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Modifying skin flaps for achieving very large decompressive craniectomies in malignant middle cerebral artery territory infarcts: A technical note

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Abstract:

INTRODUCTION: Decompressive craniectomy is a well described treatment to salvage life in large middle cerebral artery (MCA) territory infarcts. The size of the craniectomy is limited by the size of the skin incision and very large craniectomies need large skin flaps that are prone to necrosis at the wound margins.

MATERIAL AND METHODS: We describe two modifications in the skin flap that we have used in 7 patients to achieve very large bony decompressions in malignant MCA infarctions without compromising on flap vascularity. One consists of a linear extension posteriorly from the question mark or reverse question mark incision while the other is an "n" shaped incision.

RESULTS: With these modifications we achieved craniectomies of size 15.6–17.8 cm in the anteroposterior and 10.7–12 cm in vertical axis of the bone flap removed in our patients. There were no additional procedural or wound related complications in a 6-month follow up.

CONCLUSIONS: Removal of a standard size bone flap may achieve suboptimal decompression in cases of large MCA territory infarctions. Imaginative tailoring of skin flaps helps to remove larger volumes of skull with no added procedural morbidity.

Keywords:

Cerebral infarction, craniectomy size, decompressive craniectomy, malignant middle cerebral artery infarct, raised intracranial pressure, skin flap

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Introduction

The term malignant middle cerebral artery (MCA) infarction has been defined by Treadwell and Thanvi as "rapid neurological deterioration due to cerebral edema following stroke."[1] This cerebral edema can result in transtentorial herniation and death due to raised intracranial pressure (ICP). A recent article by Gu *et al*.[2] states that cerebral edema following stroke is multifactorial and based on molecular pathophysiology can be divided into cytotoxic, ionic, and vasogenic edema. Although they describe various receptors that can be targeted to prevent or decrease the severity of poststroke edema,[2] they also state that currently the treatment of cerebral edema "mostly involves symptomatic treatment" after it has developed.

Hence, decompressive craniectomy (DC) remains an important treatment option to salvage life in large cerebral infarctions or in those patients with impending herniation.[3] Wei *et al*.[4] in a systematic review and meta-analysis of randomized control trials comparing DC versus medical

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management in the treatment of malignant MCA infarction have also concluded that DC increases both survival and favorable functional recovery in both age groups above and below 60 years.

While the amount of bone that needs to be optimally removed in a standard DC is not quantified, Tagliaferri *et al*.[5] in a retrospective multicentric analysis of 526 cases say that removal of bone of adequate size is directly linked to survival. Tanrikulu *et al*.[6] have defined a standard DC as consisting of bone removal of 12 cm in the anteroposterior (AP) axis with the removal of bone up to the temporal base in a superior-inferior axis and state it is the recommendation most widely accepted in the neurosurgical community to alleviate raised ICP.

Technique of Decompression and Our Modifications

A standard DC is performed by placing a "question mark" (QM) or reverse "question mark" (RQM) incision whose lower limb begins anterior to the tragus and arches a variable distance back over the pinna and then curves anteriorly by the side of the midline. This enables the skin and galea to be reflected anteroinferiorly and the temporalis muscle to be reflected inferiorly to allow a generous frontoparietotemporal DC. The skin flap in these cases is supplied by the superficial temporal and supraorbital and supratrochlear arteries which must be preserved during dissection. The main limitation of this incision is in achieving adequate posterior decompression (of the parietal and temporal lobes) since curving it excessively backward for greater bone removal might compromise the vascularity of the flap and prevent wound healing.

One variation to prevent wound healing problems and yet achieve adequate bone removal in large infracts might be to place a linear incision directed posteriorly from the vertical limb of the QM or RQM incision which enables reflection of three flaps – one anteroinferiorly as in the standard incision for DC, the second posteroinferiorly fed by the posterior auricular and occipital arteries, and the third fed by contralateral scalp vessels. The location of the posteriorly directed linear incision can be varied depending on whether more bone needs to be decompressed from the parietal or from the temporal aspect. After DC and duraplasty, closure is done by approximating the temporalis muscle lightly. The galea is closed using inverted absorbable sutures and at the trijunction, galea from all three flaps are drawn together to prevent any leak. Tension-free skin closure is then done using interrupted nonabsorbable sutures over a subgaleal drain.

