Available online at www.sciencedirect.com

SciVerse ScienceDirect

journal homepage: www.elsevier.com/locate/ijnt

Original Article

In decompressive craniectomy procedures it does not matter which way you do the duraplasty, or, does it? A study on an experimental model

Sudip Kumar Sengupta [a,*], S. Shashivadhanan [b], K.I. Mathai [c], S.M. Sudumbrekar [d]

[a] Department of Neurosurgery, Base Hospital, Delhi Cantonment, New Delhi 110010, India
[b] Department of Neurosurgery, Command Hospital (WC), Chandimandir, India
[c] INHS Ashwini, Mumbai, India
[d] Command Hospital (EC), Kolkata, India

ARTICLE INFO

Article history:
Received 22 November 2012
Accepted 26 November 2012
Available online 10 December 2012

Keywords:
Decompressive hemicraniectomy
Durotomy
Duraplasty
Volume expansion

ABSTRACT

The pathophysiology of malignant intracranial hypertension is a deleterious cycle of increased intracranial pressure, decreased tissue perfusion, declining intracellular energy production, increasing cellular edema, and subsequent increasing intracranial pressure. Decompressive craniectomy offers an effective treatment for intracranial hypertension that is refractory to standard medical treatment. There is no standardized technique suggested for durotomy and expansile duraplasty till date. We conducted this study on a model designed from locally available materials to objectively quantify the volume expansion achieved by the various durotomy and expansion duraplasty techniques. Amongst the more popularly used techniques for durotomy and duraplasty, the apparent volume expansion achieved appears to be maximum with a horse shoe shaped incision (43 ml) as opposed to a cruciate (30 ml) or a multipinnate (36 ml) incision. However, after correcting for the volume of the outpouchings, horse shoe shaped incision looses much of it's sheen (10 cm) lagging far behind the other two duraplasty techniques. Our study has proven the generally held view that there is not much to choose from between the cruciate and multipinnate durotomy techniques in performing expansile duraplasty. A horse shoe shaped durotomy on the other hand appears to be far less fruitful.

1. Introduction

The pathophysiology of malignant intracranial hypertension is a deleterious cycle of increased intracranial pressure, decreased tissue perfusion, declining intracellular energy production, increasing cellular edema, and subsequent increasing intracranial pressure. Decompressive craniectomy offers an effective treatment for intracranial hypertension that is refractory to standard medical treatment. With renewed interest in the procedure and increasing number of the cases being done for various indications, enormous amount of research has been done regarding various aspects

* *Corresponding author*. Tel.: +91 9990411652.
E-mail address: sudipkumarsengupta14@rediffmail.com (S.K. Sengupta).
0973-0508/$ – see front matter
http://dx.doi.org/10.1016/j.ijnt.2012.11.009

of the operative technique and their implications on the outcome. However, there is no standardized technique suggested for durotomy and expansile duraplasty till date. We conducted this study on a model designed from locally available materials to objectively quantify the volume expansion achieved by the various durotomy and expansion duraplasty techniques being used in our center and as described in the literature available. Based on our observations, we have also tried to plan and test some modifications of the techniques on our experimental model.

2. Materials and methods

A ring of malleable plastic tubing was made representing the bone edge of a craniectomy defect of 10 cm diameter (Fig. 1). A non-expansile, water impermeable, cloth was used to represent dura in our experiments. The cloth was incised in different patters representing different methods of durotomy presently in use, namely, crusiate, multipinnated and horse shoe shaped (Fig. 2).

A water tight closure was achieved with a piece of cloth representing autologous tissue (now onwards referred to as “graft”) used for duraplasty. For the purpose of our experiment we took a cloth piece of the size of the craniotomy defect, to reduplicate a situation where pericranium from the free bone flap is used for duroplasty (Fig. 3A and B).

While achieving the closure, shape of the graft was variously designed based on the duraplasty techniques used by the consultants at our center (Fig. 4). While reshaping, however, no part of the graft was resected. Hence, there was no difference in the total surface area of the graft used in all the duraplasty techniques tested.

