Unilateral Decompressive Craniotomy for Management of Refractory Intracranial Hypertension following Traumatic Brain Injury: Surgical Technique and Clinical Outcome

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ABSTRACT

Background: Post-traumatic intracranial hypertension due to brain swelling following Traumatic Brain Injury (TBI) remains presenting a challenge for neurosurgeons. The aim of treatment is usually directed towards maintaining the cerebral perfusion pressure as well as prevention of progressive intracranial hypertension which aggravates brain hypoxia. Objective: To estimate the efficacy of unilateral decompressive craniotomy as well as predicting factors of favorable clinical outcome. Patients and Methods: A prospective study included twenty five patients with unilateral brain edema and midline shift following TBI. All patients were clinically assessed using Glasgow coma scale (GCS) on admission and at time of surgery. Unilateral decompressive craniotomy was performed immediately for eight patients presenting with GCS \(\leq 8\), fifteen patients with GCS > 8 were operated upon within 2-4 days of admission after having decline of their GCS despite aggressive cerebral dehydration. Postoperative clinical outcome during six months follow up interval was assessed using Glasgow outcome scale (GOS) in addition to serial brain imaging. Results: Good clinical outcome was achieved in fifteen patients (75%) at 6 months follow up interval, while stationary course was noted in four patients (20%) and poor outcome for one patient (5%). The overall survival rate was 80% (twenty patients) with five cases of mortality (20%). Complications were encountered in seven patients (28%). Conclusion: Decompressive craniotomy is quite beneficial and may be the only choice for management of refractory intracranial hypertension due to unilateral brain swelling after severe TBI. It should be performed immediately for cases with GCS \(\leq 8\), while cerebral dehydration must be tried for cases with GCS>8 saving surgical intervention for those showing no improvement or deterioration. Initial GCS more than 8 and younger age groups seem to be the most important predictors of favorable clinical outcome.

INTRODUCTION

Management of severe traumatic brain injury (TBI) had always presented a major problem for neurosurgeons. During the acute phase, the aim of medical and/or surgical management is to prevent intracranial hypertension as well as to maintain the cerebral perfusion pressure. Many surgical procedures were performed to achieve this goal, some are consensual such as lobectomies and evacuation of haematomas. Decompressive craniectomy is used for treating medically uncontrolled intracranial hypertension resulting from post-traumatic brain edema. Kocher in 1901, reported the use of large craniectomy in management of refractory post-traumatic cerebral edema. This procedure was subsequently abandoned due to its high complication rate, however, the technique returned to be used widely later on and its indications remained controversial.

Conservative treatment of post-traumatic brain edema including hyperventilation, barbiturate coma and the use of intravenous mannitol or hypertonic saline sometimes may not cause satisfactory control of post-traumatic brain swelling and the patient is subjected to rising intracranial pressure. In such condition, decompressive craniotomy would be considered the only option for trial to stop the progressive deterioration. Hinge craniotomy is performed as a better alternative to decompressive craniectomy in order to reduce the need for subsequent cranioplasty among patients surviving severe brain injury. The main considered parameter is not the survival rate, but the post-operative functional outcome.
In this study, the clinical outcome after unilateral decompressive craniotomy was recorded and analyzed in order to estimate the efficacy of the technique as well as predicting factors of favorable outcome.

**PATIENTS AND METHODS**

This prospective study was conducted on twenty five patients admitted and operated upon in Cairo University Hospitals and Police Hospitals in the period starting June 2010 to December 2013.

All patients presented to the emergency unit following head trauma. Patients were carefully assessed, full neurological examination and the Glasgow Coma Scale (GCS) for each patient were recorded and resuscitation was performed.

CT scan was done revealing severe traumatic brain injury with subsequent intracranial hypertension, unilateral brain edema and midline shift. Patients with GCS $\leq 8$ (eight patients) underwent surgery on emergency basis, while the remaining (seventeen patients) were admitted to the ICU, received aggressive cerebral dehydration in the form of mannitol 20% (1 g/Kg body weight) divided on 3 daily doses and diuretics shortly after mannitol administration $\pm$ hyperventilation maintaining PaCO$_2$ between 30 and 36 mmHg in twelve patients whom mechanical ventilation was needed (5 patients with GCS above 11 didn't need mechanical ventilation).