In the second variation, a curvilinear incision with its base directed downward is placed originating from the vertical posterior limb of the QM/RQM incision taking care not to extend it below a horizontal line drawn backward from the root of the pinna (surface marking of the transverse sinus). Two additional flaps can then be raised – the first anteroinferiorly as usual, the second inferiorly based on the posterior auricular and occipital arteries; and furthermore, the scalp above the second flap can be retracted to expose the parietal lobe. After DC and durotomy with a lax duraplasty, closure is done as described above. The blood supply to the scalp and the standard and two modified incisions with the extent of bone removal in each for achieving very large DCs are shown schematically in Figure 1a-d.

We have used these flaps in seven cases of malignant MCA territory infarcts over the last 2 years before which we were using the QM/RQM incision and were able to achieve a satisfactory decompression without encountering any skin breakdown, incision site blackening, or cerebrospinal fluid leak in any case. There was no hemorrhagic transformation of the brain abutting the DC margins in any case. One patient developed

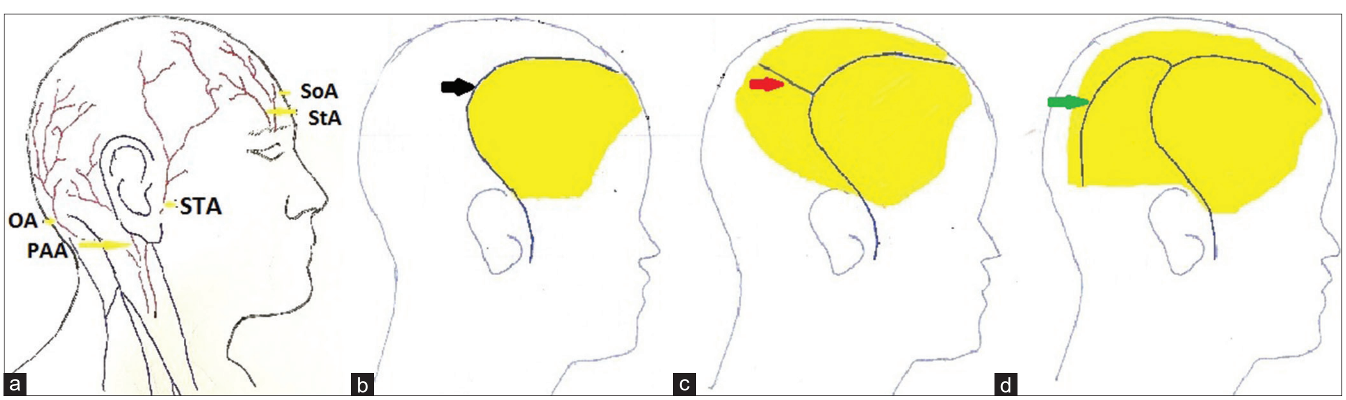

Figure 1: Schematic diagram showing (a) blood supply to the scalp; (b) standard flap for a decompressive craniotomy, (c) with a linear extension posteriorly from the original flap, and (d) with an n-shaped extension from the original flap. The area of bone removal that can be removed with the standard and modified incisions are shown in solid yellow coloration

Table 1: Summary of the cases of very large decompressive craniotomies done by either of the flap modifications

Age/sex	Side	Hours to surgery after infarct	Midline shift (mm)	Type of flap	Size of DC (AP × vertical) (cm)	Significant postoperative complications
54/male	Right	35	8	NsF	16.3×11.8	Nil
65/female	Left	48	10	LEF	15.9×12.0	Nil
36/male	Right	17	12	NsF	17.8×11.2	Seizures
55/male	Left	70	7	NsF	16.6×11.7	Seizures
62/male	Right	55	9	LEF (redo case after initial suboptimal DC)	16.4×10.9	Nil
51/female	Right	38	11	LEF	15.6×11.3	Postoperative hydrocephalus after 3 months Underwent a VP shunt and early CP
41/male	Left	26	11	NsF	16.8×11.5	Nil

