Cranial bony decompressions in the management of head injuries: Decompressive craniotomy or craniectomy?

WC Mezue, C Ndubuisi[1], SC Ohaegbulam[1], M Chikani, U Erechukwu[1]

Neurosurgery Unit, Department of Surgery, University of Nigeria Teaching Hospital, Enugu, [1]Memfys Hospital for Neurosurgery, Enugu, Nigeria

Abstract

Objective: Decompressive surgery is one of the available options in dealing with traumatic brain injury (TBI) when clinical and radiological evidence confirm that medical treatment may be insufficient. This can be achieved either by complete removal of the bone or by allowing it to float, but the indications and utility of these are yet to be resolved. This study examines the indications and outcome for both procedures.

Materials and Methods: Review of all cases of bony decompression done at the Memfys Hospital for Neurosurgery, Enugu, Nigeria from August 2002 to May 2010. Prospectively recorded data of CT, MRI, operating room, clinics and wards were utilized.

Results: There were 38 patients out of whom 35 were males and 3 females. The mean age was 36 years (range 15-80). The causes of the predisposing TBI were road traffic accidents (RTA) (79%), gunshot (10.5%), and assault (7.9%). Decompressive surgery was unilateral in 36 and bi-frontal in 2. Decompressive craniectomy with bone stored in anterior abdominal wall pocket was done in 8 patients and decompressive craniotomy with bone left *in situ* in 30. Of the latter, bone was unsecured and allowed to float in 13 and the craniotomy was lightly anchored with sutures in 17 patients. Surgery was performed within 24 h in 68.4% of cases. Mortality was 21.1% overall but was up to 25% in the more severely injured patients who had craniectomy.

Conclusion: Bony decompression is useful in the management of head trauma. Careful selection of cases and appropriate radiological assessment are important and will guide decision for either craniotomy or craniectomy.

Key words: Craniectomy, craniotomy, trauma flap, traumatic brain injury

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Introduction

The management of traumatic brain injury (TBI) is a major challenge because of the danger posed by brain edema and intracranial hypertension. Head injury is one of the most common cranial condition neurosurgeons deal with, and is likely to remain primarily under the purview of neurosurgeons for the foreseeable future. In the Memfys Hospital for Neurosurgery (MHN), it is the commonest indication for brain scanning.

Address for correspondence:
Dr. WC Mezue,
University of Nigeria Teaching Hospital,
P. M. B. 01129, Enugu, Nigeria.
E-mail: mezuec@hotmail.com

Severe TBI is a life threatening condition that requires aggressive neurosurgical management. It is well established that post-traumatic brain edema leading to refractory intracranial pressure is a major prognostic factor in TBI patients.[1] If adequate steps to decompress the intracranial pressure (ICP) are not taken early, recovery often results in severe morbidity.[2]

Options available for treatment include medical measures

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like maintaining good oxygenation, mild hyperventilation, use of mannitol or hypertonic saline and barbiturates.[3] Surgical options in the patients who do not have intra or extra-axial collections are limited to CSF drainage and cranial decompression. For patients with associated intracranial collections surgical steps anticipating progressive swelling and raised ICP must be considered at the time of primary evacuation. The dynamics obey the Monroe-Kelly doctrine and in spite of maximal medical treatment, intracranial pressure will continue to increase in a proportion of the patients.[3] The patients in whom intracranial pressure will continue to increase fall into two categories from the surgical point of view-patients where maximal medical therapy is no longer effective and patients where medical therapy needs to be augmented by cranial decompression. This distinction, which should be made early, greatly impacts the outcome in terms of morbidity and mortality. In centers where the intracranial pressure is not monitored, early decision should be based on close and frequent clinical re-assessment and repeat neuroimaging.

The first group of patients have a much poorer prognosis because of intractable raised ICP. Decompressive craniectomy has been advocated for the management of these patients, although, it has been argued that this may be at the price of poor quality of life in the survivors.[4,5] Nevertheless, this technique offers a strong appeal in these extremely ill patients and indeed the technique has been expanded to non traumatic situations,[6] Decompressive craniectomy is aimed at converting injury within the cranium with its fixed volume and limited reserve, into an open system capable of accommodating more mass.[7] Several complications have been reported for decompressive craniectomy in this setting[8] and the technique has been the subject of international randomized studies.[9, 10] Results from one of these studies, the DECRA study suggests that decompression has no advantages over medical therapy alone.[11] The result of the Rescue-ICP study, which is more rigorously defined, is still awaited.

