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Original Article

New technique for surgical decompression in traumatic brain injury: merging two concepts to prevent early and late complications of unilateral decompressive craniectomy with dural expansion

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Abstract: Introduction: Decompressive craniectomy (DC) in severe traumatic brain injury (TBI) is associated with acute and late complications. To avoid these complications, we proposed a technical modification in DC. In this paper analyze a series of patients underwent to surgical treatment for acute subdural hematoma (ASDH). Methods: We perform a prospective cohort with TBI patients undergoing DC for treatment of diffuse hemispheric brain swelling and ASDH. The effect of modified craniectomy was assessed using postoperative CT. Clinical outcome was evaluated at ICU mortality in 2 weeks. Results: Comparing the CT scans before and after surgery, the midline shift decreases from median of 11 mm to 5.5 mm (P<0.001). Only one patient had presented uncontrolled intracranial hypertension after surgery. Postoperative mortality in the intensive care unit within 14 days was 48.8%. Conclusion: this is an interesting technical modification. In this pilot study, we observed ICP control, avoiding the complications of classical decompression.

Keywords: Traumatic brain injury, subdural hematoma, decompressive craniotomy

Introduction

Severe traumatic brain injury (TBI) management over the years has been disappointing despite the progress and development of intensive care units and new surgical techniques. The unilateral decompressive craniectomy has been held as a potential savior procedure and remains in evidence since 1971, when Ransohoff et al [1] achieved mortality reduction from 80-90% to 60% for acute subdural hematoma (ASDH) patients undergoing surgery. However, this procedure is associated with several acute and late complications [1-4]. To avoid early and late complications produced by decompressive craniectomies (DC) in severe TBI, mainly subdural hematoma and diffuse injury, current literature suggests modifications in surgical techniques in the acute phase, such as durotomy instead of conventional dural opening and preservation of bone flap [5-7]. Some authors consider that brain herniation through the craniectomy is partly responsible for the poor prognosis in severe TBI patients, despite ICP reduction achieved by the craniectomy and conventional dural opening [8, 9]. Burger et al [5] described a technique where the dura was opened by three to four durotomies from midline to the temporal base. Also, Alves and Bullock [6] described the "Basal durotomy" to prevent massive intraoperative swelling. Aiming to preserve the bone, Tucci et al [7] described a technique where the bone flap is replaced and fixed only in the frontal region. Ko et al [10] described a craniectomy (in situ hinge craniectomy), fixing the bone in the temporal region, including patients with stroke and head trauma. Therefore, we propose a modification of the traditional decompressive craniectomy merging these two concepts: durotomies and bone preservation to control intracranial pressure but avoiding acute and

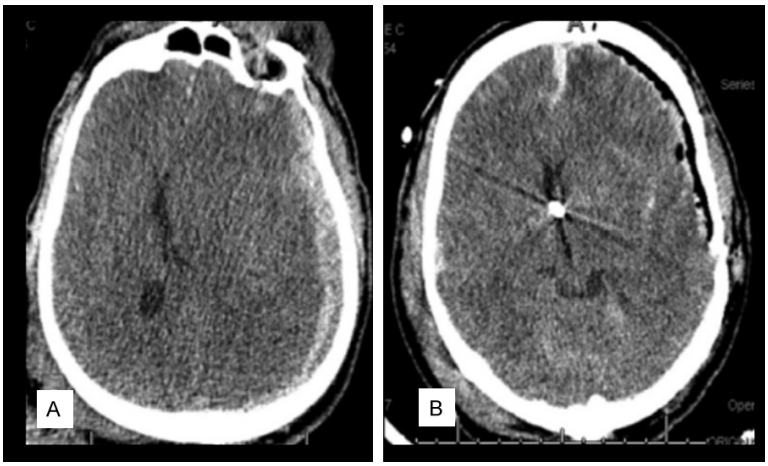

Figure 1. Head CT of a 46 years-old male patient, victim of car accident, admitted with 7 points on the Glasgow Coma Score, anisochoric pupils (left > right). A: Preoperative CT. B: Postoperative CT with improvement in midline shift.

late complications. We performed modified Burger type durotomies, in which three to four durotomies are performed from midline to the projection of sylvian region and one or two durotomies are performed parallel to the projection of the temporal gyri. The durotomies were covered by the galea to avoid CSF leak. The preservation of the bone was based on Tucci's technique, replacing the bone but fixing it only superiorly along the sagittal line, allowing for expansion of the temporal portion of the bone flap and brainstem decompression. In this paper, we describe a cohort of patients with ASDH and brain swelling in which this technique was used for hematoma treatment, decompression and ICP control.

Methods

Study population

We performed a prospective cohort study with severe TBI patients undergoing decompressive craniectomy for treatment of diffuse hemispheric brain swelling and ASDH. All patients underwent modified cranial decompression for treatment of malignant intracranial hypertension.