Cerebral dehydration was tried for a maximum period of 4 days provided no deterioration occurred. Fifteen patients were operated upon after 48 hours of failure of conservative treatment while two patients showed decline in GCS after 3 and 4 days.

All patients included in this study were presenting with post-traumatic unilateral brain edema and midline shift, while patients with GCS $<5$, bilateral dilated fixed pupils or lost brain stem reflexes were excluded.

**Operative technique**

Under general anesthesia, with the patient's head turned 70-80° contralaterally and after installation of proper antibiotic and anti-epileptic coverage. Large fronto-temporo-parietal question-mark skin incision was done with its lower end just in front of the ear tragus. Careful sparing of the superficial temporal artery (to avoid necrosis of the flap) as well as the frontotemporal branch of the facial nerve while splitting the temporalis fascia was performed.

Bone flap measuring about 11x13 cm based on the temporalis muscle was performed with proper beveling of its rostral side. The dura mater was then incised in X-shaped manner creating four triangles based on sides of the craniotomy (this pattern may be modified according to the degree of intra-operative brain swelling.

Subdural hematomas (in seven patients) were evacuated, any cortical bleeding was secured and the whole brain surface was covered by surgicel.

Duoplasty was then performed using loose pericranial graft (in fifteen patients) or synthetic dural patch (in ten patients) sutured gently to the heads of the four dural triangular flaps.

The bone flap was gently replaced with loose suturing of the overlying temporalis fascia to the pericranial edges using 4 or 8 interrupted non absorbable sutures leaving the flap gently overlying the swollen brain underneath without any compressing force. The wound is then closed in layers with subgaleal suction drain.

Patients were admitted to the ICU under close observation and monitoring of their vital signs, neurological status and GCS. CT brain scan was performed on the first post-operative day, then on the third and seventh day (Fig.1) except if any neurological deterioration occurred. Then CT scans were performed at weekly intervals for the first month and monthly intervals for the next 5 months.

Clinical outcome was assessed using Glasgow Outcome Score (GOS) immediately post-operative and during the hospital stay which ranged from 14-30 days (mean 20 days), in addition to one and four months following surgery. Good clinical outcome is considered when GCS improved by 2 or more points, Stationary course if GCS had no change or one point of increase while poor outcome refers to any decline of GCS.

**Statistical methods:**

Data were analyzed using IBM SPSS Advanced Statistics version 20.0 (SPSS Inc., Chicago, IL). Numerical data were expressed as median and range. Qualitative data were expressed as frequency and percentage. Chi-square test (Fisher’s exact test) was used to examine the relation between qualitative variables. A p-value $< 0.05$ was considered significant.
RESULTS

Twenty five patients were included in the study, eighteen males (72%) and seven females (28%). The patients age ranged from 7 - 49 years (mean 27). Age distribution of the patients is illustrated in table 1.

<table>
<thead>
<tr>
<th>Age group (years)</th>
<th>Number of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Below 10</td>
<td>2 (8%)</td>
</tr>
<tr>
<td>10 – 20</td>
<td>6 (24%)</td>
</tr>
<tr>
<td>20 – 30</td>
<td>7 (28%)</td>
</tr>
<tr>
<td>30 – 40</td>
<td>3 (12%)</td>
</tr>
<tr>
<td>40 – 50</td>
<td>4 (16%)</td>
</tr>
<tr>
<td>50 – 60</td>
<td>3 (12%)</td>
</tr>
</tbody>
</table>

On admission, each patient's clinical status was carefully assessed and GCS was recorded. CT scan was performed reporting unilateral brain edema, midline shift in all patients with associated brain injuries as illustrated in table 2.

