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Original Research Article

A Prospective Study of Complications and Outcome after Decompressive Craniectomy in Traumatic Brain Injury in a Tertiary Care Hospital

Dr. Gaurav Dhakre[1], Dr Amit Dagar[2], Dr. Laxmi Narayan Gupta[3]

[1]Consultant Neurosurgery, Nayati Hospital, Agra, Uttar Pradesh.
Ex-Senior Resident, Department of Neurosurgery, Post Graduate Institute of Medical Education and Research & Dr. Ram ManoharLohia Hospital, New Delhi
[2]Assistant Professor, Department of Neurosurgery, Vardhman Mahavir Medical College & Safdarjung Hospital, New Delhi
[3]Professor, Department of Neurosurgery, Post Graduate Institute of Medical Education and Research & Dr. Ram Manohar Lohia Hospital, New Delhi

Corresponding Author: Dr Amit Dagar

ABSTRACT

Background: Decompressive craniectomy is most effective when used in conjunction with duraplasty. Decompressive craniectomy already has been proposed as a last ditch procedure in cases of uncontrollable raised intracranial pressure of various origins.
Methods: This was a prospective observational study of patients with traumatic brain injury who underwent Decompressive craniectomy over a period of 18 months. A total of 96 patients were included in the study. Patients were followed up over a period of 3 months to identify the complications and outcome after decompressive craniectomy. The data was analysed using SSPE software (Chicago, Illinois, USA). P value of 0.05 was considered as statistically significant.
Results: Final outcome was compared with various variables and there was no significant correlation when compared with age, sex, mode of injury, side and type of procedure (p-value>0.05). On comparision of final outcome with preoperative GCS, postoperative GCS, and postoperative neurological status there was significant correlation (p-value<0.05). Incidences of complications were compared with various variables but no significant correlation found.
Conclusion: The survival rate of 83.9% was promising and 48.4% had favourable outcome. We conclude that those patients who had poor pre and postoperative GCS, they had more incidence of unfavourable outcome.

Key words: Decompressive Craniectomy, Traumatic Brain Injury, Glasgow Outcome Scale

INTRODUCTION

Trauma is the commonest cause of death in young people worldwide and half the fatalities are caused by traumatic brain injury. [1] India holds the highest number of road accidents in the world. According to the National Crime Records Bureau, total of 4,96,762 'Traffic Accidents' were reported during the year (2015), which include 4,64,674(93.5%) 'Road Accidents', 2,669(0.5%) 'Railways Crossing Accidents' and 29,419 (5.9%) 'Railway Accidents'. The traffic accidents caused injuries to 4,86,567 persons and 1,77,423 deaths during 2015. [2]

Mortality and morbidity rates for TBI patients remain high despite improvements in emergency care, medical and surgical treatment options, and rehabilitation. The common treatment for

TBI is to stabilize the primary injury and eliminate conditions which may lead to secondary injuries. [3]

The pathophysiological entity of post traumatic brain swelling is not yet fully understood. It has been indicated that cytotoxic edema, rather than vasogenic edema could contribute to this phenomenon. Acute post traumatic brain swelling can be classified into hemispherical brain swelling and diffuse brain swelling based on CT scans. Without appropriate management, the subsequent increase in ICP with extensive swelling and distension of cerebral tissues would lead to deterioration of patients. The treatment of brain swelling and associated intracranial hypertension involves reducing the volume of one of the intracranial constituents such as CSF, the use of osmotic diuretics to reduce brain extracellular water. Other methods include elevation of the head, sedation, paralysis and hypothermia. Another option to reduce the ICP when refractory to treatment is to increase the intra cranial volume by performing a decompressive craniectomy. [1] According to Brain Trauma Foundation guidelines, DC is considered in two different situations. It is performed at the time of evacuation of a space occupying ICH or it is performed in patients with diffuse brain swelling and ICH after maximal medical treatment. [3]

DC surgery involves removal of large bone flap on the side of the affected brain hemisphere to increase the volume of cranial cavity in order to create more space for the swelling of brain and is most effective when used in conjunction with dural opening and duraplasty. [1,4] DC already has been proposed as a last ditch procedure in cases of uncontrollable raised ICP of various origins including cerebral infarction, diffuse cerebral hypoxia, subarachnoid hemorrhage, and traumatic brain injury. [5,6] Many studies show that DC is a technically simple operation with a low incidence of complications. [4]

Most papers [1,3,5-7,11,15,16] have concentrated on treatment of intracranial hypertension and outcome and relatively few have detailed the complications of the procedure. Whilst herniation through the craniectomy defect has been reported as a complication, this phenomenon occurs so commonly that it could almost be the natural sequel of the decompressive procedure. Subgaleal and subdural effusion occurs so commonly with DC that it is merely considered a routine. [5]

Syndrome of the trephined (also known as the as sinking flap syndrome) is experienced by the proportion of the patients following large craniectomy.

Whilst hydrocephalus develops primarily as a result of severe head injury, it is possible that a DC could alter CSF dynamics adversely and thereby placing this group of patients at a great risk of developing hydrocephalus [5,7] Development of the new contusion and hematoma or expansion of the preexisting contusion and hematomas especially around the margin of craniectomy site has also been reported by many researchers. CSF leak has been mentioned in context of inadequate dural closure, inadequate galeal and skin closure, local infection and hydrocephalus. DC increases the incidence of delayed intracranial hematomas and subdural effusion, some of which need further surgical intervention. [8-11]

This study is intended to elaborate the complications associated with DC. The neurosurgeons should be prepared to diagnose and treat a spectrum of DC complications.