The volume (V^1) of intact dura, in its part expected to be projecting into a craniectomy defect in case of raised intracranial pressure was measured first. Volume measurement was achieved by pouring a measured volume of Plaster of Paris paste into cavity created by the concavity of the cloth piece representing the dura, attached to the plastic ring. POP paste was filled upto the brim (Fig. 5).

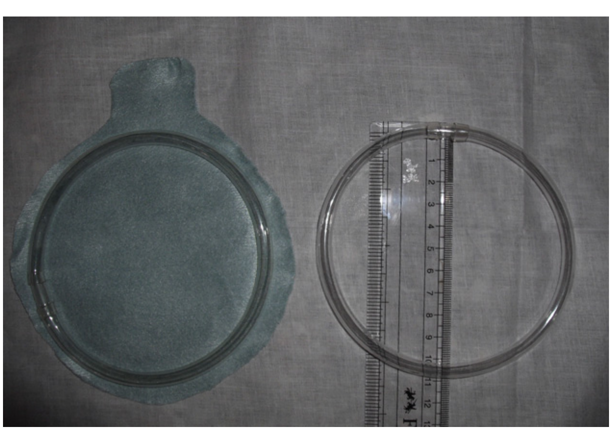

Fig. 1 – A ring of malleable plastic tubing, representing the bone edge of a craniectomy defect of 10 cm diameter.

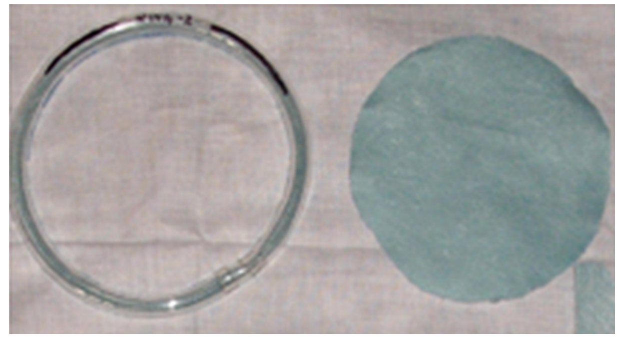

Fig. 2 – A cloth piece of the size of the craniotomy defect, to reduplicate a situation where pericranium from the free bone flap, fixed to the ring.

Similarly, maximum volume (V^2) achievable in the new space created by the expansile duraplasty, in the event of raised ICP was measured in all the different expansile duraplasty techniques (Fig. 6). The volume expansion (V^3) achieved in each technique was calculated by substracting V^1 from V^2.

Measurements for each of the duraplasty shapes were repeated thrice. All the measurements were taken in ml. For a reading which was in a fraction, nearest ml reading was accepted.

The aim of our study was to calculate the difference in volume expansion achievable by various expansile duraplasty techniques, but there were certain obvious observations on the shapes which could not be ignored. All of them developed outpouchings or pockets where the POP paste had percholated (Fig. 7) and contributed to the volume. We never see such outpouchings in the images obtained in the cases of decompressive craniectomies. At this point we hypothesized that the redundant folds of the dura mater, created due to the duroplasty, fall over each other and get compressed against the inner surface of the scalp and these spaces which were getting filled up in the experimental model are not available to the intracranial contents.

Taking this view under consideration, we repeated the volume measurements with the outpouchings eliminated by suturing them to the undersurface of the graft (Fig. 8).

Based on the findings of the study a modification of the duraplasty technique was planned which would reduce the number of sharp outpouchings while augmenting the dura with the same surface area as with the standard procedures (Fig. 9). The volume augmentation achieved by this technique was also quantified both with and without obliteration of the outpouchings.

3. Results

Volume (V^1) of un incised dura over it’s segment projecting convexly outwards from a 10 cm diameter craniectomy defect

Reading 1–80 cc
Reading 2–79 cc
Redaing 3–81 cc
Mean – 80 cc

Volume achieved after various duraplasty techniques.

