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Decompressive craniectomy bone flap hinged on the temporalis muscle: A new inexpensive use for an old neurosurgical technique

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Abstract

Background: The neurosurgical procedure of hinge decompressive craniectomy (hDC), or hinge craniotomy (HC), as described from units in the advanced countries makes use of metallic implants, usually titanium plates and screws, which may not be economically viable in resource-limited practice settings.

Methods: We describe our surgical techniques for performing this same procedure of hDC in a developing country using the patient's own temporalis muscle instead of any other potentially costly implants.

Results: The technique as described appears to be successful in achieving intracranial decompression in cases of traumatic brain swelling in which it has been used. Clinical and radiological illustrations of the feasibility, and practical utility, of the procedures in four clinical scenarios of traumatic brain injury are presented. Like all other techniques of HC, this "new" surgical technique of hDC temporalis saves the survivors the added imperative of future cranioplasty of the usual postcraniectomy skull defect. Unlike the others, the procedure eliminates the added cost of the metallic implants needed to perform the former techniques.

Conclusions: The procedure of hDC temporalis appears to be a viable option for performing the surgical procedure of HC and has added cost-cutting economic benefits for resource-limited practice settings.

Key Words: Decompressive craniectomy, developing countries, hinge craniotomy, hinge decompressive craniectomy, Nigeria, temporalis muscle, traumatic brain injury

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INTRODUCTION

The possible place of decompressive craniectomy (DC) in the neurosurgical management of traumatic brain injuries (TBI) in the developing countries recently attracted our interest.[1] There are several technical details of the surgical procedure of DC however with practical and cost implications in resource-limited practice areas like our own.[3,8,9,13,15] One such detail of great significance is the immediate and final disposition of the cranial bone flap raised at the time of the acute surgical care.[10] And of all the methods so far devised for this purpose, the technique of on-site hinging of the bone flap to the calvarium, the so-called *in situ* hinge decompressive craniectomy (hDC), also known as hinge craniotomy (HC),[17,18] appears to be the most appealing to us for its potential practical utility in low-middle income countries (LMIC). Whereas this on-site hinging of the bone flap has usually been facilitated with some form or other of cranial implants like various titanium plates and screws, these still having further significant cost implications for our practice, it has been our intuitive deduction that the age-old neurosurgical osteoplastic technique of cranial bone flap elevation could be made to serve this same purpose. Hence an evolving surgical technique in our practice in which we also achieve on-site storage of the bone flap for a hinge craniotomy as described[12,18,23] but use the patient's own ipsilateral temporalis muscle instead for the hinge and not some other metallic implants. We call this surgical technique "hinge DC temporalis" in short and here present the evolution of the technique and a case series illuminating some of our ongoing insights in its potential utility for our kind of resource-limited neurosurgical practice setting.

MATERIALS AND METHODS

First and foremost, we present a clinical case-based illustration of our surgical technique for the performance of "hDC temporalis" that is *in situ* hDC using the temporalis muscle; and then, the summary of some salient pre- and postoperative clinical/radiological points of note in three other cases treated using this technique.

Surgical technique of *in situ* hinge DC using the temporalis muscle

This initial report is for a unilateral frontal-temporal-parietal hDC; the technique however appears to also be very feasible for a synchronous bilateral procedure.

Clinical /surgical illustration

A 44-year-old man presented in our unit with moderate head injury (HI) 1 day after road accident out of state. On examination he had depressed consciousness, Glasgow coma score (GCS) of 11/15: E4V2M5; equal, 3 mm, reactive pupils; left facial and hemibody limb weakness, and fairly stable vital signs: temperature 38.0°C, pulse 68/min, respiratory rate 24/min, and blood pressure 170/90 mmHg. Cranial CT obtained on the day of trauma showed a right frontotemporoparietal (FTP) cortical brain contusion, slight brain swelling and focal areas of subarachnoid hemorrhage [Figure 1a]. The basal cisterns and the midline were preserved. He was admitted into the hospital's general intensive care unit (ICU) for nonoperative care with clinical and hemodynamic monitoring. He initially maintained his baseline clinical state until 7 days later when his clinical condition worsened, and GCS dropped to 9/15. A repeat cranial CT showed gross worsening of the right-sided brain swelling with right--left midline shift and marked obliteration of the CSF spaces in the ipsilateral cerebral sulci, the lateral, IIIrd and IVth ventricles, and the basal cisterns [Figure 1b]. He was taken to the operative room for decompressive craniectomy.