REVIEW OF LITERATURE

Decompressive craniectomy has been in existence since ancient times. However, first reports of more recent clinical use come from the beginning of the 20th century, when it was used as a palliative treatment for symptoms of the raised ICP, mostly in patients with brain tumors. Apart from traumatic brain injury it has been used for ICP control in malignant cerebral edema following stroke, intracranial hemorrhage, subarachnoid hemorrhage, infections and other encephalopathies associated with brain edema. [7]

The Brain Trauma Foundation guidelines for the management of severe traumatic injury relegate DC to the second tier of therapy for severe TBI along with barbiturates and induced hypothermia. Improved outcome following DC is categorized as class III evidence in the latest edition of these guidelines and it is mentioned as an option in the evidence based guidelines for the surgical management of acute subdural hematoma. Bilateral DC has thus usually been used as a last resort therapy. [12]

When the skull removed in the setting of elevated ICP, it is immediately lowered and mass effect on midline structures is improved. However, DC is not without complications.

SeungPil Ban et al [13] have found in the analysis of complications following DC for traumatic brain injury that several complications occurred after the surgery, such as, contusion expansion, postoperative epilepsy, external cerebral herniation, ICH contralateral to the craniectomy defect, subdural effusion, CSF leakage through the skin incision, postoperative infection, posttraumatic hydrocephalus, and syndrome of the trephined.

Eightynine patients, mean age of 51.4 years old, underwent DC. Hematoma contralateral to the DC defect occurred in 5 patients. Contusion expansion occurred in 11 patients. External cerebral herniation occurred in 13 patients and CSF leakage in 2 patients. Postoperative infection occurred in 4 patients. Subdural effusion occurred in 29 patients and was the most common complication encountered. Posttraumatic hydrocephalus occurred in 10patients and a ventriculoperitoneal (VP) shunt was placed in all. Syndrome of the trephined occurred in 8 patients, and these patients improved after cranioplasty. The clinical outcomes were determined using GOS score. Final outcomes were evaluated at postoperative 6 months or at death. Twenty one of 89 patients who underwent DC died within 1 month of surgery (GOS 1). Of these, 15 patients died of intractable intracranial hypertension and 6patients succumbed to other medical problems. Of the 68 survivors after DC, 42 patients achieved functional recovery (GOS 4 & 5) and 26 nonfunctional recovery (GOS 2 & 3). Their analysis showed that patients with the poor GCS score (≥ 8) at admission ($p < 0.001$), older patients (≥ 65, $p = 0.010$), patients with the midline shift exceeding 10 mm ($p < 0.05$) and patients with bilaterally unreactive pupils ($p < 0.005$) showed worse clinical outcome rates.

Complications following DC for TBI were found to occur at specific times, and the poor GCS score (≤ 8) and the older age (≥ 65) were found to be related to the occurrence of these complications. In addition, the lack of complications was found to be significantly associated with functional recovery (GOS 4&5) after surgery, and contusion expansion was found to affect postoperative outcome significantly.

S. Honeybul [5] has found in a retrospective analysis that was undertaken of 41 patients who had a DC for severe head injury in the years 2006 and 2007 at the two major hospitals in Western Australia. Complications attributable to the DC were herniation of the cortex through the bone defect, 18 patients; subdural effusion, 22 patients; seizures, 5 patients and hydrocephalus, 4 patients. Complications attributable to the subsequent cranioplasty were infection, 4 and bone flap resorption, 6 patients. Syndrome of the trephined occurred in 3 of those patients whose bone flap had significantly resorbed. Two deaths occurred as a direct complication of the craniectomy or cranioplasty procedure.

Pedro Grille et al [14] studied the DC in severe traumatic brain injury: prognostic factors and complications total of 64 patients with severe TBI who underwent a DC were studied. The overall mortality in the study was 43% (27/64). Of the patients who survived, 14 were discharged from the ICU with severe neurological lesions (GOS

2 or 3), while 22 had good neurological outcomes (GOS 4 or 5). Of all patients studied, 22 had good neurological outcomes and were discharged from the ICU without neurological lesions or with light lesions.

Salvatore Chibbaro et al [15] have studied the role of DC in the management of severe head injury with refractory cerebral edema and intractable intracranial pressure. They retrospectively reviewed a series of 221 patients operated on for a head injury during a 25-month period. Of these, 48 patients underwent a DC. All data available on patient's GCS score, pupil size and reaction, and ICP were collected and analyzed. The patient's outcome was evaluated by the GOS and the results compared with the data available in the Traumatic Coma Data Bank. Furthermore, the results were analyzed in respect of the time of surgical intervention (early or late), age, and the preoperative GCS. DC reduced the midline shift in all .At a mean follow-up of 14 months, 6 patients died, 7 were discharged home with a GOS of 5, 18 showed a favorable outcome after rehabilitation with a GOS of 4 and 5, 6 had a severe disability (GOS 3), 9 were in a vegetative state (GOS 2), and 2 were lost to follow-up. The younger age, earlier surgery, and higher preoperative GCS score were related to better outcome ($P < .001$, $P < .05$, and $P < .034$, respectively). Their results seem to support the idea that DC coupled with neurointensive care may be an effective way to reduce intractable raised ICP, and probably to improve patient outcome.