Duraplasty technique	Mean volume (V^2)	Volume expansion (V^3) achieved V^2-V^1	Mean volume after obliteration of outpouching (V^C)	True volume expansion achieved (V^R) V^C-V^1
Horse shoe	123 ml	43 ml	90 ml	10 ml
Cruciate	110 ml	30 ml	103 ml	23 ml
Multiple radial Incision	116 ml	36 ml	102 ml	22 ml
Experimental design	148 ml	68 ml	114 ml	34 ml

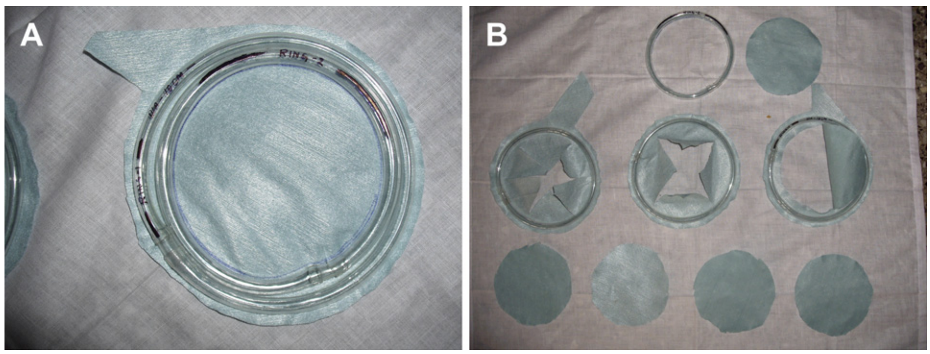

Fig. 3 – A: Cloth piece and the ring. B: Cloths incised in different patters representing different methods of duratomy presently in use, namely, crusiate, multipinnated and horse shoe shaped.