The second group of patients have a more tractable ICP. These include patients who presented with moderate head injury (GCS 9-12) but who subsequently deteriorated with mass lesions causing significant brain shifts. For these patients a more limited operation in the form of decompressive *craniotomy* may be sufficient. In these patients, response to medical therapy is enhanced by bony decompression as part of planned intracranial procedures such as evacuation of hematoma. Effective decompression is achieved by allowing the cranial flap either to float completely free or to anchor it lightly with sutures. Both procedures require large cranial flaps.

In this study, we report our experience with and discuss the utility of both procedures.

Materials and Methods

All patients who had cranial decompressive surgery in the MHN between August 2002 and May 2010 were reviewed. Data recorded prospectively in the computerized tomography (CT), Magnetic Resonance Imaging (MRI) and operating room suites and from the intensive care unit and clinics were retrospectively reviewed. All patients had CT of the brain and 4 patients had MRI as part of the diagnostic workup. Follow-up scans were done as indicated. Perioperative antibiotic prophylaxis was used in all cases with 1gm ceftriaxone at induction. This was continued for 48-72 h post operatively.

In the absence of ICP monitoring, selection for operation was based on Glasgow coma score (GCS), image findings of severe TBI and clinical evidence of ICP unresponsive to maximal medical management. All patients treated with CSF drainage were excluded as were patients where it was impossible to determine a criteria for choosing one or other modality of treatment. Patients who had decompressive craniotomies either had admission GCS over 8 and subsequently deteriorated or had GCS less than 8 with imaging findings of intracranial hematoma. Patients who had decompressive craniectomy either had admission GCS less than 8 without any evidence of mass lesion on imaging but radiological and clinical evidence of sustained raised ICP or had mass lesions where ICP at surgery was accessed as likely to become intractable.

All patients were first resuscitated. Medical management included ventilation for patients with GCS below 8, maintaining good oxygenation as measured by both pulse oxymetry and blood gas analysis, mild hyperventilation to a pCO_2 of 4 to 4.5 KPa and use of mannitol. The duration of medical therapy for raised ICP varied in both cases being much shorter in patients with mass lesions.

Clinical outcome assessed infection rate and mortality. The discharge outcome was measured using the Glasgow outcome scale (GOS).

Results

There were 35 males and 3 females giving a male to female ratio of 12:1. The age range was 15 to 80 years with a mean of 36 years. The causes are as outlined in Table 1. Imaging findings are shown in Table 2. A combination of the findings was present in most of the patients. Extra axial collection without other intra-axial injury was present in 2 patients. Majority of patients who underwent decompressive craniotomies had associated mass lesions and 40% had associated midline shift on admission, while decompressive craniectomy patients had predominantly multiple brain contusions and diffuse axonal injury with midline shift in 87.5% and effacement of basal cisterns in 62.5%.

Intervention

Thirty patients had decompressive *craniotomies* and 8 had decompressive *craniectomies* with bone flap stored in abdominal pockets [Figures 1 and 2]. The majority of patients (68.4%) were operated upon within 24 h and 18.4% within 4 h of admission [Table 3]. Mannitol and mild hyperventilation to a pCO_2 of 4-4.5 KPa was used in all cases with GCS less than 5.

Decompression was unilateral in 36 patients (right 23, left 13) and bifrontal in 2 patients. The dura was left open in all cases of decompressive *craniectomy* and in 6 patients with *craniotomy*. Dural closure in the remaining 24 patients was with autologous material, pericranium in 21 and temporalis fascia in1. Two patients had incomplete duraplasty.

Of the 30 with decompressive craniotomy, the bone was left floating in 17 cases and anchored lightly with sutures in 13. In the patients who had craniectomy, subsequent cranioplasty was with bone stored in abdominal wall pocket in 5 and with polymethylmethacrylate (acrylic) in 1. Table 4 shows GCS at admission and operation. Six patients initially admitted with mild and 12 with moderate head injuries subsequently deteriorated from intracranial hematoma and needed craniotomies.

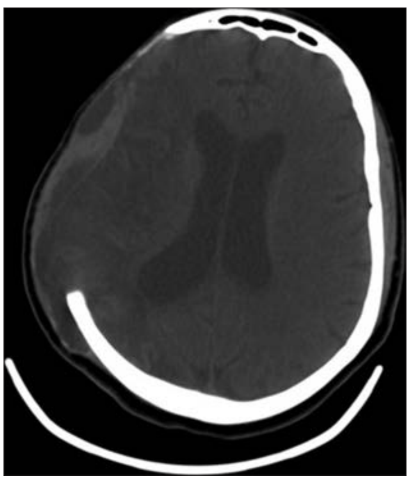

Figure 1: Right fronto-parietal decompressive *craniectomy*

Table 1: Causes of TBI

Causes	Decompressive craniotomy	Decompressive craniectomy	Total (%)
RTA	23	7	30 (78.9)
Gunshot	4	-	4 (10.5)
Assault	3	-	3 (7.9)
Fall	-	1	1 (2.6)
Total	30	8	38 (100)

Outcome

The patient's Glasgow outcome score (GOS) at discharge is compared with their admission GCS in Table 5. Six patients admitted with mild head injury subsequently deteriorated and had craniotomies. Outcome in this group was good with a GOS of 5 in 83.3%. Of the 12 patients admitted with moderate head injuries, 66.7% had a GOS of 3 or below.