AP: Anteroposterior, CP: Cranioplasty, DC: Decompressive craniectomy, LEF: Linear extension flap, NsF: N-shaped flap, VP: Ventriculoperitoneal

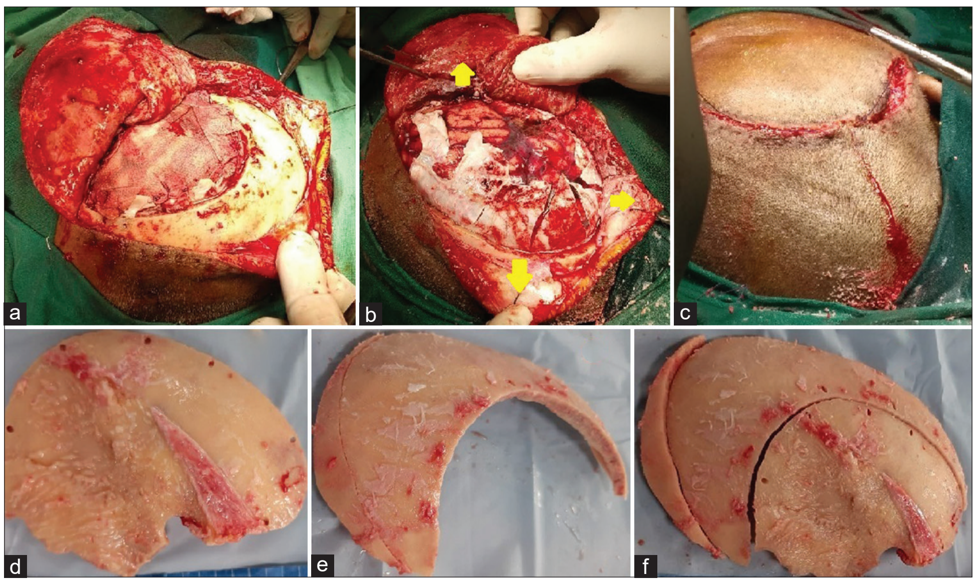

Figure 2: Intraoperative images of a redo case where initial decompression was inadequate showing (a) reopening up of the old flap with additional bone visible after placement of the linear posterior extension; (b) reflected skin flaps (yellow arrows) and brain after durotomy and expansion of the original decompressive craniotomy; (c) closure after approximation of the skin flaps; (d) the original bone flap; (e) additional bone removed in two pieces and (f) composite bone flap after a very large decompression showing the additional advantage of the modified skin incision

postoperative hydrocephalus after 3 months which was shunted at the time of cranioplasty. The clinical details of these patients are given in Table 1.

Discussion

It is an axiom in neurosurgery that the base of the skin flap must be wider than its height to ensure adequate blood flow to even the most distal sites and unilateral DC flaps are thus often curved across the midline.[7] As the size of the DC is limited by the size of the skin flap,[8] neurosurgeons are loath to make very large trauma flaps for fear of skin breakdown due to compromised vascularity. Gopalakrishnan *et al*.[8] have mentioned that the large size of the flap and injury to the superficial temporal artery predisposed the wound margins to ischemia at the posterior parietal and temporal areas and state that limiting the extension of the flap behind the ear may "reduce the chance of wound breakdown." The two skin flaps described above are innovations that allow for the preservation of adequate blood flow to the skin flaps and at the same time allow the removal of greater amount of bone. There is one article describing the former technique for postoperative salvage decompressive craniotomy following the unexpected rise of ICP in the postoperative period[9] while one other article describes the latter technique for traumatic brain injury.[10]

In cases of traumatic brain injury, where the aim is clot removal or contusionectomy in addition to decompression very large DCs are often not performed.[5] However, a suboptimal DC for raised ICP following large MCA territory infarction (where no brain is removed) may defeat the aim of the surgery itself as external cerebral herniation through the defect can cause obstruction of cortical venous outflow at the edges of the defect and further increase cerebral edema.[9] As a good venous outflow is related to a good functional outcome,[2] very large DCs will be helpful in these patients.