Setting

All patients included in the study had our hospital as initial care center, a level I trauma center, located in the largest city in South America. All patients underwent neurosurgical examination, cervical spine and plain chest radiography, as well as head computed tomography (CT). During this period, 2241 trauma patients were admitted and, of these, 587 had severe TBI. Excluded from the study were those with prior neurological disorders, diuretics use, major systemic trauma associated with important blood loss and hemodynamic instability and those with midline shift smaller than subdural thickness.

Technique

The modified vertical linear durotomies (one or two frontal and two parietal, approx. 5 cm) and horizontal durotomies (two temporal, approx. 5 cm). Autologous tissue of subgaleal on durotomies, hermetic suture with prolene 4.0 points in separate, in order to avoid direct contact of the cerebral cortex with bone flap or cerebrospinal fluid fistula. Modified hinge craniotomy 12 cm in diameter in the major axis with fixing the bone flap in three frontoparietal points with mononylon 2.0 wires (**Figures 1** and **2**).

Outcomes

The effect of the modified technique was assessed by imaging (midline shift improvement) and clinical (ICP control rate and 14-day mortality) outcomes. The institution ethics committee approved the study protocol.

Results

The sample is composed of 43 patients with a mean age of 45.9 ± 20.1 years and 35 (81.4%) were male. The most common mechanism was traffic accident (69.8%). All patients were admitted between 30 minutes and 6 hours after trauma, 22 had isochoric pupils, 18 had unilateral anisochoric pupil and three had ocular trauma that did not allow evaluation. Midline shift in the initial CT was less than 5 mm in 11.6%, 39.5% ranged from 5 to 10 mm and 48.8% had more than 10 mm deviation. The volume of the hematoma was less than 30 ml in 30.2% of the patients, between 30 and 50

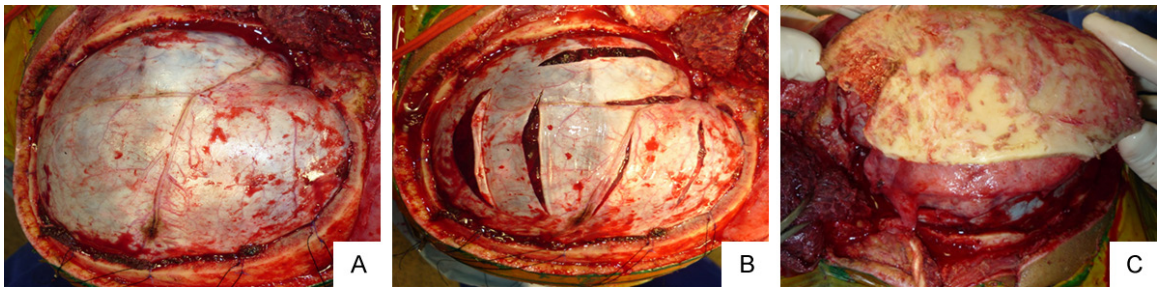

Figure 2. Proposed surgical technique modification. A: Large fronto-temporo-parietal craniotomy. B: Linear durotomies to allow brain expansion and evacuation of the hematoma. C: Replacement of the bone flap, to be fixed only on the frontal bone to allow post-operative brain expansion.

Table 1. Traumatic brain injury sample characterization, complications and outcomes (n=43)

Variables	n (%)
Male gender	35 (81.4)
Trauma mechanism	
Traffic accident	35 (69.8)
Aggression	10 (23.3)
Fall from height	5 (7.0)
Hematoma volume	
< 30 ml	13 (30.2)
30-50 ml	18 (41.9)
> 50 ml	12 (27.9)
Midline shift	
< 5 mm	5 (11.6)
5-10 mm	17 (39.5)
> 10 mm	21 (48.8)
Complications	
Infection	2 (4.7)
Hemispheric edema	1 (2.3)
Postoperative epidural hematoma	1 (2.3)
Contralateral hematoma	1 (2.3)
Outcomes	
ICP control	42 (97.7)
ICU 14-day mortality	21 (48.8)

ICP: Intracranial pressure; ICU: Intensive care unit.

ml in 41.9% and more than 50 ml in 27.9% (**Table 1**).

Operation was performed in less than 4 hours in eight cases, from 4 to 6 hours in ten and more than 6 hours in 25 patients. Comparing the CT scans before and after surgery, the midline shift decreased from a median of 11 mm to 5.5 mm ($P < 0.0001$) (**Figure 3**). ICP was controlled on all patients but one (97.7%) and the ICU 14-day mortality was 48.8%.

We observed complications in 5 patients: 2 surgical site infections (with removal of bone flap), 1 with progressive hemispheric edema (with removal of bone flap), 1 postoperative ipsilateral epidural hematoma and 1 contralateral subdural hematoma. ICP was controlled on all patients but one (97.7%) and the ICU 14-day mortality was 48.8%.

Discussion

Decompressive craniotomy is considered a second-tier therapy on the Brain Trauma Foundation guidelines and, according to the European Brain Injury Consortium, the final therapy level to control intracranial hypertension. A well-defined threshold to indicate the decompression does not exist. Several studies indicate that dural opening is crucial for an effective ICP reduction and there are many techniques available [11].