The infection rate was 7.9%, two patients in the craniotomy group and one in the craniectomy group. Bone flap infection occurred in one patient necessitating discarding the bone. One patient was admitted with established post-traumatic meningitis and was not regarded as post-operative infection. One patient died before cranioplasty. Overall, mortality was 21.1%. Two patients (25%) in craniectomy group and 6 in the craniotomy group died. One patient admitted with mild head injury and meningitis died. The other 7 mortalities occurred in patients with severe head injury.

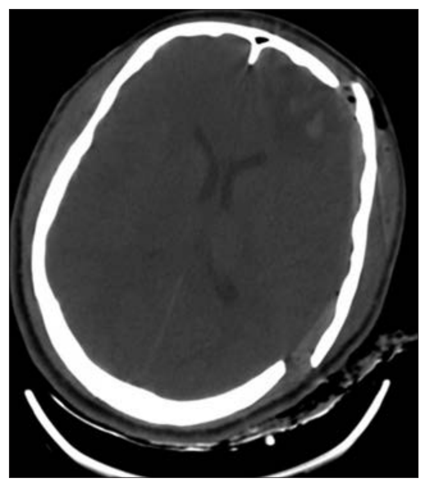

Figure 2: Left fronto parietal decompressive *craniotomy*

Table 2: Imaging findings

Findings	Decompressive craniotomy (n = 30) (%)	Decompressive craniectomy (n = 8) (%)	Total no. of patients
Brain contusion	6 (20%)	4 (50)	10
ICH	17 (56.7%)	1 (12.5)	18
ASDH	5 (16.7%)	2 (25)	7
EDH	2 (6.7)	-	2
DAI	1 (3.3)	3 (37.5)	4
Midline shift >10mm	12 (40%)	7 (87.5)	19
Effacement of basal cisterns	9 (30%)	5 (62.5%)	14

ICH=Intracerebral hemorrhage, ASDH=Acute subdural hematoma, EDH=Extradural hematoma, DAI=Diffuse axonal injury

Table 3: Admission to operation time

Time (hours)	Decompressive craniotomy	Decompressive craniectomy
	No. of patients (%)	No. of patients (%)
<4	5 (16.7)	2 (25)
4-12	2 (6.7)	3 (37.5)
12-24	13 (43.3)	1 (12.5)
24-48	4 (13.3)	2 (25)
48-72	3 (10)	-
>72	3 (10)	-
	30 (100)	8 (100)

Table 4: GCS on admission and at operation

Glasgow coma scale (GCS)	Patients	Operations	
		Craniotomies	Craniectomies
GCS on admission			
12-15	6		
9-12	12	NA	NA
3-8	20		
GCS at operation			
12-15	0	0	0
9-12	6	6	0
3-8	32	24	8
		30	8

Table 5: Discharge outcome using the Glasgow outcome scale (GOS)

Discharge GOS	Craniotomy *N*=30	Craniectomy *N*=8
Good recovery [5]	9 (30%)	-
Mild disability [4]	7 (23.3%)	2 (25%)
Mod disability [3]	5 (16.7%)	3 (37.5%)
Severe disability [2]	3 (10%)	1 (12.5%)
Death [1]	6 (20%)	2 (25%)

Discussion

Adequate decompressive craniotomy or craniectomy via large temporo-parietal trauma flaps are surgical modalities for management of severe TBI. Proper handling of the dura at the time of operation is essential in both techniques if decompression is to be achieved.[3] The dura was widely opened and the brain surface protected with gel foam or surgicel in all patients who had craniectomy. In the less critically swollen patients who had craniotomies, the dura was loosely repaired using autologous material providing space for expansion. The need for cranioplasty in those with craniectomy must be anticipated. Autologous bone storage in anterior abdominal wall pocket is a cost effective method in developing countries.[12]

Decompressive craniotomies with bone flap loosely fixed or left floating is adequate in patients with controlled ICP. In patients with malignant raised ICP, it is impossible to primarily replace the bone and craniectomies are necessary. This condition carries high morbidity and mortality. In our series, the mortality for this group was 25%. This is similar to reports in the literature.[13, 14] Mortality is lower (20%) in patients who had decompressive craniotomy. Excluding mortality in the patient who presented with meningitis from assault with a matchet, this falls to 16.7%. In keeping with other studies, mortality is related to severity of injury and intractable ICP. It is in the more severely injured patients that cranial decompression is indicated.

