ORIGINAL ARTICLE
https://doi.org/10.1590/1806-9282.20210139

Decompressive hinge craniectomy with linear durotomies for ischemic stroke: a pilot study

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SUMMARY

OBJECTIVE: Decompressive craniectomy may be a life-saving measure in ischemic stroke patients, who still have several associated complications. The objective of this study is to evaluate a novel decompressive surgery technique for severe hemispheric ischemic stroke.

METHODS: For the hinge decompressive craniectomy (HDC), linear durotomies were performed. Vertical (one or two frontal and two parietal), and two horizontal (temporal), with approximately 5 cm long, linear durotomies were carried out. Duroplasty was performed using an autologous subgaleal tissue graft fixed with separate sutures to avoid CSF leak and direct contact of the cortex with the bone flap. The bone flap was fixed in three parietal locations. We compared 10 patients who underwent our modified HDC with 9 patients submitted to classical decompressive craniectomy (CDC). The primary outcome of this study was mortality.

RESULTS: Nineteen patients were included, with a mean age of 52.3 years (±8.2). Four (44%) patients from the HDC group had to be reoperated to remove the bone flap because of brain swelling worsening, but none of them died. The average time of HDC was 90 minutes. Overall 14-days mortality was 21.1% (n=4), and cumulative six-months mortality was 42.1% (n=8). Five (50%) patients submitted to CDC died, while 3 (33.3%) submitted to HDC died (χ^2=0.07, p=0.79). The mean length of stay was 46.7 days (±32.1) for HDC and 38.7 (±27.1) for CDC (p=0.60).

CONCLUSIONS: We present a modified technique of hinge craniectomy with linear vertical and horizontal durotomies, which seems to have reduced operative time and mortality compared to classical decompressive craniotomy, although the difference was not statistically significant.

KEYWORDS: Craniectomy. Stroke. Intracranial hypertension.

INTRODUCTION

Strokes that affect over 2/3 of a hemisphere, or malignant infarctions, are relatively rare, representing 1 to 10% of all supratentorial ischemic strokes (IS). However, they are associated with extremely high mortality rates, sometimes up to 80%[1]. Given the prevalence of IS, any therapeutic advances in this area would have a significant impact on our population.

The indications, timing, and technique of decompression for refractory intracranial hypertension (rIH) after IS are still controversial. Amorim et al. described the role of surgical decompression in the reestablishment of blood flow to the penumbra area and fluid distribution in the ischemic zone[2].

Although CDC is widely accepted for treating rIH, it is associated with significant morbidity, including the postoperative risk of seizures, hydrocephalus, infection, and progression of preexisting hematomas. Furthermore, it later requires a cranioplasty or a second surgical procedure to reimplant the bone graft.

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Conflicts of interest: the authors declare there is no conflicts of interest. Funding: none.
Received on February 12, 2021. Accepted on March 14, 2021.

New techniques have been developed, including different dural opening patterns and hinge-like craniectomies, and both the replacement of wide duroplasty with durotomies and the substitution of CDC with hinge-like techniques have proven effective[3-9]. However, these two emerging concepts have not yet converged in a single model to prevent early and late complications associated with unilateral decompressive craniectomy with dural expansion.

We have previously described a hinge craniectomy with superior fixation of the bone flap associated with vertical and horizontal linear durotomies and hermetic dural closure with autogenous galea. This technique demonstrated clear benefits in the treatment of patients with acute subdural hematomas secondary to traumatic brain injuries, reducing mortality and late complications of CDC[8]. The objective of the present study is to evaluate this technique applied to severe hemispheric IS, in terms of mortality and operative time.

METHODS

This study compared CDC and hinge decompressive craniectomy (HDC) for the treatment of patients with severe hemispheric stroke. From 2012 to 2014, 19 patients were selected at Hospital das Clínicas da Faculdade de Medicina da Universidade de São Paulo (HCFMUSP).

They were admitted to the Hospital with hemispheric IS, and the decision to perform craniectomy was multifactorial and discussed in interdisciplinary meetings. The most critical parameter to indicate craniectomy in these cases is the involvement of >2/3 of a hemisphere, which predisposes to significant intracranial hypertension, particularly after 2 or 3 days. The selection of the technique was based on the team's individualized judgment. Data were collected retrospectively.

HDC technique

For the HDC, linear "Burger type" durotomies were performed. Vertical (one or two frontal and two parietal), and two horizontal (temporal), with approximately 5cm long., linear durotomies were carried out. Duroplasty was performed using an autologous subgaleal tissue graft fixed with separate sutures (4.0 Prolene), to avoid CSF leak and direct contact of the cortex with the bone flap. We performed a 12x8 cm hinge craniotomy with bone flap fixation in three parietal locations to prevent inward displacement of the flap after deswelling.

CDC technique

The CDC consisted of a 12x8 cm craniectomy with a C-shaped duroplasty and placement of an autologous graft hermetically sutured. The bone flap was placed in the abdominal subcutaneous tissue.