Zweckberger *et al*.[11] in a review state that there is evidence that larger craniectomies (more than >14 cm) in malignant strokes predict favorable outcomes. Chung *et al*.[12] too comparing very large (14–16 cm) with standard (12 cm) DCs for right-sided infarcts note that the former is associated with more favorable outcomes and less mortality at 3 months. They also state that these larger flaps are not associated with increased surgical complications.[12] Using these variations of the skin flaps as opposed to standard DC flaps (in fresh and reoperated cases), we were able to achieve AP diameters of 15.6–17.8 cm and vertical diameters of 10.7–12 cm in our patients with no additional procedural or wound-related complications or mortality during at least 6-month follow-up [illustrative examples Figures 2-5].

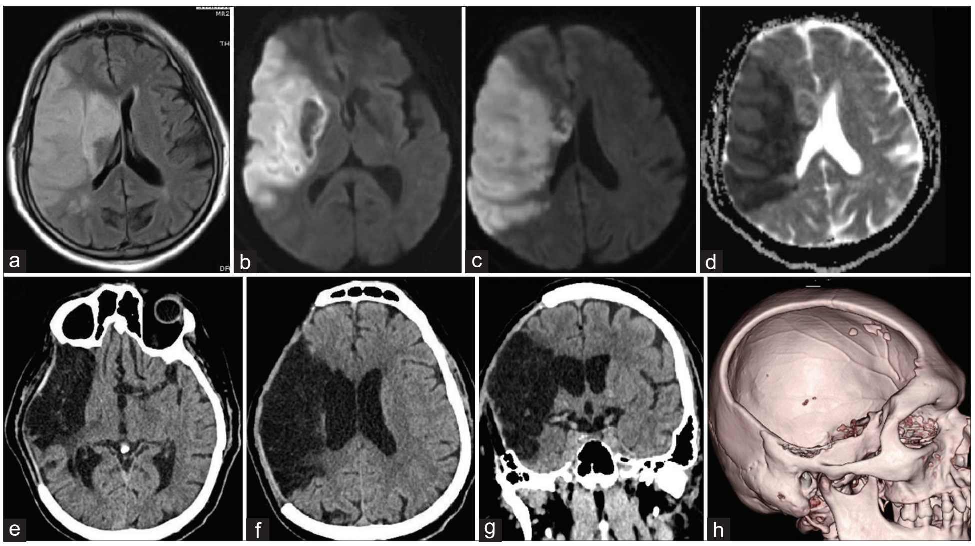

Figure 3: Axial FLAIR (a) and Diffusion-weighted (b and c) with ADC MR images (d) of a patient with a large right MCA territory infarct. Postoperative axial (e and f) CT images show no residual midline shift and with mass effect and extent of bone removal in AP dimensions while the coronal (g) reconstruction shows decompression in the superoinferior axis. A 3D reconstruction of the large DC that was achieved by the linear posteriorly directed incision (h) is also shown. FLAIR: Fluid attenuated inversion recovery, ADC MR: Apparent diffusion coefficient magnetic resonance, MCA: Middle cerebral artery, CT: Computed tomography, AP: Anteroposterior, DC: Decompressive craniectomy