Arabi et al [16] have found in the study of outcome following DC for malignant swelling due to severe head injury. The numbers of patients in the study were 50. Subdural hygroma developed in 25, contusion progression developed in 8, wound infection occurs in 1, hydrocephalous in 5 patients and bone resorption in 6 patients. They reported a favourable outcome in 13 of 17 patients, when the DC was performed within 48 hrs. Surgeons at the University of Virginia Health Science Center performed 35 bifrontal craniectomies to treat severe refractory post traumatic cerebral edema. They found a statistically significant improvement in outcomes after bifrontal DC. Moreover, patients undergoing surgery within 48 hrs of admission had favourable outcomes in 13 of 28 cases compared to unfavourable outcomes in 7 patients who underwent the procedure more than 48 hours after admission. [6]

Flint et al [17] in their study found post-operative expansion of hemorrhagic contusions after unilateral DC in severe traumatic brain injury. Expansion of hemorrhagic contusions in TBI patients is common, but its frequency following DC has not been well established. The aim of this retrospective study was to determine the rate of hemorrhagic contusion expansion following unilateral hemicraniectomy in severe TBI, to identify factors associated with contusion expansion, and to examine whether contusion expansion is associated with worsened clinical outcomes. CT scans of 40 consecutive patients with non-penetrating TBI who underwent decompressive hemicraniectomy were analyzed. Hemorrhagic contusion volumes were measured on initial, last pre-operative, and first post-operative CT scans. Mortality and 6-month GOS score were recorded. Hemorrhagic contusions of any size were present on the initial head CT scan in 48% of patients, but hemorrhagic contusions with a total volume of >5 cc were present in only 10%. New or expanded hemorrhagic contusions of >or=5 cc were observed after hemicraniectomy in 58% of patients. The mean volume of increased hemorrhage among these patients was 37.1+/-36.3 cc. The Rotterdam CT score on the initial head CT was strongly associated with the occurrence and the total volume of expanded hemorrhagic contusions following decompressive hemicraniectomy. Expanded hemorrhagic contusion volume greater than 20 cc after hemicraniectomy was strongly associated with mortality and poor 6-month GOS even after controlling for age and initial GCS score. Expansion of hemorrhagic contusions is common after decompressive hemicraniectomy following severe TBI. The volume of hemorrhagic contusion expansion following hemicraniectomy is strongly associated with mortality and poor outcome. Severity of initial CT findings may predict the risk of contusion expansion following hemicraniectomy, thereby identifying a subgroup of patients who might benefit from therapies aimed at augmenting the coagulation system.

Huang AP et al [18] studied the role of DC as the primary surgical intervention for hemorrhagic contusion and its outcome. Fifty-four consecutive patients with GCS scores of less than or equal to 8, a frontal or temporal hemorrhagic contusion greater than 20 cm^3 in volume, and a midline shift of at least 5 mm or cisternal compression on CT scan were studied. Sixteen underwent traditional craniotomy with hematoma evacuation, and 38 underwent craniectomy as the primary surgical treatment. Mortality, reoperation rate, Glasgow Outcome Scale-Extended (GOSE) scores, and length of stay in both the acute care and rehabilitation phase were compared between these two groups. Mortality (13.2% vs. 25.0%) and reoperation rate (7.9% vs. 37.5%) were lower in the craniectomy group, whereas thelengthofstayinboththeacutecaresettingand therehabilitationphaseweresimilarbetween these two groups. The craniectomy group also had better GOSE score (5.55 vs. 3.56) at 6 months. DC is safe and effective as the primary surgical intervention for treatment of hemorrhagic contusion. This study also suggests that patient with hemorrhagic contusion can possibly have better outcome after craniectomy than other subgroup of patients with severe traumatic brain injury.

Jiang JY et al [19] studied the efficacy of standard trauma craniectomy for refractory intracranial hypertension with severe traumatic brain injury. To compare the effect of standard trauma craniectomy (STC) versus limited craniectomy (LC) on the outcome of severe TBI with refractory intracranial hypertension, they conducted a study at five medical centers of 486 patients with severe TBI (GCS</= 8) and refractory intracranial hypertension. In all 486 cases, refractory intracranial hypertension, caused by unilateral massive fronto-temporoparietal contusion, intracerebral/ subdural hematoma, and brain edema, was confirmed on a CT scan. The patients were randomly divided into two groups, one of which underwent STC (n = 241) with a unilateral fronto temporoparietal bone flap (12x15cm), and the second of which underwent LC(n=245) with a routine temporoparietal bone flap (6 x 8 cm). At 6-month follow-up, 96 patients in the STC group had a favorable outcome on the basis of the GOS, including 62 patients who had a good recovery and 34 who showed moderate deficits. Another 145 patients in the STC group had an unfavorable outcome, including 73 with severe deficits, 9 with persistent vegetative status, and 63 who died. By comparison, only 70 patients in the LC group had a favorable outcome, including 41 who had a good recovery and 29 who had moderate deficits. Another 175 patients in the LC group had an unfavorable outcome, including 82 with severe deficits, seven with persistent vegetative status, and 86 who died ($p < 0.05$). In addition to these findings, the incidence of delayed intracranial hematoma, incisional hernia, and CSF fistula was lower in the STC group than in the LC group ($p < 0.05$), although the incidence of acute encephalomyelocele, traumatic seizure, and intracranial infection was not significantly different in the two groups ($p > 0.05$). The results of the study indicate that STC significantly improves outcome in severe TBI with refractory intracranial hypertension resulting from unilateral fronto temporoparietal contusion with or without intracerebral or subdural hematoma. This suggests that STC, rather than LC, be recommended for such patients.

X. F. Yang et al [20] studied the surgical complications secondary to DC in patients with a head injury. They reviewed a large series of patients who underwent this surgical procedure to establish the incidence and type of postoperative complications. From 1998 to 2005, DC was performed in 108 patients who suffered from a closed head injury. The incidence rates of complications secondary to DC and risk factors for developing these complications were analysed. In addition, the relationship between outcome and clinical factors was analysed. Twenty-five of the 108 patients died within the first month after surgical decompression. A lower GCS at admission seemed to be associated with a poorer outcome. Complications related to surgical decompression occurred in 54 patients. Herniation through the cranial defect was the most frequent complication within 1 week and 1 month, and subdural effusion was another frequent complication during this period. After 1 month, the “syndrome of the trephined” and hydrocephalus were the most frequent complications.