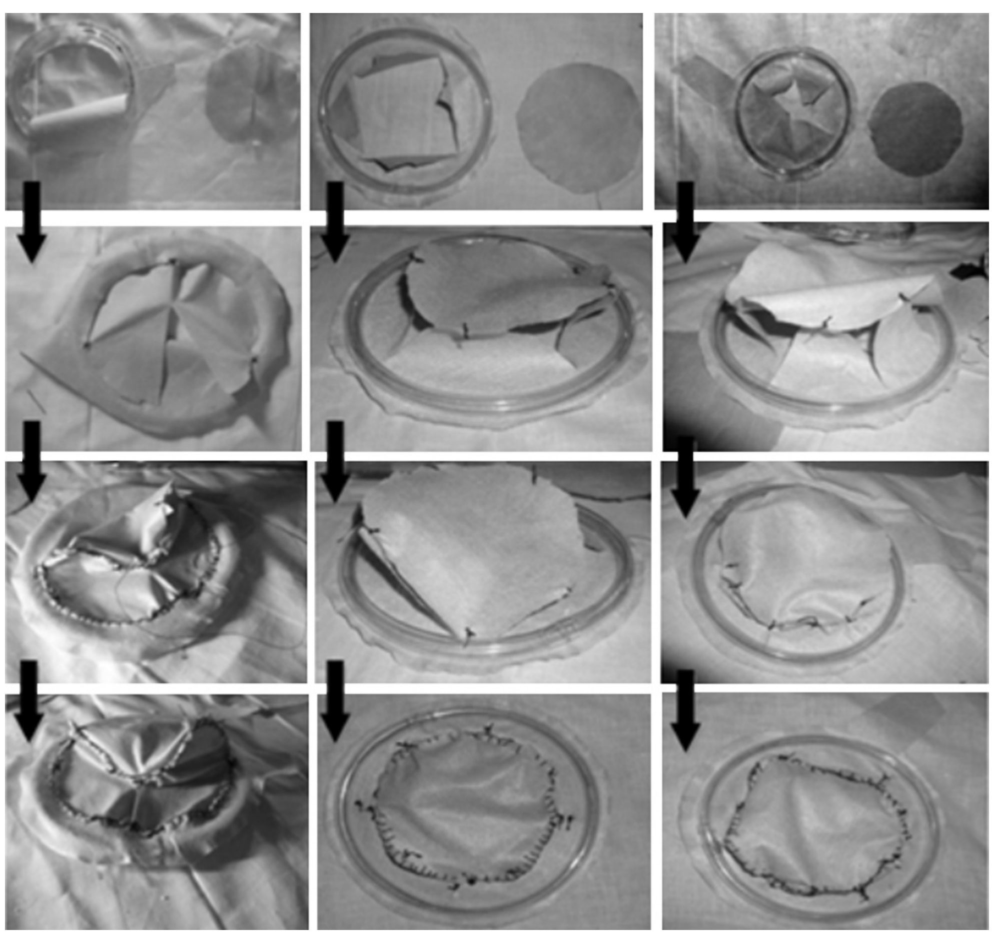

Fig. 4 – Shape of the graft was variously designed. Arrows indicate the sequential steps in which patches of pericranium of the size of the craniectomy flap was sutured to the variously designed dural defects in the model.

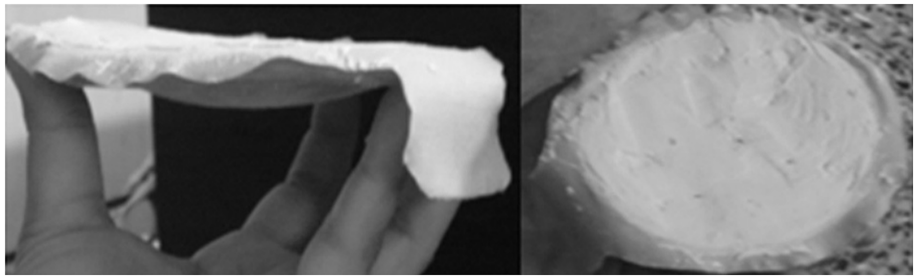

Fig. 5 – POP paste was filled upto the brim.

Fig. 6 – POP paste filled up to measure additional volume of space available after expansile duraplasty.

Fig. 8 – Outpouchings eliminated by suturing them to the undersurface of the graft. Arrows indicate the stitches taken to obliterate the out pouchings.

Amongst the more popularly used techniques for durotomy and duraplasty, the apparent volume expansion achieved appears to be maximum with a horse shoe shaped incision (43 ml) as opposed to a cruciate (30 ml) or a multipinnate (36 ml) incision. However, after correcting for the volume of the outpouchings, horse shoe shaped incision looses much of it's sheen (10 cm) lagging far behind the other two duraplasty techniques. Considering that in our experiments, the margin of error has been ± 2 cm, in estimating the volume, there is nothing much to choose from between the cruciate (23) and multipinnate (22) incisions in as far as the achieved corrected volume expansion (V^R) is concerned.

The experimental duroplasty designed by us proved to have a fair lead over the commonly used techniques in ability to achieve volume expansion in both with (34 ml) or without (68 ml) correction for the outpouchings.

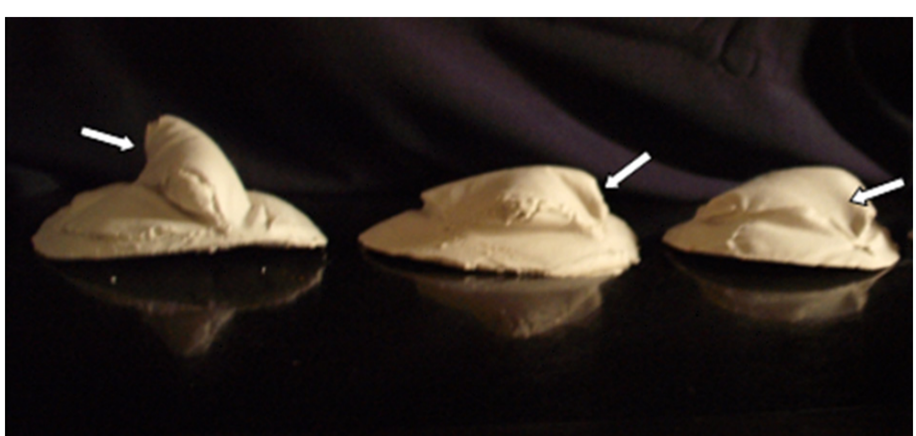

Fig. 7 – POP paste percholated into the outpouchings or pockets and contributed to the volume. Arrows indicate the POP outpochings.