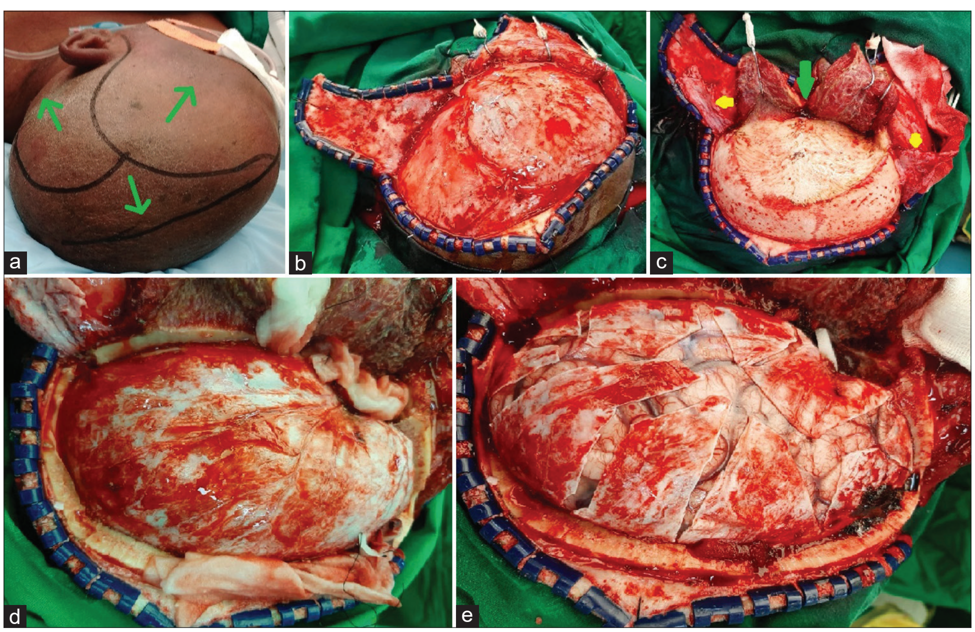

Figure 4: Intraoperative images showing (a) preoperative skin marking of the n-shaped incision with the green arrows indicating the 3 directions in which the various flaps are to be retracted; (b) view after the 3 flaps have been retracted anteroinferiorly, posteroinferiorly, and superiorly; (c) extent of exposed bone that can be removed after the temporalis is divided (green arrow) and retracted inferiorly with the lifting of pedicled pericranial flaps (yellow arrows); (d) bulging dura after craniectomy and (e) adequate brain decompression after durotomy

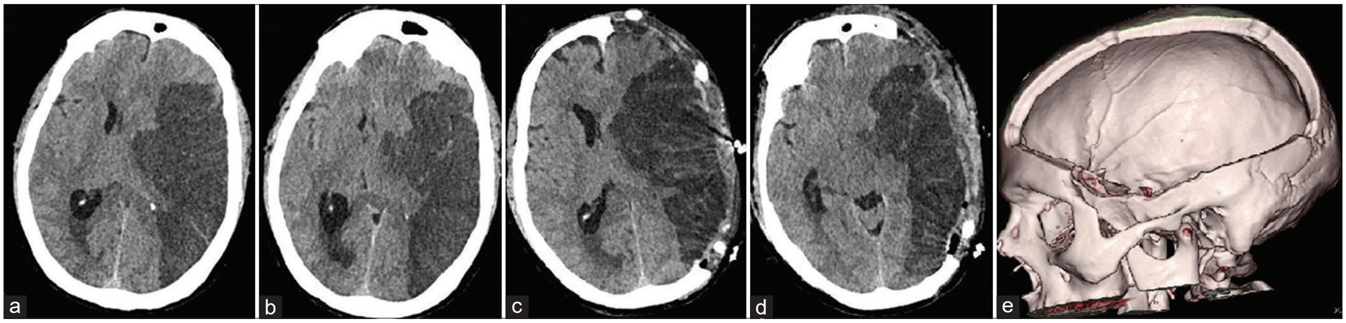

Figure 5: Axial CT images preoperatively (a and b) showing a large left MCA territory infarct with, mass effect and midline shift. Postoperative axial CT images on the 1st postoperative day (c and d) showing adequate AP bone removal and opening up of the ventricles and cisterns. A 3D reconstruction (e) of the large DC that was achieved by the n-shaped incision is also shown. CT: Computed tomography, MCA: Middle cerebral artery, AP: Anteroposterior, DC: Decompressive craniectomy

Conclusions

Bony decompression in large MCA territory infarcts may be suboptimal if the usual skin flaps with standard DCs are performed. Although our series using such flaps is very small, we feel that imaginative tailoring of the skin flaps can aid in the removal of larger volumes of the skull which in turn may result in better outcomes by reducing ICP adequately.

Ethical statements

The study was approved by the Institutional Ethics Commitee of National Neurosciences Centre, Calcutta (No.: NNC/IEC/APPV/2016/027) on March 25th, 2016 and was performed in accordance with the Declaration of Helsinki.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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