Gerd-Helge Schneider et al [21] studied the effect of secondary decompression on ICP, cerebral perfusion pressure (CPP) and neurological outcome. 62 patients decompressed after severe head injury were included in the retrospective study. Decompression was performed when ICP could not be controlled by non-surgical treatment. Mean age was 36.6 years. Initial GCS was 6. Outcome was determined 6 months after trauma according to the GOS and the functional Barthel-Index (BI). In the last hour before decompression ICP was40.5 ± 1.6 mmHg and CPP was 65.3 ± 2.1 mmHg. ICP was significantly reduced to 9.8 ± 1.3 mmHg by surgery and CPP improved to 78.2 ±2.3 mmHg. 12 hrs following decompression mean ICP rose to 21.6 ± 1.7 mmHg again (CPP: 73.6 ± 1.7 mmHg), but in the following period ICP could be kept below 25 mmHg in the majority of patients. 6 months after trauma 22.5% of the patients had died (except one all these patients were aged more than 50 yrs). 48.4% of patients survived with an unfavourable outcome (GOS 2 + 3), while 29.1% had a favourable outcome (GOS 4 + 5). They found that DC is highly effective to treat otherwise uncontrollable intracranial hypertension and improves CPP.

Barbara M.Eberle et al [3] have studied the surgical control of traumatic intracranial hypertension may improve outcome. The analysis included the effect of DC on ICP and timing of DC on functional outcomes and survival. Of 106 patients who underwent DC, 43 patients met inclusion criteria. Of those, 34 were operated within the first 24hfromadmission.DCdecreasedtheICPsignificantlyfrom37.8± 12.1mmHgto12.7 ±8.2 mmHg in survivors and from 52.8 ± 13.0 to 32.0 ± 17.3 mmHg in non-survivors. Overall 25.6% died, and 32.5% remained in vegetative state or were severely disabled. Favourable outcome (Glasgow Outcome Scale4 and 5) was observed in 41.9%. No tendency towards either increased or decreased incidence in favourable outcome was found relative to the time from admission to DC. 33.3% with favourable outcome were operated on within the first 6 hr. They concluded that DC lowers ICP and raises CPP to high normal levels in survivors compared to non-survivors. The timing of DC showed no clear trend, for either good neurological outcome or death. Overall, the survival rate of 74.4% is promising and 41.9% had favourable neurological outcome.

Zhang Guo Liang et al [21] compare the effect of extensive duraplasty and subsequent early cranioplasty on the recovery of neurological function in management of patients with severe traumatic brain injuries received DC. They found that early cranioplasty in those with extensive duraplasty in previous craniotomy is feasible and helpful to improving ADL and long-term quality of life in patients with severe traumatic brain injuries.

Aims and Objectives

To study the complications and outcome after decompressivecraniectomy in traumatic brain injury.

MATERIAL AND METHODS

Study Design: Prospective and Observational.

Study period: October 2015 to March 2017.

This study was conducted in the Department of Neurosurgery PGIMER and RML Hospital, New Delhi. All patients of traumatic brain injury undergoing decompressive craniectomy from October 2015 till December 2016 were included in the study.

INCLUSION CRITERIA:

All Adult patients with TBI presenting in the Department of Neurosurgery, PGIMER and RML Hospital.

EXCLUSION CRITERIA:

1. Traumatic Brain Injury associated with injury to chest, aerodigestive tract and spine.
2. Patients with preexisting cardiac, respiratory and spinal comorbidities.
3. Craniectomy done as a second surgery.
4. Craniectomy done for other indications like Tumour or Infarct.

Study Methodology:

Data of all the patients included in the study were taken regarding their name, age, sex and address. Mode of trauma was noted. The GCS of the patients at admission have been assessed. Preoperative investigations like NCCT head was done to reveal the type of intracranial injury. Similarly transit period from the time of accident to the operative decompression was also noted. Patients with other associated injuries have been excluded from the study. Postoperative neurological recovery was reviewed in a time bound manner.

Technique:

- Decompressive Craniectomy was done in bicoronal or fronto temporoparietal technique depending upon the indication.
- Adequate bony decompression was ensured by following standard landmarks.
- The size of bone flap was approximately 12*15cm. The dura was opened in C-shaped manner. Evacuation of hematoma was done. Duraplasty was done by autologous graft or artificial graft as indicated. The bone flap was implanted in the subcutaneous tissue of the abdominal wall until reinsertion several weeks later.

Complication attributable to the decompressive craniectomy

1. Any new hematoma and contusion attributable to surgery.
2. Herniation of the cortex through the bone defect (defined as.>1.5cm outside the craniotomy defect)
3. Subdural/subgaleal collection (defined as a low density collection>1 cm maximal thickness)
4. Syndrome of the trephined.
5. Hydrocephalus (defined as dilatation of the ventricular system with accompanying clinical features that required placement of a shunt).
6. CSF leak.
7. Surgical site infection and meningitis.

All these details were filled in a proforma for statistical analysis.

Follow up Protocol:

All the patients who underwent DC were followed in the ward/ICU daily to note any evolving complication and investigation was ordered accordingly to establish cause effect relationship. After discharge, the patient was followed up at one and three months duration along with fresh NCCT Head. The patient was instructed to follow up in emergency department in case of neurological deterioration. Any complication attributable to DC was noted. Outcome of the patient was assessed at the end of 3 months by GOS.