<table>
<thead>
<tr>
<th>Associated injuries on admission</th>
<th>Number of patients (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unilateral acute subdural hematoma</td>
<td>7 (28%)</td>
</tr>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>21 (84%)</td>
</tr>
<tr>
<td>Hemorrhagic contusions</td>
<td>8 (32%)</td>
</tr>
<tr>
<td>Skull fractures</td>
<td>9 (36%)</td>
</tr>
</tbody>
</table>

Unilateral brain edema with midline shift was recorded on the right side in seventeen patients (68%), lateralizing signs were noted in fifteen patients (60%) on admission in the form of unilateral dilated pupils in eight patients (32%), contralateral weakness in seven patients (28%).

GCS of patients on admission was recorded. All patients with GCS 8 or less (eight patients-32%) were operated upon immediately, the remaining seventeen patients were operated upon after decline of their GCS despite aggressive cerebral dehydration within 2 days (fifteen patients – 60 %), 3 and 4 days for two patients (8%).

GCS of patients on admission and at the time of operation is illustrated in figure 2.
All seven patients having associated acute subdural haematoma were surgically evacuated. These patients presented with GCS less than 8 and were operated upon immediately.

Clinical evaluation was recorded at one month and 6 months postoperatively and assessed as Glasgow Outcome Scale (GOS) in table 3.

As shown in table 3, good clinical outcome was achieved in thirteen patients (59%) after 1 month follow up. Five of these thirteen patients (38.4%) were having GCS \( \leq 8 \) at the time of operation. At 6 months postoperative interval, good outcome was noted in fifteen patients (75%) with those having GCS at the time of surgery \( \leq 8 \) were seven patients (46.6%).

At six months follow up interval, residual neurological deficits were noted in six patients (30%) in the form of contralateral hemiparesis in all six patients, dysphasia in four patients (20%) having initial dominant hemisphere injury.
Postoperative complications (table 4) were encountered in seven patients (28%). Two patients developed postoperative intracerebral haemorrhage and both had been surgically evacuated within the 1st postoperative day. One of them died few hours following surgery. Four patients (16%) experienced seizures in a period ranging from 12 hours to 5 days postoperatively, while one patient presented with seizures on admission, all were controlled medically within 2–7 days. One patient (4%) had postoperative cerebritis on the 5th postoperative day and was treated by broad spectrum intravenous and intrathecal antibiotic therapy, infection was controlled in 2 weeks, the patient developed hydrocephalus 5 days later and was operated upon for ventriculo-peritoneal shunt placement.

The mortality rate in this study was 20% (5 patients) at 6 month interval (all were presenting with GCS ≤ 8). Three patients died within 1–10 days postoperatively due to cardiac and respiratory failure, while two patients died within few days following the 1st postoperative month from severe chest infection and cardiac failure.

Table 5 illustrates the relation between different factors and good clinical outcome at 6 month postoperatively.

As shown in table 5 -although statistically insignificant- good clinical outcome was related to several factors as initial GCS, age, timing of surgical intervention, which may be considered as predicting factors for good outcome after being widely studied with larger series.

**DISCUSSION**

Post-traumatic intracranial hypertension due to brain swelling following Traumatic Brain Injury (TBI) remains a challenge for neurosurgeons as well as neurointensive care staff. The aim of treatment is usually directed towards maintaining the cerebral perfusion pressure as well as prevention of progressive intracranial hypertension which aggravates brain hypoxia. 10,11

Intracranial pressure monitoring is an important tool for evaluation and follow up of patients. 21 However, since ICP monitoring was not feasible in both centers where cases were managed, clinical, vital and radiological follow up were used for evaluation and follow up of patients included in the current study.

Decompressive craniectomy/craniotomy was a subject of great debate and numerous publication over the last two decades, as an aggressive procedure for treating post-traumatic brain swelling that does not respond to medical therapy which occurs in 10 to 15% of patients and contributes to increased rates of morbidity and mortality. 19

In this study, Decompressive craniotomy - as a better alternative to craniectomy which needs further intervention (cranioplasty) later on - was performed in 25 patients with unilateral brain swelling following TBI. Good clinical outcome was achieved in fifteen patients (75%) at 6 months follow up interval, while stationary course was noted in four patients (20%) and poor outcome for one patient (5%). The overall survival rate was 80% (20 patients) with five cases of mortality (20%). Complications were encountered in seven patients (28%).