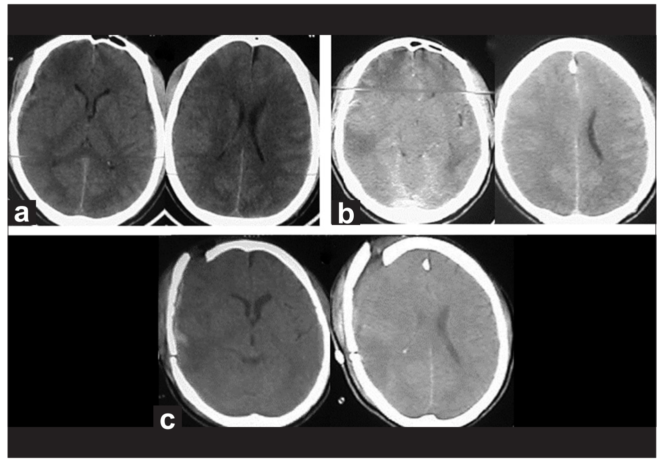

Figure 1: The procedure of HC using the temporalis muscle, cranial CT films of the illustrated surgical case (a) axial brain images at presentation showing the non-surgical multifocal bilateral brain contusions worse on the right and only slight cerebral swelling with no gross mass effect; (b) axial brain images of the same patient when he deteriorated clinically 7 days later. There is diffuse brain swelling worse to the right associated with effacement of the ventricles and basal cisterns, and a midline shift; (c) axial brain images on POD 6 show evidence of mobility and elevation of the free bone flap, measurable extracranial brain expansion, and reversal of the intraaxial mass effect

Surgical procedure

Positioned supine with left lateral rotation of the head under general endotracheal anesthesia a right FTP large trauma scalp flap was raised. Next, anterior and posterior vertical cuts were made with Bovie on the respective borders of the temporalis muscle and the same elevated off the temporal squama *only at the temporal fossa floor* [Figure 2a]. Using established neurosurgical techniques an osteoplastic FTP skull flap was raised and the completion craniectomy done with rongeurs to make sure the cranial bone window reaches down into the temporal fossa floor [Figure 2b]. This cranial opening revealed a tense dusky dural covering over the cerebral lobes with absent brain pulsation. The dura was then opened in a cruciate fashion revealing markedly swollen brain with multifocal contusions [Figures 2b and c]. Some of the latter were debrided in the usual fashion and an augmented loose dural closure was done [Figure 2d]. The bone flap was then returned floating *in situ* over the swollen brain *but still attached to the ipsilateral temporalis muscle* [Figure 2e]. The anterior and posterior vertical cuts in the temporalis muscle were then sutured back. These suture lines were carried superiorly only as far as the upper border of the main belly of the temporalis, at the superior temporal line. This was to ensure that the bone flap would remain mobile to accommodate the extracranial cerebral expansion [Figure 2f]. A wound drain was placed next and two-layer water-tight scalp closure performed as usual [Figure 2g]. Using an elastic crepe bandage a bulky gauze dressing of the wound was finally placed and the patient was moved back to the ICU for continuing care. While in the ICU, the on-site hinged cranial bone flap was clinically determined to be indeed mobile under the scalp flap. The latter was tense as expected in the first few postoperative days (POD) but did not suffer any wound complication as a consequence. Due to logistic reasons, we were able to obtain a postoperative cranial CT only on POD 6. This revealed a fairly mobile bone flap, and measurable extracranial cerebral expansion, under the intact scalp flap. There was also progressive reversal of the midline shift and of the obliteration of the sulcal, ventricular, and basal CSF cisterns [Figure 1c].