STATISTICAL ANALYSIS

- Descriptive statistics like frequency and percentage were used to describe the study results.
- A p-value of < or =0.05 was considered to be significant.
- Appropriate statistical test was applied.

SSPE software (SSPE, Chicago, Illinois, USA) was used for statistical analysis.

RESULTS

A total of 96 patients were recruited for the prospective study over a period of one year and three months (From October 2015 to December 2016). Patients were followed up over a period of 3 months to identify the complications and outcome after DC.

Of the 96 patients, there were 3 patients lost in follow up. For the remaining 93 patients, there were 15 mortalities. So, 100% follow up could be achieved for 3 months for remaining 78 patients.

Age Profile of Study Population

The age of patients ranged from 18 years to 60 years. Maximum number of patients were between 18-30 years (35), followed by 31-40 years (28), 41-50 years (18), and 51-60 years (12).

(Table 1)

Table 1

Age Group	Frequency	Percent	Cumulative Percent
18-30yr	35	37.6	37.6
31-40yr	28	30.1	67.7
41-50yr	18	19.4	87.1
51-60yr	12	12.9	100.0
Total	93	100.0	

Distribution of Study Population According to Gender

Majority of patients in this study were males 78(83.9%) as compared to females 15(16.1%).(Table 2)

Table 2

Sex	Frequency	Percent	Cumulative Percent
Male	78	83.9	83.9
Female	15	16.1	100.0
Total	93	100.0	

Distribution of Study Population According to Mode of Injury

Maximum numbers of patients have road traffic accidents 70 (75.3%), followed by fall 18 (19.4%), and physical assault 5 (5.4%).(Table 3)

Table 3

Mode of Injury	Frequency	Percent	Cumulative Percent
RTA	70	75.3	75.3
Fall	18	19.4	94.6
Assault	5	5.4	100.0
Total	93	100.0	

Distribution of Study Population According to Preop GCS

Maximum numbers of patients have preop GCS between 9-12(64), followed by 5-8(17),13- 14(10),3-4(2) and none of the patients have preop GCS 15.(Table 4)

Table 4

Preop GCS	Frequency	Percent	Cumulative Percent
3-4	2	2.2	2.2
5-8	17	18.3	20.4
9-12	64	68.8	89.2
13-14	10	10.8	100.0
15	0	0	100.0
Total	93	100.0	

Distribution of Study Population According to Side of Procedure

Maximum numbers of patients were operated on right side 52 (55.9%), followed by left side 32 (34.4%), and bilateral 9 (9.7%).(Table 5)

Table 5

Side	Frequency	Percent	Cumulative Percent
Right	52	55.9	55.9
Left	32	34.4	90.3
Bilateral	9	9.7	100.0
Total	93	100.0	

Distribution of Study Population According to Type of Decompressive Craniectomy

Fronto temporoparietal (FTP) decompressive craniectomy was done in 84 (90.3%) patients and bifrontal decompressive craniectomy was done in 9 (9.7%) patients.(Table 6)

Table 6

Type	Frequency	Percent	Cumulative Percent
FTP	84	90.3	90.3
Bifrontal	9	9.7	100.0
Total	93	100.0	

Distribution of Study Population According to Postoperative GCS

Post operatively 42 (45.2%) patients have GCS between 13-14, followed by 28 (30.1%) have GCS between9-12, 15 (16.1%)patients have GCS between 5-8, 5 (5.4%) patients have GCS between 3-4, and 3 (3.2%) patients have GCS of 5.(Table 7)

Table 7

Postop GCS	Frequency	Percent	Cumulative Percent
3-4	5	5.4	5.4
5-8	15	16.1	21.5
9-12	28	30.1	51.6
13-14	42	45.2	96.8
15	3	3.2	100.0
Total	93	100.0	

Postoperative Neurological Status in Study Population

Postoperative neurological status was same in 15 (16.1%) patients, improved in 57 (61.3%) patients, and worsened in 21 (22.6%).(Table 8)

Table 8

Postop GCS	Frequency	Percent	Cumulative Percent
Same	15	16.1	16.1
Improved	57	61.3	77.4
Worsened	21	22.6	100.0
Total	93	100.0	

Complications After Decompressive Craniectomy In Study Population

1. Expansion of hematoma (Figure 1) occurred in 14 (15.1%) patients. Out of these 14 patients, 2 patients were re-explored for expansion of hematoma with significant mass effect. GCS of the two patients were 13 and 10. After re-exploration GCS was worsened in 1 patient and improved in another i.e. GCS were 12 and 11respectively. (Table 9)

Table 9

Expansion of Hematoma	Frequency	Percent	Cumulative Percent
Yes	14	15.1	15.1
No	79	84.9	100.0
Total	93	100.0	

2. New hematoma formation (Figure 2) occurred in 5 (5.4%) patients. All new hematoma patients were managed conservatively as mass effect was not significant. (Table 10)

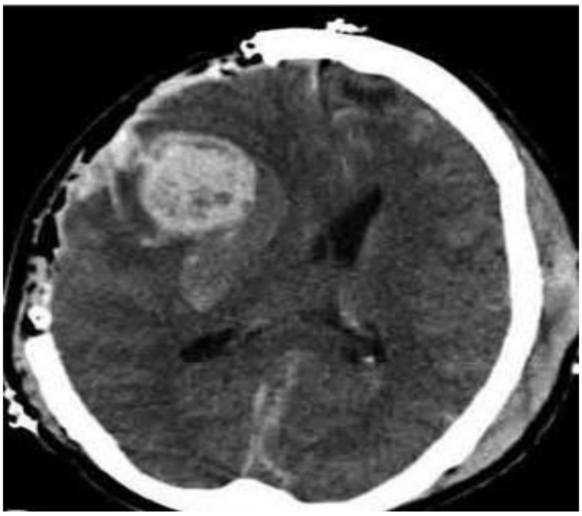

Figure 1.CT scan image showing expansion of hematoma

Table 10

New Hematoma Formation	Frequency	Percent	Cumulative Percent
Yes	5	5.4	5.4
No	88	94.6	100.0
Total	93	100.0	