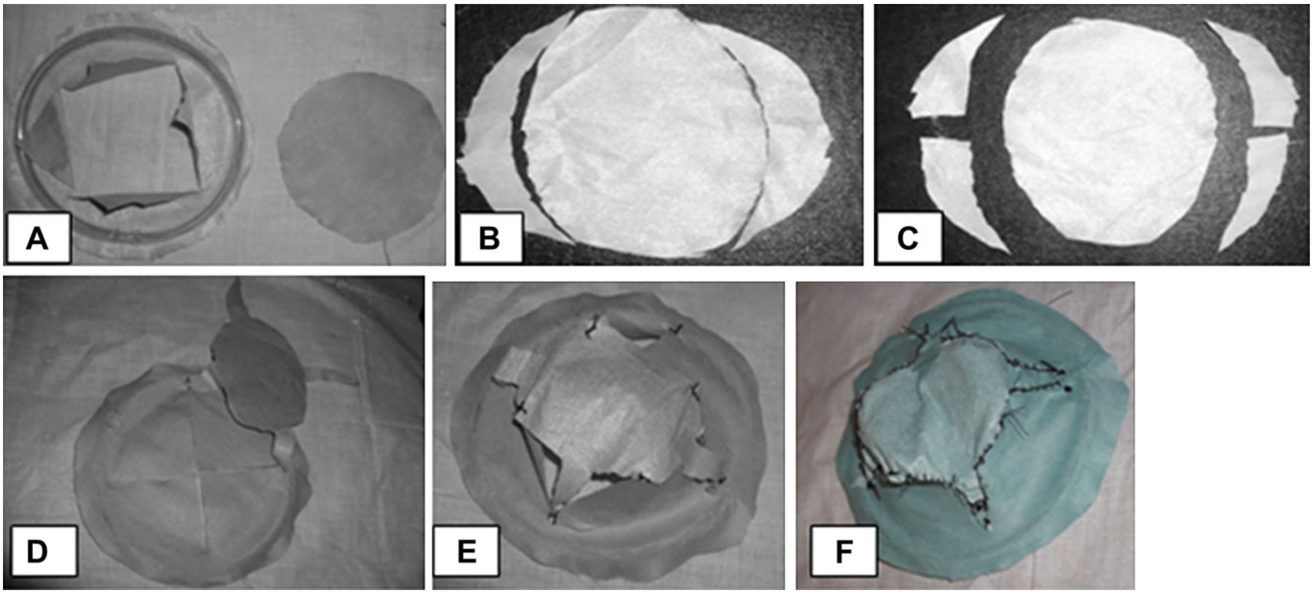

Fig. 9 – A modified duraplasty technique. A: Dural defect and a patch of the size of the free bone flap. B: Two concavo convex pieces removed from the two sides of the flap. C: Pieces so removed, divided in two halves. D: Four small pieces so designed, stitched to the four corners of the central piece. E: Four extensions of the flap sutured to the four corners of the dural defect. F: Duraplasty completed.