The patient made progressive clinical improvement: was extubated in the ICU on POD 4; the scalp swelling progressively regressed, the bone flap spontaneously settling back in place; the wound healed by primary intention and the wound staples/stitches were removed on the POD 12. The patient was discharged home 6 weeks post-op fully conscious and at approximate lower moderate deficit status on the extended Glasgow outcome scale (GOSE). He sustained this neurological improvement and was already at the level of GOSE lower normal at the last outpatient review 10 months post-op. He displayed no concerning issues regarding his bone flap site. The latter had actually settled down back in place.

RESULTS

Some aspects of the clinical and radiological course of three other patients managed with this surgical technique are here presented to further illustrate some of its other nuances.

A. A 34-year-old young man presented with moderate TBI, GCS 11, from a pedestrian motor vehicle accident (MVA). Cranial CT obtained 2 days post-trauma (logistic delay) revealed an acute extradural haematoma (EDH) under a right temporoparietal linear skull fracture and diffuse brain swelling worse on the left side with multifocal haemorrhagic contusions. Marked intracranial pressure effects were evidenced by effacement of all the CSF spaces in the ventricles and the basal cisterns, and a left--right midline shift [Figure 3a]. During a 1-day delay (logistic reasons) for a scheduled DC the patient's neurological condition suddenly worsened to GCS 9/15. Daring all the initial constraining logistic issues, the surgical procedure, that is hDC temporalis as described above, was then carried out precipitously. Cranial CT obtained POD 3 is shown revealing good mobility of the bone flap and appreciable intracranial decompression [Figure 3b-d]. The patient thereafter made uneventful progressive clinical recovery and was discharged 3 weeks post-op fully conscious and at about the lower moderate deficit on the GOSE. This neurological level had improved to lower normal at the outpatient visit 3 months posthospital discharge. We have now followed up this young man for 17 months post-op. He maintained his neurological improvement; he is back to his normal occupation and has no functional or esthetic issues with his cranial bone flap site [Figure 3e].

B. Another 35-year-old young man presented with mild TBI, GCS 13/15, following a driver MVA. By a highly fortuitous coincidence 3 days after admission his neurological condition worsened to GCS 9/15 and the earlier requested but delayed cranial CT scanning was also obtained about the same time. This revealed an ASDH of the left FTP region with ipsilateral brain swelling and mass effect [Figure 4a]. The hDC temporalis was then performed urgently showing intraoperative evidence of marked brain swelling and the onsite elevation of the cranial bone flap after surgical wound closure. He could not afford follow-up neuroimaging but his postoperative course, followed clinically, showed progressive improvement and he was discharged home at the lower moderate deficit status 4 weeks post-op. He was back to near-normal status level, and his cranial flap spontaneously returned to normal, by the time of his last outpatient visit 3 months post-op [Figure 4b].

C. A 33-year-old woman presented with severe TBI, GCS 8/15, and anisocoria. Cranial CT showed diffuse severe brain swelling worse on the left side which also revealed evidence of brain contusion, traumatic SAH, and ASDH [Figure 5a]. A preemptive surgical decompression was carried out using the hDC temporalis technique. The immediate post-op clinical and plain skull X-ray evaluation [Figure 5b], suggested good mobility of the bone flap to facilitate extracranial cerebral expansion for ICP modulation. This woman made such a rewarding, dramatic, and progressive postoperative neurological improvement that she resumed her pretrauma trading business 6 months post-op. Repeat cranial CT by this time also showed evidence of good intracranial neuraxial restoration, and good realignment of the cranial bone flap [Figure 5c]. There were no other issues concerning her general neurological status or that of the cranial bone flap as at the last clinic visit 18 months post-op when she was discharged from regular outpatient follow-up.

DISCUSSION

We have presented here a technical case series illustrating some aspects of a technique of hinge decompressive craniectomy (hDC), or hinge craniotomy (HC), which has potentials, using our technique, for great utility in resource limited practice environments of many LMIC.

