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CASE REPORT

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Bilateral Cranioplasty in Severe Acquired Brain Injuries. Techniques, Outcomes, and Clinical Case Report

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ABSTRACT

Bilateral cranioplasty is a complex neurosurgical procedure performed to reconstruct or repair cranial defects involving both hemispheres of the skull. Indications include trauma, decompressive craniectomy, infection, tumor resection, or congenital anomalies. Recent advances in biomaterials and surgical planning have improved outcomes, yet bilateral cases remain challenging due to larger defect size, risk of complications, and the need for precise symmetry. This article reviews current techniques, materials, clinical outcomes, and complication management in bilateral cranioplasty.

ARTICLE HISTORY

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KEYWORDS

Bilateral Cranial Defect, Cranioplasty, Custom-Made Implant, Titanium, PEEK, Surgical Outcomes, Complications

Abbreviations

3D: Three-Dimensional

CP: Cranioplasty

DC: Decompressive Craniectomy

PEEK: Polyetheretherketone

PSI: Patient-Specific Implant

CT: Computed Tomography

CSF: Cerebrospinal Fluid

Introduction

Cranioplasty is a restorative surgical procedure aimed at reconstructing cranial defects for protection, cosmetic restoration, and neurological recovery. Bilateral cranial defects, though less common than unilateral ones, present unique challenges due to the extent of bone loss, increased risk of complications, and the technical demands of achieving both functional and aesthetic restoration. The main indications for bilateral cranioplasty include severe traumatic injuries, gunshot wounds, failed previous cranioplasties, and decompressive craniectomies performed for refractory intracranial hypertension. Cranioplasty (CP) is the main reconstructive procedure in neurosurgery, performed in approximately 80% of patients who have undergone procedures such as the removal of neoplastic masses or large hematomas responsible for increased intracranial pressure (ICP). Reconstruction is performed by inserting an autologous bone implant or a customized prosthetic device. Cranioplasty restores the anatomical integrity of the skull but can also improve neurological function. In literature, it has been shown that this procedure can contribute to the recovery of motor and cognitive functions, including memory, attention and executive functions. In any case, it is a reconstructive procedure that is always preferable to perform to prevent trephine patient syndrome, restore correct intracranial pressure and allow better management of decubitus ulcers.

Surgical Techniques and Materials

Modern bilateral cranioplasty utilizes a range of surgical approaches and implant materials.

Custom Made 3D Titanium Implants

Recent studies have demonstrated the feasibility and safety of simultaneous closure of bilateral cranial defects using custom-made three-dimensional (3D) titanium implants. These implants are designed based on preoperative imaging and manufactured to fit each patient's unique anatomy, offering superior contouring and stability. In a series of 26 patients, the mean defect area was substantial (right: 35.0 ± 19.03 cm^2; left: 29.24 ± 22.51 cm^2), with etiologies including trauma and gunshot wounds. Postoperative complications were minimal, with no mortality reported.

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Modified Bilateral Pi Craniectomy

For reduction cranioplasty in cases such as hydrocephalic macrocephaly, a modified bilateral Pi craniectomy can be employed. This technique involves anterior coronal and posterior lambdoid bone cuts, with bilateral peninsular bone flaps reduced medially and the sagittal suture de-roofed. The reconstructed skull is stabilized with metal meshes. This approach allows for controlled bone resection and avoids risky posterior skull reconstruction, which is especially beneficial in patients with a flat occiput.

Material Selection

Besides Titanium, Polyetheretherketone (PEEK) and autologous bone grafts are commonly used. Comparative studies indicate that PEEK may have lower rates of certain complications, such as pneumocephalus and epidural effusion, compared to titanium mesh, although overall complication rates are similar6. Autologous bone remains the first choice when feasible, but prosthetic materials are preferred in cases of large or complex defects.

Clinical Outcomes

Neurological and Cosmetic Results

Long-term studies indicate that cranioplasty, including bilateral procedures, can result in favorable neurological outcomes and high patient satisfaction regarding cosmetic appearance. In a cohort of 202 patients, 42.6% achieved a favorable neurological outcome, and 86.5% were satisfied with the cosmetic result. Quality of life improvements are also reported, although outcomes may vary depending on the underlying etiology of the cranial defect4.