Figure 2.CT scan image showing new hematoma formation

3. Skin flap infection occurred in 5 (5.4%) patients. All patients were managed conservatively with culture sensitive antibiotics.(Table 11)

Table 11

Skin Flap Infection	Frequency	Percent	Cumulative Percent
Yes	5	5.4	5.4
No	88	94.6	100.0
Total	93	100.0	

4. Bone flap infection occurred at preservation site in 8 (8.6%) patients. Bone flap was discarded in all 8 patients

and then antibiotics were given according to culture sensitivity.(Table 12)

Table 12

Bone Flap Infection	Frequency	Percent	Cumulative Percent
Yes	8	8.6	8.6
No	85	91.4	100.0
Total	93	100.0	

5. Subdural effusion (Figure 3) occurred in 15(16.1%) patients. Tapping of subdural effusion was done in two cases and post taping GCS was improved in one case and same in another case. One patient developed contralateral subdural effusion and burr hole drainage of effusion was done. Post intervention GCS improved in this case. All other patients with subdural effusion were managed conservatively.(Table 13)

Table 13

Subdural Effusion	Frequency	Percent	Cumulative Percent
Yes	15	16.1	16.1
No	78	83.9	100.0
Total	93	100.0	

Figure 3.CT scan image showing sub dural effusion

6. Herniation of brain (Figure 4) occurred in 7 (7.5%) patients. No active intervention was done in all 7patients.(Table 14)

Table 14

Herniation of Brain	Frequency	Percent	Cumulative Percent
Yes	7	7.5	7.5
No	86	92.5	100.0
Total	93	100.0	

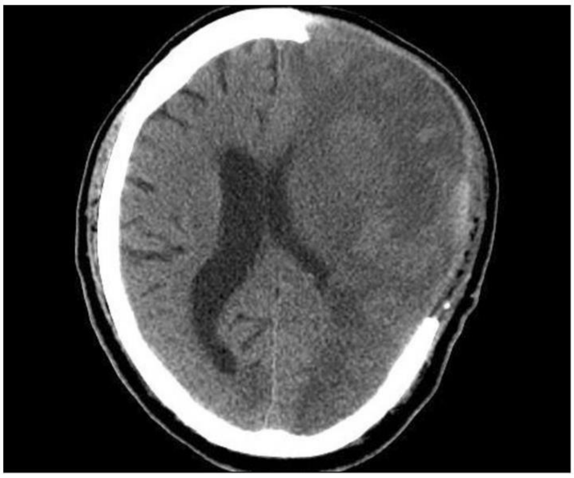

Figure 4.CT scan image showing external cerebral herniation of brain

7. Post decompressive craniectomy hydrocephalus (Figure 5) was seen in 6 (6.5%) patients. Four patients were managed by ventriculoperitoneal shunt and improvement in GCS was there post shunting. In 1 patient external ventricular drainage (EVD) was placed due to poor GCS but no improvement in GCS after EVD. This patient expired after few days of intervention. One patient of hydrocephalus was managed conservatively.(Table 15)

Table 15

Post DC Hydrocephalus	Frequency	Percent	Cumulative Percent
Yes	6	6.5	6.5
No	87	93.5	100.0
Total	93	100.0	

Figure 5.CT scan image showing post decompressive craniectomy hydrocephalus with EVD

8. Post DC seizures occurred in 5 (5.4%)patients.(Table 16)

Table 16

Seizures	Frequency	Percent	Cumulative Percent
Yes	5	5.4	5.4
No	88	94.6	100.0
Total	93	100.0	

9. CSF leak occurred in 2 (2.2%) patients. Both the patients had poor postop GCS. One patient was managed by suturing at leaking site and in another patient lumbar drain was inserted. There was no improvement in GCS after intervention. Both patients expired after few days due to meningitis.(Table 17)

Table 17

CSF Leak	Frequency	Percent	Cumulative Percent
Yes	2	2.2	2.2
No	91	97.8	100.0
Total	93	100.0	

10. Syndrome of trephined occurred in 1 (1.1%) patients. This patient developed newly appearing symptoms including headache, irritability, memory problems, and mood disturbances one month after the surgery.(Table 18)

Table 18

Syndrome of Trephined	Frequency	Percent	Cumulative Percent
Yes	1	1.1	1.1
No	92	98.9	100.0
Total	93	100.0	

Final Outcome in Study Population

There were 15 (16.1%) mortalities (GOS-1) in the present study population. 33 (35.5%). patients had unfavourable outcome (GOS-2 & 3). Overall, 48 (51.6%) patients have unfavourable outcome. 45 (48.4%) patients showed favourable outcome (GOS-4&5). (Table 19)

Table 19

Final Outcome (GOS)	Frequency	Percent	Cumulative Percent
Death(GOS-1)	15	16.1	16.1
Unfavourable (GOS-2 & 3)	33	35.5	51.6
Favourable(GOS-4&5)	45	48.4	100.0
Total	93	100.0	

Correlation Between Complications and Various Variables

In our study, incidence of complications was compared with various variables but no significant correlation found. When incidence of complications was compared with age there was no significant correlation although incidence of complications was more in higher age group. No statistical significant correlation was found when the incidence of complications were compared with age, sex, mode of injury, preop GCS, side of procedure, postop GCS, postop neurological status and final outcome(p-value>0.05).(Table 20-27)