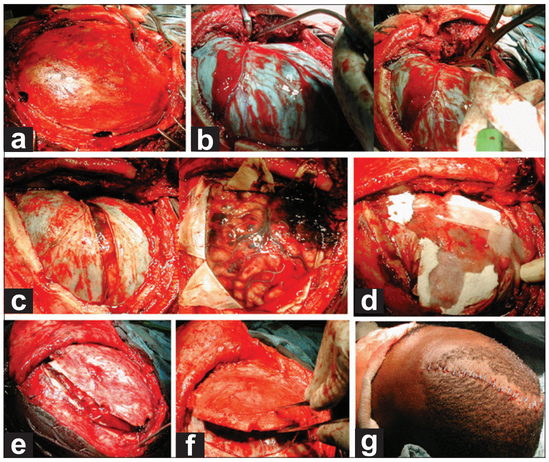

Figure 2: Illustrations for the surgical technique of HC utilizing the temporalis muscle, the hDC temporalis. (a) A large right-sided FTP osteoplastic cranial bone flap is being raised pedicled on the temporalis muscle; (b) completion craniectomy down to the middle fossa floor; (c) the tense, dusky dural brain covering is opened revealing the much swollen and contused brain; (d) after adequate debridement of the brain contusion a loose expansile dural closure is done; and (e) the bone flap is returned *in situ* on a hinge of its own temporalis muscle. Although the vertical cuts in the latter have been sutured back, the bone flap remains spontaneously mobile and is seen floating over the still swollen brain; (f) is an inset from another case further illustrating the great mobility of the hinged bone flap (g) water tight skin closure

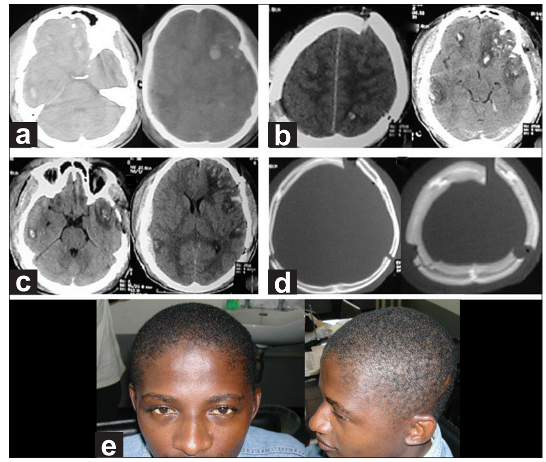

Figure 3: The cranial CT of case illustration A. (a) Axial images showing the significant brain injuries including bilateral multifocal haemorrhagic contusions, traumatic SAH, right parietal EDH and diffuse brain swelling with marked mass effect worse on the left (b-d) brain images 3 days following hDC temporalis showing good mobility of the bone flap and good extracranial cerebral expansion resulting in a positive reversal of the intracranial intraaxial mass effect. The ventricular space realignment is also evident; (e) clinical photograph of this patient at 12 months post-op. The bone flap is well settled in place; and it here presents no apparent evidence of impending inanition

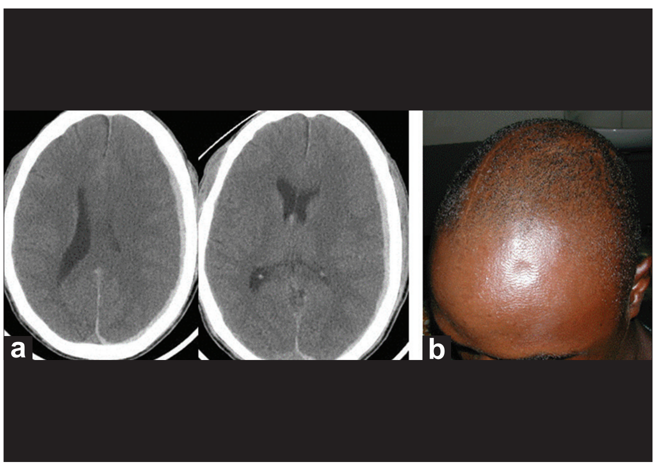

Figure 4: The clinical illustration B. (a) Axial cranial CT images showing the left-sided ASDH, significant ipsilateral brain swelling and mass effect; (b) the patient at the outpatient visit 3 months post-op. The bone flap is already spontaneously returned on-site obviating any need for subsequent cranioplasty