The duraplasty has some major disadvantages such as increased surgical time, parenchymal hemorrhage (41.6%), infarcts adjacent to the craniectomy limits (28.4%) and rapid brain expansion [4]. Burger et al [5] proposed linear durotomies associated with DC. Burger et al [5] described mean ICP decrease by 44% after removal of the bone flap and another 26% after the durotomies. Within 24-72 h after DC, the ICP became stable (< 20 mmHg). In this study, 3-4 durotomies were performed and allowed removal of any subdural or parenchimal hematoma. Besides, the duration of surgery was around 90 minutes, which is shorter than classic DC with duraplasty. Thus, preliminary results indicate that this technique has the potential to overcome the disadvantages of craniectomy with conventional duraplasty. Guilburg and Gil [12] advocate that ASDH requiring DC has high-

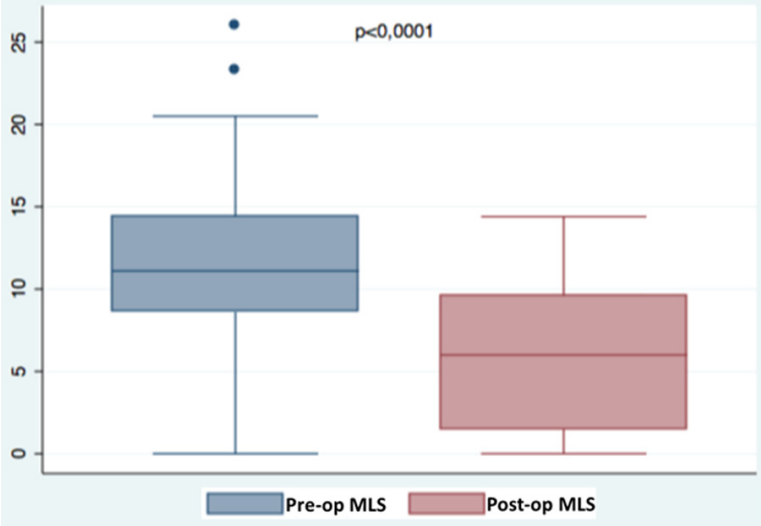

Figure 3. Preoperative (median 11 mm) and postoperative (median 5,5 mm) midline brain shift (MLS).

er mortality and poor functional recovery. So far, these patients are undergoing early surgical decompression and intensive care management. One of the factors contributing to the deterioration can be the rapid surgical decompression leading to extrusion of the brain through the bone defect and secondary axonal lesion. To avoid the adverse effect of decompression and abrupt disruption of brain tissue, Guilburg and Gil [12] have adopted a new technique for removal of ASDH, especially when the midline shift was greater than the thickness of hematoma. Their results showed lower mortality and good functional recovery using this technique. In 2012, Feng [13] demonstrated in a comparative study between craniotomy with classic durotomy and lattice durotomy that the latter method had better results in the prevention of cerebral herniation and avoidance of encephalomalacia, without worsening cerebral perfusion. On the other side, there was significant worsening infusion herniated tissue via the classical craniectomy, as measured by common CT perfusion and CT 3 weeks after surgery.

Kano et al [14], using hinge craniotomy technique, a modification of DC, shown in a retrospective study of patients operated from 2004 to 2011 that this technique allows proper and safe control of ICP in both TBI and stroke, allowing skull expansion in response to brain swelling.

None of these studies put together these two concepts of 1) linear durotomies and 2) hinge craniotomy, as a way to prevent herniation and extrusion of brain tissue and, consequently, to prevent the complications of acute and chronic bone defect [18]. In our study, we merge these concepts with some technical modifications: 3-4 longitudinal durotomies in the frontal and parietal region and 1-2 durotomies in the temporal region. We believe that with this modification we can avoid sudden cerebral herniation and allow decompression of the brainstem. The second modification was the replacement of the bone flap, similar to studies of Goettler and Tucci [7] and Ko & Segan [10]. However, we propose to fix the bone flap in the upper region (next to the sagittal suture) which allows gradual expansion of the temporal lobe, avoiding the need for subsequent cranioplasty.

In our series, we observed a mortality rate of 48.8%, which is not unexpected considering patients' severity. Stone et al [15] studied 206 surgical patients with ASDH and they described a mortality up to 62%. Haselsberger et al [17] studied a large patient series with ASDH finding an overall mortality of 57%. Seelig et al [15] using the conventional technique reported a mortality up to 95% in patients with ASDH depending on the time between trauma and surgery.

This is an interesting surgical technique modification, aiming ICP control and avoiding acute and late complications. We observed similar results in mortality compared to series using the so-called standard technique of decompression in severe TBI with satisfactory ICP control rates. However, randomized clinical trials are still needed to draw more definite conclusions.

Disclosure of conflict of interest

None.

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