Table 20

Age (Years)	Complications		Total	p-value
	Yes	No		
18-30	18	17	35	0.273
31-40	17	11	28	
41-50	10	8	18	
51-60	10	2	12	
Total	55	38	93	

Table 21

Sex	Complications		Total	p-value
	Yes	No		
Male	48	30	78	0.283
Female	7	8	15	
Total	55	38	93	

Table 22

Mode of Injury	Complications		Total	p-value
	Yes	Yes		
RTA	40	30	70	0.764
Fall	12	6	18	
Assault	3	2	5	
Total	55	38	93	

Table 23

Preop GCS	complications		Total	p-value
	Yes	No		
3-4	2	0	2	0.610
5-8	11	6	17	
9-12	36	28	64	
13-14 15	6 0	4 0	10 0	
Total	55	38	93	

Table 24

Side of Procedure	complications		Total	p- value
	Yes	No		
Right	30	22	52	0.484
Left	18	14	32	
Bilateral	7	2	9	
Total	55	38	93	

Table 25

Postop GCS	complications		Total	p- value
	Yes	No		
3-4	4	1	5	0.781
5-8	10	5	15	
9-12	15	13	28	
13-14	24	18	42	
15	2	1	3	
Total	55	38	93	

Table 26

Post op Neurological status	complications		Total	p- value
	Yes	No		
Same	11	4	15	0.461
Improved	28	29	57	
Worsened	16	5	21	
Total	55	38	93	

Table 27

Final Outcome (GOS)	complications		Total	p-value
	Yes	No		
Death(1)	11	4	15	0.467
Unfavourable(2&3)	19	14	33	
Favourable(4&5)	25	20	45	
Total	55	38	93	

Table 28

Variables		Final outcome GOS (Death=1, unfav=2, fav=3)			p-value
		1	2	3	
Age (years)	18-30	4	12	19	0.371
	31-40	8	7	13	
	41-50	3	5	10	
	51-60	0	9	3	
sex	Male	13	26	39	0.614
	Female	2	7	6	
Mode of Injury	RTA	12	25	33	0.669
	Fall	3	7	8	
	Assault	0	1	4	
Preop GCS	3-4	1	0	1	<0.0001
	5-8	10	6	1	
	9-12	4	27	33	
	13-14	0	0	10	
	15	0	0	0	
Side of Procedure	Right	10	16	26	0.458
	Left	3	15	14	
	Bilateral	2	2	5	
Type of DC	FTP	12	31	40	0.35
	Bifrontal	3	2	5	
Postop GCS	3-4	5	0	0	<0.0001
	5-8	10	5	0	
	9-12	0	27	1	
	13-14	0	1	41	
	15	0	0	3	
Post op Neurological status	Same	1	11	3	<0.0001
	Improved	0	15	42	
	Worsened	14	7	0	

Table 29

Complications		Final outcome GOS (Death=1, unfav=2, fav=3)			p-value
		1	2	3	
Expansion of hematoma	Yes	1	8	5	0.169
	NO	14	25	40	
New Hematoma	Yes	0	2	3	0.598
	NO	15	31	42	
Skin flap infection	Yes	1	3	1	0.402
	No	14	30	44	
Bone flap infection	Yes	0	2	6	0.227
	No	15	31	39	
Subdural effusion	Yes	2	4	9	0.614
	No	13	29	36	
Herniation of brain	Yes	5	2	0	<0.0001
	No	10	31	45	
Hydrocephalus	Yes	1	1	4	0.582
	No	14	32	41	
Seizure	Yes	0	4	1	0.096
	No	15	29	44	
CSF leak	Yes	2	0	0	0.005
	No	13	33	45	
Syn. of trephined	Yes	0	0	1	0.583
	No	15	33	44	

Correlation Between Final Outcome and Various Variables

Final outcome was compared with various variables and there was no significant correlation when compared with age, sex, mode of injury, side and type of procedure (p-value>0.05). On comparision of final outcome with preop GCS, postop GCS, and postop neurological status there was significant correlation (p-value<0.05).

Patients who had poor preop and postop GCS have more chances of unfavourable outcome and favourable outcome was there in those patients who had good preop and postop GCS. (Table 28)

On comparision of final outcome with individual complication there was statistical significant correlation with external herniation of brain and CSF leak (p-value<0.05). There was no significant correlation when final outcome was compared with expansion of hematoma, new hematoma formation, skin flap infection, bone flap infection, subdural effusion, hydrocephalus, seizures, and syndrome of trephined.(Table 29)

DISCUSSION

The present study was intended to elaborate the complications and outcome after DC in traumatic brain injury. Most of the studies till date have concentrated more on the management aspect of raised intracranial pressure and few have outline the complications associated with DC.

This study was conducted in the neurosurgery department of PGIMER & DR. RML Hospital, New Delhi. There were 96 patients recruited in the study, however there were 15 deaths and 3 patients were lost in follow up. Of the remaining 78 patients, 100% follow up could be achieved up to 3 months. Of the 93 patients, 78 were male 15 were female with age ranging from 18 to 60 years. In our study, patients were divided into four age groups and there were maximum number of patients in young age group. Post operatively neurological status was improved in 57 (61.3%) patients and worsened in 21 (22.6%) patients and 15 (16.1%) had same neurological status. Of the 93 patients, 14 (15.1%) had evidence of expansion of hematoma/ contusion on serial CT Scans. Two patients were again operated for hematoma evacuation due to significant mass effect. Post operatively one patient had improved & another worsened. In our study, 5 (5.4%) patient developed new hematoma formation. All were managed conservatively. However, there were less number of patients developing expansion of hematoma or new hematoma formation as compared to study of Flint et al (2008). [17] They found higher evidence of expansion of hematoma 23 of 40 patients (58%) and new hematoma formation in 11 (28%) out of 40patients.