Data

The primary outcome of this study was mortality. Covariates studied include age, gender, affected hemisphere, comorbidities, midline shift, hospital length of stay (LOS), and complications. Data were collected from medical records, pre and postoperative CT scans, and phone calls.

Data are presented as counts (valid %), if categorical, and mean (±standard deviation) or median (interquartile range, IQR), as appropriate. Chi-squared tests were used to compare categorical data between groups. Welch's t-tests were employed for continuous data, except for the comparison between pre and postoperative shifts within the same groups (paired t-tests). Analyses were conducted in R (R Foundation for Statistical Computing, Vienna, Austria).

RESULTS

Nineteen patients were included, with a mean age of 52.3 years (±8.2). All of them were initially treated according to the American Heart Association guidelines for ischemic stroke. The median time between ictus and surgical decompression was one day.

Nine were treated with HDC, and 10 underwent CDC (Table 1). Four (44.4%) patients from the HDC group had to be reoperated to remove the bone flap because of brain swelling worsening, but none of them died. The average time of HDC was 90 minutes.

Overall, 14-day mortality was 21.1% (n=4), and cumulative six-months mortality was 42.1% (n=8). Five (50%) patients submitted to CDC died, while 3 (33.3%) submitted to HDC died (χ^2=0.07, p=0.79). Mean LOS was 46.7 days (±32.1) for HDC and 38.7 (±27.1) for CDC (p=0.60).

Overall median preoperative midline deviation was 7 mm (IQR=7.5). The median preoperative shift for patients submitted to HDC was 6 mm (IQR=9) and 7 (IQR=3) for those submitted to CDC. Preoperative scan records were missing for one patient of the CDC group.

One patient presented with a midline shift >12 mm and did not survive. Nine others presented with shifts between 7–12 mm, of whom 5 (55.5%) died. Other eight presented with shifts between 0–6 mm, of whom 2 died (33.3%). Postoperatively, median shift was 6 mm (IQR=4) overall, 7 mm (IQR=4) for HDC, and 5 mm (IQR=3.75) for CDC. Comparing pre and postoperative midline shifts, CDC provided a significant improvement (p=0.02), while HDC did not (p=0.71) (Table 2 and Figure 1).

Table 1. Patient characteristics.

	HDC (n=9)	CDC (n=10)	Total (n=19)
Delta ictus-surgery	1 (0)	1 (0.75)	1 (0)
Age	54 (±7.7)	50.7 (±8.8)	52.3 (±8.2)
Female	4 (44.4%)	3 (30%)	7 (36.8%)
GCS	13 (4)	12 (3.75)	13 (4)
Anisocoria	1 (11.1%)	4 (40%)	5 (26.3%)
Midline shift	6 (9)	7 (3)	7 (7.5)

Data are presented as median (interquartile range), mean (±standard deviation), or count (valid %), as appropriate.
HDC: our modified hinge decompressive craniectomy; CDC: classical decompressive craniectomy; GCS: Glasgow coma scale.

Table 2. Midline shift.

Midline shift	HDC	CDC	Overall
Preoperative	6 (9)	7 (3)	7 (7.5)
Postoperative	7 (4)	5 (3.75)	6 (4)
0–6 mm	5 (55.5%)	3 (33.3%)	8 (44.4%)
7–12 mm	3 (33.3%)	6 (66.6%)	9 (50%)
>12 mm	1 (11.1%)		1 (5.6%)

Data are presented as median (interquartile range) or count (valid %).
HDC: our modified hinge decompressive craniectomy; CDC: classical decompressive craniectomy.

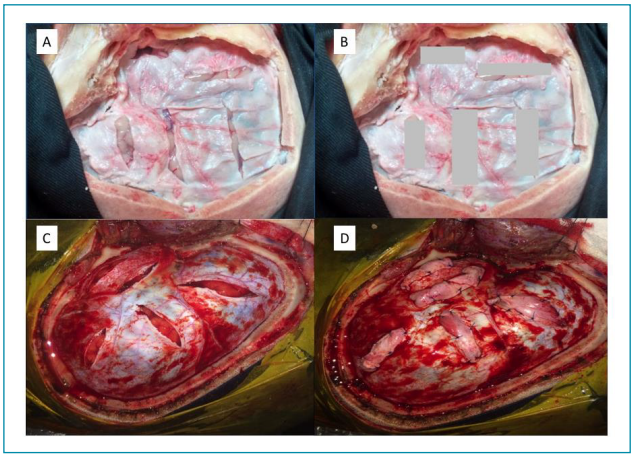

Figure 1. Hinge craniectomy with autologous duroplasty and linear durotomies. (A) Anatomical specimen used to picture the linear durotomies. Vertical durotomies were performed over the frontal and parietal lobes, and horizontal durotomies were performed over the temporal lobe. (B) Anatomical specimen used to picture the linear durotomies. Schematic representation of the duroplasties with autologous subgaleal graft to avoid bone/brian contact and to prevent cerebrospinal fluid leak. Patient with severe hemispheric stroke and clinically refractory intracranial hypertension submitted to our modified hinge craniectomy with vertical and horizontal durotomies (C) and autologous subgaleal graft (D) to prevent brain herniation and cerebrospinal fluid leak.

