8%; $p = 0.07$), although the difference did not reach statistical significance (Table 3). Amongst the three patients in the post-infective group, two had the same microorganisms as the initial infection (methicillin-resistant *Staphylococcus aureus* and methicillin-sensitive *S. aureus*), while one had a shift from mixed infection by methicillin-resistant *S. aureus* and *Pseudomonas aeruginosa* to coagulase negative *Staphylococcus*.

3.6. Interval between craniectomy and cranioplasty

All patients were divided into three groups according to the time interval between craniectomy and cranioplasty. Sixty (37.0%) patients had cranioplasty within 90 days, 50 (30.9%) between 91 and 180 days, and 52 (32.1%) after 180 days. The infection rates in these three groups were 6.7%, 8.0% and 9.6%,