4. Discussion

Decompressive craniectomy originally described by Kocher for traumatic brain injury, is being performed more frequently for malignant cerebral infarct with good results.[1–3] It is also being considered for severe encephalitis.[4] It is reported that simply by performing a craniotomy, there is a 15% decrease in intracranial pressures and when accompanied by durotomy, there is a 70% decrease in ICP.[5] Many techniques for decompressive craniectomy have been described with variations on the basis of location, size, and durotomy. While there is a general consensus on the size of the craniectomy bone flap size,[3,4,6] the durotomy shape and the necessity or technique of duroplasty are yet to be standardized. The various techniques described for durotomy are cruiate,[7] horse shoe shaped with the flap reflected toward the superior sagittal sinus and circumpherential[8] with or without radial releasing incisions.[5]

Technique of expansion duraplasty has not been elaborated by most of the authors. In the studies in which a technique has been mentioned, options ranged from the pericranium or engineered dural substitute been sewn loosely to the dural edges[5] or tucked under the bony margins of the defect[5] to lay a sheet of dural substitute over the entire area of exposed dura.[9]

Attempts have been made to measure the volume decompression achieved by craniectomy. Munch et al[10] used CT to make morphometric analysis for assessing the volume of decompression and its effect on the basal cisterns and on midline shift. They showed an average cranial defect surface area to be 67.9 cm^2 (corresponding to a dia of approximately 9.34 cm), corresponding to a mean volume of 92.6 cm^3. However, no correlation was sought between the cranioplasty technique and volume expansion achieved. The value we obtained for a cruciate durotomy (103 cm^3) and multiple radial durotomies (102 cm^3) with a water tight closure after obliterating the outpouchings with a craniotomy defect of 10 cm roughly corresponds to their findings.

Our study has proven the generally held view that there is not much to choose from between the cruciate and multipinnate durotomy techniques in performing expansile duraplasty. A horse shoe shaped durotomy on the other hand appears to be far less fruitful. The duraplasty technique designed at our center appears to be much superior to it's more popular counterparts, but even this technique creates some outpouchings. Since possible herniation of swollen brain tissue through the outpouchings created in any form of duraplasty can jeopardize the vascularity of the segment, leaving the dura wide open with a dural graft overlying the defect may be a much more viable option. In case a water tight closure of the dura is the prime concern, one must obliterate all the possible outpouchings carefully, on completion of the duraplasty.

Conflicts of interest

All authors have none to declare.

REFERENCES

1. Schwab S, Steiner T, Aschoff A, et al. Early hemicraniectomy in patients with complete middle cerebral artery infarction. *Stroke*. 1998;29:1888–1893.
2. Vahedi K, Hofmeijer J, Juettler E, et al. Early decompressive surgery in malignant infarction of the middle cerebral artery: a pooled analysis of three randomized controlled trials. *Lancet Neurol*. 2007;6:215–222.
3. Xiao-Feng Yang, Yu Yao, Wei-Wei HU, et al. Is decompressive craniectomy for malignant middle cerebral

artery infarction of any worth? *J Zhejiang Univ Sci B*. 2005;6B(7):644–649.
4. Schwab S, Junger E, Spranger M, et al. Craniectomy: an aggressive treatment approach in severe encephalitis. *Neurology*. 1997;48:412–417.
5. Smith ER, Carter BS, Ogilvy CS. Proposed use of prophylactic decompressive craniectomy in poor-grade aneursymal subarachnoid patients presenting with associated sylvian hematomas. *Neurosurgery*. 2002;51:117–124.
6. Toussaint Charles Philip, Origitano TC. Decompressive craniectomy Review of indication, outcome, and implication. *Neurosurg Q*. 2008;18:45–53.
7. Mathai KI, Sahoo PK. Decompressive craniectomy: an effective but underutilized option for intracranial pressure management. *Indian J Surg*. 2008;70: 181–183.
8. Demchuk A. Hemicraniectomy is a promising treatment in ischemic stroke. *Can J Neurol Sci*. 2000;27:274–277.
9. Valadka Alex B, Robertson Claudia S. Surgery of cerebral trauma and associated critical care. *Neurosurgery*. 2007;61(SHC suppl 1). SHC-203–SHC-221.
10. Munch E, Horn P, Schürer L, et al. Management of severe traumatic brain injury by decompressive craniectomy. *Neurosurgery*. 2000;47:315–323.