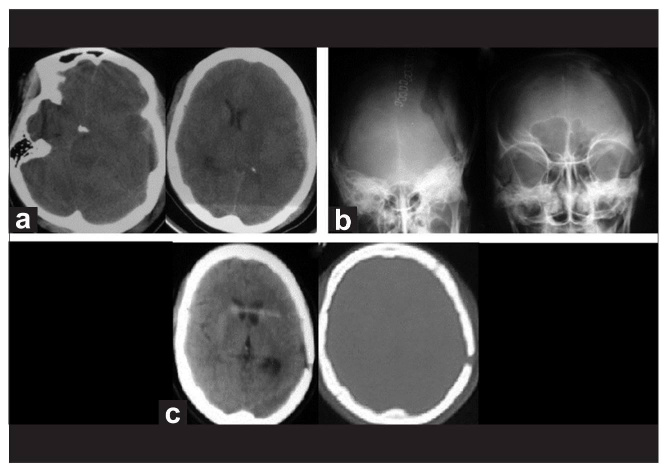

Figure 5: The clinical illustration C, severe HI following MVA. (a) Axial cranial CT films showing left ASDH and traumatic SAH; there is diffuse severe brain swelling with significant mass effect (b) plain skull X-ray images on POD 2 showing good bone flap mobility (c) axial brain and bone CT imaging 6 months post-op showing resolution of the intracranial intraaxial brain inflammatory changes. More particularly, the bone flap is seen here spontaneously sitting snugly back in place

In this technique, the hDC temporalis, the surgical procedure of HC is performed exactly as described by earlier workers but here the hinge used to achieve mobile cranial-decompressing storage of the skull flap *in situ* is the native temporalis muscle and not some other metallic implants.

The place of decompressive craniectomy, in the resource limited areas of the developing countries, as a damage control brain surgery[1,12,22] for traumatic raised ICP is a subject as yet hardly explored in the neurosurgical literature. This is a paradox; for the majority of the LMIC are hardly the place for the usual protocol driven, dedicated-neurocritical-care-units-based, and CT-intensive recommendations for the initial medical management of traumatic raised ICP; and DC, where there is a qualified neurosurgeon, may be the only means of addressing this critical problem in these regions.[1,2,5,16,22,26] In our own practice for instance, the only practical means available to us for nonsurgical control of traumatic raised ICP from diffuse brain swelling is that of low therapeutic intensity index[17] indeed, and consists essentially only of the patient's head elevation, osmotic diuretics (which are only mannitol and lasix), some sedation, and a highly competitive opportunity for intubation and mechanical ventilation in a multidepartmental ICU with limited bed capacity.[16] There is currently no facility for ICP monitoring either.

We have therefore recently begun to investigate the place of DC, even prophylactic DC, in our practice.[1,17]

Surgical decompressive craniectomy

The current gold standard technique of DC compels each patient to have at least two major surgical and general anesthetic encounters.[3,17] The first is for the acute cranial decompressive surgery and the second for the downstream cranioplasty of the ensuing cranial defect. Even so there are other important clinical and logistical considerations during the acute decompressive surgery concerning the storage site for the cranial bone flap raised. Current practices include further invasive surgical dissections, *in vivo*, in various other parts of the same patient's anatomy either distant to the cranial window in sites like the thighs or the abdominal wall;[4,6,10,23] or close by on the head, as a separate subgaleal pouch,[11,19,21] or *in situ* over the cranial window.[12,18,23] There are other choices for extracorporeal storage of the bone flaps. These include deep freezing, tissue banking, irradiation, and a variety of sterile solutions.[6,14,24] Needless to say, they all have important logistic considerations that make them impractical for difficult practice settings of majority of the LMIC. However, the procedure of HC which makes for *in vivo in situ* "storage" of the cranial bone flap during hDC obviates many of the problems of these other techniques of native or artificial bone flap storage.[17]