Complication Rates

Bilateral cranioplasty is associated with higher rates of complications compared to unilateral procedures. Common complications include wound dehiscence, cerebral edema, implant infection or failure, and subcutaneous effusion. Careful preoperative planning, precise surgical technique, and appropriate implant selection are critical to minimizing risks.

Clinical Case Report

The primary objective of this case report is to analyze the cognitive profile, motor and functional performance of a patient with Severe Acquired Brain Injury (GCA) undergoing bilateral CP. Secondary objective was to evaluate the caregiver's compliance in achieving one of the objectives of the Individual Rehabilitation Project (PRI), namely returning home.

Materials and Methods

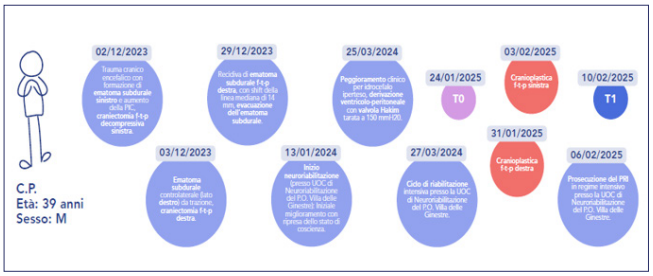

Figure 1: C.P. Age 31 Gender M. 23/02/12. Cranial-encephalic trauma with left subdural hematoma and increased ICP, left full-thrombotic decompressive craniectomy.

23/03/12. Contralateral (right side) subdural hematoma from traction, right f-t-p craniectomy.

23/29/12.Recurrence of right f-t-p subdural hematoma, with 14mm midline shift, evacuation of the subdural hematoma.

24/13/01.Start of neurorehabilitation (at the Neurorehabilitation Unit of the Villa delle Ginestre Hospital): Initial improvement with recovery of consciousness.

24/25/03. Clinical worsening due to hypertensive hydrocephalus, ventriculoperitoneal shunt with Hakim valve set at 150 mmH20.

24/27/03. Intensive rehabilitation cycle at the Neurorehabilitation Unit of the Villa delle Ginestre Hospital.

25/24/01. T0

25/31/01. Right F-T-P cranioplasty

25/03/02. Left F-T-P- cranioplasty

25/06/02. Continuation of the individual rehabilitation project in intensive care at the Neurorehabilitation Unit of the Villa delle Ginestre Hospital.

25/10/02 T1

"Assessment Performed at T0 and at T1: Levels of Cognitive Functioning (LCF); Coma Recovery Scale-Revised (CRS-R); Glasgow OutcomeScale-Extended (GOSE); Rehabilitation Complexity Scale-Extended (RCS-E); Barthel Index (BI)".

T1: interview with the caregiver, discussion on the continuation of the rehabilitation process.

At T1, an interview was conducted with the caregiver and the multidisciplinary team to establish the continuation of the process: the caregiver's compliance was found to have increased in relation to the possibility of managing the patient at home.

Results

Figure 2: The Table in Figure 2 Shows the Results of the Scores on the Assessment Scales Used.

LCF: Levels of Cognitive Functioning.

GCS: Glasgow Coma Scale.

CRS-r: Coma Recovery Scale Revised.

GOSE: Glasgow Outcome Scale Extended.

RCS-e: Rehabilitation Complexity Scale Extended.

BI: Barthel Index.

Discussion

Bilateral cranioplasty requires a multidisciplinary approach, integrating neurosurgical expertise, advanced imaging, and collaboration with biomedical engineers for custom implant design. The choice between simultaneous and staged reconstruction should be individualized based on patient factors and defect characteristics. Advances in 3D printing and biomaterials have significantly improved the precision and safety of these procedures.

Although no improvement in the cognitive profile, motor performance and functional performance assessed using different rating scales has yet been highlighted, cranioplasty has certainly played a fundamental role in increasing caregiver compliance in relation to the possibility of managing the patient at home and consequently making it possible to achieve one of the objectives set in the PRI, namely returning home. The evaluation performed at T0 and T1 will be performed 2 months after cranioplasty to evaluate any changes over time in the cognitive, motor and functional profile and the possible appearance of complications [1-22].

Conclusion

Bilateral cranioplasty is a feasible and increasingly safe procedure for the reconstruction of extensive cranial defects. Custom-made implants, particularly 3D-printed titanium or PEEK, offer excellent anatomical restoration and functional outcomes. Meticulous preoperative assessment and surgical planning are essential to reduce complications and optimize patient recovery.

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