Comparison of patients with similar initial GCS (3-8) in the two groups suggests that survival for decompressive craniotomy flaps (20% mortality) may be better but this does not completely reflect the difference in the severity of the injury or the level of ICP in the two groups. The value of decompressive craniectomies for severe TBI still remains unresolved. The recently published DECCRA study,[11] suggests that although decompressive craniectomy achieved lowered ICP it did not lower mortality. This raises the question as to whether patients with ICP levels below 25mm Hg that are not sustained above 15 min should be regarded as candidates for decompressive craniectomies.[15] Such patients may benefit more from decompressive craniotomies as the 3-5 mm space gained by allowing the bone to float may be sufficient to accommodate the pressure. Many patients with middle cerebral artery (MCA) infarcts and subarachnoid haemorrhage (SAH) fall into this category. In addition, if patients with decompressive craniectomies survive, further surgery will be necessary to replace the bone flap with its associated morbidity.[8] These have resulted in poor uptake of decompressive craniectomies in our sub-region [16]

However, in a study comparing the efficacy of decompressive craniectomy and routine large temporoparietal flaps in unilateral acute post-traumatic brain swelling in severe TBI, Qui *et al*, showed that unilateral decompressive craniectomy was superior in controlling ICP and in reducing mortality. [17] They showed that neurological outcomes were improved, although, the rate of secondary surgeries was higher when compared to routine trauma flaps. Decompressive craniectomy has also been shown to decrease the therapeutic intensity level and the cumulative ischemic burden of the brain.[18] It is not surprising that the indications for decompressive craniectomies are rapidly expanding.[5, 6] It is now widely accepted treatment for large MCA territory infarcts [4, 19] and is increasingly being used for poor grade SAH.

Majority of the patients who had craniectomy in this study had RTA. This is probably an indication of the severity of head injury from this cause. All 4 patients with gunshot injuries received them from low velocity missiles. In the first 12 h, 62.5% of patients had craniectomy while only 23.4% had craniotomy during the same period. These findings indicate that decompressive craniotomy is more relevant for patients who are less severely injured. Imaging findings also showed that patients who had craniectomy were more critically injured with pronounced contusions, combinations of pathology and more midline shifts requiring urgent intervention to reduce severe raised intracranial pressure. 87.5% had significant midline shift and 62.5% had effacement of basal cisterns [Table 2]. This was 40% and 30% respectively for patients who had craniotomies indicating that these patients in general are less severely injured.

It is therefore possible to develop a clinico-radiological criteria for selecting patients for decompression in the absence of ICP monitoring. These two modalities of treatment should be seen as applying to different categories of patients and criteria for their use should be more rigorously defined. Currently the criteria overlap, especially in centers that do not routinely use ICP monitoring and this presents difficulties with data analysis. In such circumstances, patients with mass lesions with a potential to expand, especially in critical locations such as the temporal base, should be considered early for decompressive craniotomy. In this series, 6 patients admitted with mild head injury with a GCS of 12 subsequently deteriorated. The potential for this was predictable from their image findings, which showed ASDH in 3, EDH in 1 and ICH in 2. Patients with such lesions even when they do not require surgery immediately, should be admitted for observation in a neurosurgical facility with the potential for immediate intervention in case of any deterioration. When deterioration can be anticipated, early craniotomy may reduce need for a later craniectomy. On the other hand, patients with basal cistern effacement with multiple brain contusions with or without acute subdural haematoma should be considered early for decompressive craniectomy.

In centers where ICP is not routinely monitored, as is the case in many resource poor centers in developing countries, decompressive craniotomies should be the primary procedure, especially as the option of removal of the floating flap adds additional safety margin. Until more evidence on the utility of decompressive craniectomy becomes available, the low morbidity profile of decompressive craniotomies makes this a viable alternative even for the very severe TBI.

This study is limited by its retrospective nature and the fact that ICP was not directly monitored. The need for decompression was based on clinical and radiological evidence of raised ICP.

Conclusion

Traumatic brain injury (TBI) continues to be an enormous public health problem despite major advances in modern medicine. The cost to society is enormous. This study shows that adequate bony decompression can save lives. It is possible to predict patients who may benefit from decompressive craniotomy early in the care pathway and this modality appears to offer better outcomes in terms of both mortality and morbidity. This is particularly relevant for poor resource centers. Careful selection of cases and appropriate radiological assessment are important.

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