DISCUSSION

We present a modified HDC to treat intracranial hypertension due to IS. With this technique, surgeries lasted an average of 90 minutes, which is significantly faster than the CDC. Even though 4 (44.4%) patients who underwent HDC crossed over to the CDC group, mortality in the group initially treated with HDC was still lower than CDC (not statistically significant). Therefore, we hypothesize there is a subgroup of patients with malignant IS for whom the HDC is sufficient for decompression.

CDC presents multiple disadvantages, such as hydrostatic edema, vasoparesis, brain herniation through the bone defect, and potentially harmful axonal stretching[10,11]. Late complications of CDC are also well known, including sinking skin flap syndrome and metabolic and hydrodynamic dysfunctions, leading to neuropsychological alterations in patients without bone flap. For these reasons, studies have suggested a hinge-like fixation of the bone flap in the superior border of the craniotomy[6-8].

New approaches

New techniques include dural phenestrations[3], basal durotomy in the shape of an inverted "U" with concomitant duroplasty[4], lattice-pattern[5], and longitudinal durotomies[6]. These studies yielded positive results but have not addressed the problem of the bone opening, which unavoidably demands a second operation to perform cranioplasties.

Other authors have focused on solving the traditional skull defect. Goettler and Tucci developed the "Tucci Flap," maintaining the bone flap through anterior fixation to the skull[7]. Another hinge-like approach was published in a large series in 2007, with inferior temporal fixation of the bone flap. However, the authors did not modify the wide duroplasty technique[8].

Comparing techniques

Kenning et al. found no differences comparing CDC and their proposed hinge craniectomy in 50 patients (30 traumatic injuries, 10 IS, 10 hemorrhagic strokes)[12]. In 2012, studying 28 patients with IS, the same authors concluded that hinge craniectomy in middle cerebral artery (MCA) strokes resulted in higher intra-hospital mortality compared to CDC, although cosmetic and functional long-term results were superior. Furthermore, all surviving patients submitted to CDC required a second operation, while only 20% of those treated with hinge techniques did[13].

Hinge craniectomies were also proven to have low infection rates, providing safe and adequate intracranial pressure control in both trauma and stroke cases. It allows expansion of the flap to relieve brain swelling but contains parenchymal herniation[8].

Burger et al. proposed durotomies to substitute classical duroplasty[14]. In their study, intracranial pressure dropped 44% after removal of the bone flap, and an extra 26% after vertical durotomies. Ten days after surgery, there was no pressure rebound, even after sedation weaning and intracranial pressure became stable after 24–72 hrs (<20 mmHg). In our study, although midline shifts were reduced more significantly in the early postoperative period with CDC, mortality was not significantly different between groups. These findings suggest that secondary brain swelling observed after classical craniectomies might be due to oversized and unrestrained dural opening.

The DESTINY II trial randomized 112 patients with extensive IS to either CDC or intensive clinical treatment. The primary outcome was survival without severe disability in 6 months. Patients who underwent surgical decompression presented significantly lower mortality (33%) compared to clinical treatment (70%). Infections were more frequent in the surgical group, and brain herniation was more frequent in the clinical group[15,16].

In our institution, eligibility criteria for decompressive craniectomy after IS are age >18 or ≤60 years; significant brain swelling presenting within 48 hours after stroke; GCS at admission >3 and <15, with progressive consciousness impairment, NIHSS 7. We merged the existing concepts of linear durotomies and hinge-like fixation of the bone flap, with the original added feature of 3-4 frontoparietal and 1-2 temporal durotomies. To the best of our knowledge, no studies have yet proposed a similar approach.

It is noteworthy that 44% of patients submitted to HDC had to be reoperated to remove the bone flap due to progression of brain swelling, placing the flap in the abdominal subcutaneous tissue. Nonetheless, no herniation was observed through the durotomies, which were maintained. Mortality was not significantly different between the two groups. However, both groups present lower mortality rates compared to standard clinical treatment, which can be as high as 70%, as reported in previous studies[16].

CONCLUSIONS

We present a modified technique of hinge craniectomy with linear vertical and horizontal durotomies, which seems to have reduced operative time and mortality compared to classical decompressive craniotomy, although the difference was not statistically significant. Further studies are necessary to compare different techniques accurately.

ETHICAL STATEMENT

IRB approval was waived due to the retrospective nature of the study.

AUTHORS' CONTRIBUTIONS

AFA: Conceptualization, Data curation, Methodology, Investigation. **SAS**: Data curation, Methodology, Writing – original draft. **RFI**: Data curation, Methodology, Writing – original draft. **VSN**: Methodology, Writing – original draft. **GN**: Investigation, Methodology. **JPMT**: Data curation, Formal analysis, Software. **MJT**: Supervision, Writing – review & editing. **EGF**: Supervision, Writing – review & editing.

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