In situ hinge craniotomies

In the year 2007, the technique of HC was reported by three different independent working groups.[12,18,23] In it, the cranial bone flap raised in the typical fashion for the traditional DC is stored not *ex vivo*, nor elsewhere *in vivo*, but on site and over the craniotomy window in a door-hinge fashion. This is facilitated with some simple ingenious applications of titanium miniplates and screws. Not only is there preliminary evidence that the technique is able, just as well as the more traditional DC, to mitigate otherwise uncontrollable raised ICP, it has the particular attraction that it serves to eliminate the added surgical and or logistic imperatives of either the *in vivo* or extracorporeal disposition of the free cranial bone flap of DC. Above all, it virtually removes the clinical and surgical imperatives of post-DC cranioplasty and the possible complications of the cranioplasty.[13,17,25]

The surgical paradigms of the foregoing techniques of HC led us to the intuitive evolution of the technique here presented, the hDC temporalis. Here the native temporalis muscle is the hinge allowing the mobile retention, *in situ*, of the cranial bone flap. It is not a new neurosurgical invention per se but essentially a surgical technique based on the same old one of Wagner's and Cushing's;[7] only that it is here being explored for the new aim of making the procedure of DC as inexpensive as could make it economically feasible in any resource limited practice like our own. It appears so far that we have reasons to be hopeful of the eventual realization of this aim. And apart from this write up we could lay our hands on only one other recent publication, an abstract, suggesting the use of a technique similar to it by one other independent group of workers.[20] This publication was however in a non-English speaking medium making it difficult for us to really appraise the details of their technique in comparison with ours.

Limitations of the technique of hDC temporalis

There are a few possible limitations of this technique that readily come to mind. One is the possibility of wound complications, including breakdowns and CSF leak, under such possible wound tension. This has not been a major experience for us but it is well worth keeping this in mind by close attention to details to ensure a water tight two-layer closure of the surgical scalp wound.[12,18]

Without any doubt, there is enough ground to suspect that by retaining the cranial bone flap on-site under the scalp and directly over the swollen brain the techniques of HC including our own may limit the extents of the cerebral expansion and intracranial decompression possible following DC. Evidence exists however in some of the advanced neurosurgical units of the West that have the facility for ICP monitoring that uncontrollable preoperative raised ICP does respond to the procedure and that measurable good patients' outcomes are obtained.[18,23] In fact, a recent elegant study comparing both HC and the traditional DC in identical patient populations found that although the HC did indeed show comparatively smaller volume of postoperative cerebral expansion both procedures achieved equivalent ICP control under the same intensity of adjunct postsurgical general medical treatment protocols.[17]

The one main difference between the "new" technique of HC being proposed by us and the preceding ones is the fact that the temporalis muscle is retained in ours, while it is usually completely raised and so is out of the way of the cranial flaps in the others. It may therefore be logical to suspect that the presence of the bulk of the temporalis muscle may further limit the available volume for cranial decompression in our procedure. There is some evidence nonetheless that hinged frontal bone elevation of as little as 10 mm affords an up to 6% increase in the total cranial capacity[18] an apparently enough volume increase to modulate the Monro-Kellie doctrine in cases of raised ICP.[3] It is arguable however that the only objective way to explore this fact would be to monitor the ICP pre- and post-op and we certainly desire to do so whenever logistics permit. It is noteworthy all the same that this same limitation plaqued the previous reports on HC by earlier workers.[12,17,18,23] What is apparent to us so far however as evidenced in this report and our ongoing observations on the clinical and radiological outcomes of our patients is that the technique of HC based on the temporalis muscle as here described appears to be effectual in at least "borderline" cases of severe raised ICP.[18] It is possible that it may not be so feasible in cases with severe brain swelling.[18] Intraoperative clinical decision making in such situations therefore needs to be individualized and the more accommodating traditional DC may thus be found more appropriate.[17,18]

CONCLUSIONS

This is an illustrated technical case series showing the possible practical utility of the surgical technique of hinge decompressive craniectomy using the temporalis muscle, the "hDC temporalis." It is an intuitive adaptation of some earlier procedures of hinge DC also called hinge craniotomy which, in the advanced countries where they are described, make use of expensive metallic foreign body implants. This new procedure, in that it makes use of the patient's own body tissue, the temporalis muscle, is much less expensive than its forerunners; and our initial observations suggest that it might be just as effective as they are.

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