Survival rates since the late 1980s were reported to be as high as 70%, while more recent studies revealed survival rates ranging from 60 to 95%, with favorable outcome in 60 – 70% of survivors. 14,15

Several predictive factors for prognosis of decompressive craniotomy were considered, most
importantly the initial GCS and age group of patients as well as timing of surgical intervention, associated brain lesions and medical status of patients. 12

Gouello et al. 12 performed unilateral decompressive craniectomy in fifty eight cases ranging from 2–64 years of age with TBI and associated unilateral brain swelling. They reported 50% favorable clinical outcome at mean follow up period of 30 months. Surgical complications were observed in 6.7% of cases. Seventeen deaths occurred during the first postoperative month, these patients were excluded from the follow up. This slightly differs from the results of the current study with less rate of favorable clinical outcome (75% in this study). This is mainly attributed to the longer follow up period. Less complication rate was reported (28% in this study) which is owed to the difference in sample size as well as excluding mortalities within the first postoperative month.

Gouello and colleagues found the initial GCS greater than 8 as the only statistically significant predictive factor for good long-term outcome.

Saade et al 22 retrospectively analyzed the clinical outcome in fifty six patients with unilateral brain swelling and midline shift following TBI who underwent unilateral decompressive craniectomy (96.4%) of patients, in order to evaluate the different prognostic factors. They reported the presence of mydriasis with absent pupillary reflex and GCS 4 & 5 as the only statistically correlating predictor of poor prognosis. Sharda et al 26 reported postoperative hypoxia and unmaintained cerebral perfusion pressure as important predictor of poor prognosis in their study on one hundred and ten patients undergoing decompressive craniectomy after TBI.

The Cochrane collaboration 2009 23 reviewed the literature based on one hundred and fifty four studies. The review revealed a real benefit of decompressive craniectomy in patients with severe TBI in terms of reduction of mortality rate and providing better chance for long-term favorable outcome.

Differences in age groups were observed between various series. Better clinical outcome was usually associated with younger patient population. In this study at six months follow up interval, eleven out of fifteen patients with good outcome (73.3%) were below 30 years of age which goes in agreement with different studies; Guerra et al 13 excluded patients over 50 years of age from their study. Taylor et al 27 studied pediatric series, while Echer et al 6 included patients with a mean age of 24 years and all reported higher rates of favorable prognosis with younger age groups.

Time for operative decompression was also studied analyzing its relation to morbidity and/or subsequent mortality. In agreement with this study, time to surgical intervention did not appear to be a reliable prognostic factor. However, patients with initial GCS ≤ 8 were operated upon immediately as well as those who experienced declines of GCS later. Faleiro et al 7 reported slightly higher mortality rate in early surgery group than when surgery was performed after 24 hours (59% and 53%). Wen et al 29 noted no improvement of functional outcome with early surgery.

Gaab et al 11 studied thirty seven patients below 40 years of age with initial GCS ≥ 7, they obtained better survival and mortality rates (86.5% and 13.5%) than this study. This difference is attributed to the exclusion of older age and lower GCS from their study which demarcates both factors as important predictors of good prognosis. Similarly, Schneider et al 25 reported (91.6%) survival rate of their cases below 30 years of age, they determined the age limit for decompressive craniectomy at a maximum of 50 years.

Schmidt et al 24 performed hinge craniotomy using titanium plates in a hinged fashion for cerebral decompression in twenty five patients with mean age of 38.2 years, they reported 52% survival rate which is much less than this study (75%). This is mostly attributed to the differences in age group, initial GCS and surgical technique. Two of their cases required subsequent cranioplasty due to cranial deformity and infection.

CONCLUSION

Decompressive craniotomy is quite beneficial and may be the only choice for management of refractory intracranial hypertension due to unilateral brain swelling after severe TBI. It should be performed immediately for cases with GCS ≤ 8, while cerebral dehydration must be tried for cases with GCS>8 saving surgical intervention for those showing no improvement or deterioration. Initial GCS more than 8 and younger age groups seem to be the most important predictors of favorable clinical outcome.

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