Arabi et al [16] found expansion of hematoma in 8 (16%) out of 50 patients, which was comparable to our results. Other studies have lower incidence of expansion of hematoma as compared to our study. Chibbaro & Taconi [15] found 3 (6%) patient out of 48 and Huang et al [18] found 2 (5%) out of 38 patients with expansion of hematoma. One theory explaining this expansion of hematoma or new hematoma formation is that bone removal in DC could lead to loss of tamponade effect, facilitating hematoma expansion both ipsilaterally and on rare occasions contralaterally. [24]

In our study, skin flap infections were occurred in 5 (5.4%) patients. Bone flap infection at preservation site occurred in 8 (8.6%) patients, which required urgent removal of infected bone flap. All patients were managed with culture sensitive antibiotics. Our results are comparable to the results of study of Huang et al & Yang et al. Huang et al [18] found 2 (5%) patients out of 38 and Yang et al [23] found 4 (6%) patients out of 68 with infection. But other studies found lower incidence of infection. Arabi et al [16] found 1 (2%) patients out of 50, Chibbaro&Taconi [15] found 1 (2%) patients out of 48 and Jiang et al [19] found 8 (3%) patients out of 241 with infection. Most studies report infection rate not more than3-7%. [16,18-20]

In our study, sub dural effusion occurred in 15 (16%) patients. Subdural effusion was tapped in two patients and GCS improved in one patient and same in another. One patient developed contralateral subdural effusion and required burr hole drainage due to significant mass effect. This patient had improvement in GCS after drainage of the effusion. In our study, incidence of subdural effusion is lower than most of the other studies. Arabi et al [16] found subdural effusion in 25 (50%) patient out of 50, Huang et al [18] found 10 (26%) out of 38 patients, and Yang et al [20] found 18 (26%) out of 68 patients. Our results are comparable with the results of Jiang et al, [19] they found subdural effusion in 38 (16%) out of 241 patients. Pedro Grille et al [14] found lower incidence of subdural effusion i.e. 6 (11%) out of 64 patients. The cause of subdural effusion is altered CSF circulation dynamics following decompression. However, some authors have suggested increased cerebral perfusion pressure [27] or injury to arachnoid- dura interphase layer as a result of trauma or iatrogenic surgical disruption as the link between effusion and DC. [16] In our study, external herniation of brain occurred in 7 (7.5%) patients. The incidence of herniation of brain in our study is lower as compared to other studies. S.Honeybul [5] found 18 (51%) out of 41 patient with external herniation of brain. Yang et al [20] reported herniation in 30 (27.8%) patients out of 108. Though cortical herniation is considered a complication of DC, it occurs so commonly that it can merely be a sequel of the procedure. The lower incidence of this complication in our study is due to large size of craniectomy, allowing the brain to expand outward without constriction and it is considered as a complication when brain tissue in the centre of the bone defect was 1.5 cm above the plane of outer table of the cranium.

In our study, post DC hydrocephalus occurred in 6 (6.5%) patients. Four patients were managed by VP shunt and there was improvement in outcome after shunt. In one patient external ventricular drain was placed due to poor GCS and there was no improvement. One patient was managed conservatively. Our results are comparable with the study of Huang et al, [18] they found 3 (8%) out of 38 patients with post DC hydrocephalus. Other studies have higher incidence of post DC hydrocephalus. Arabi et al [16] found 5 (10%) out of 50 patients and Yang et al [20] found 20 (21%) out of 68 patients. Choi et al [25] found 20.7% incidence of post DC hydrocephalus.

The incidence of seizures in our study is 5 (5.4%) patients which is slightly less than reported incidence of 7-20%. [5,8] Whilst it would appear that this complication develops primarily because of the severe head injury, the cerebral manipulations that occur with the decompressive procedure has some influence. When severe head injuries are considered, the incidence is 10-15% for adults. Of those patients who have a DC the incidence of seizures varies from 7-20%.The incidence if CSF leak in our study is 2 (2.2%) patients. One patient was managed by suturing leaking site and another by insertion of lumbar drain. There were no improvement in both patients and both developed meningitis and expired after few days. Our results are comparable with the study of SeungPil Ban et al, [13] they found 2 (2.2%) out of 89 patients developed CSF leak post DC.

Syndrome of trephined was seen in one patient in our study, who developed symptoms including headache, irritability, memory problems and mood disturbances one month after the surgery. These symptoms improved after cranioplasty. In the study by SeungpilBan [13] 8 out of 89 patients developed this syndrome and all improved after cranioplasty. The mechanisms underlying the development of these symptoms are still the subject of debate. One theory describes the sinking of the scalp overlying the cranial defect, which, without bone support, transmits atmospheric pressure directly on to the surface of the brain. This reduces the subarachnoid space and presses against the underlying cortex, resulting in turbulent CSF circulation and decreased cortical perfusion. [20] Another, theory attributes these symptoms to two factors. First, parenchymal injury elicits fluid shifts into the brain tissue and decreased resistance at the craniectomy site allows fluid accumulation in the area underlying the defect. Second, decompensated CSF flow can manifests as leakage of CSF and edema fluid into vulnerable areas of the injured parenchyma underlying the defect. Both of these factors could lead to impaired cortical blood flow to the region underlying the defect. [24]

In our study, final outcome was assessed after 3 months by GOS. There were 15 (16.1%) mortalities (GOS-1), unfavourable outcome (GOS-2 &3) in 33 (35.5%) patients and favourable outcome (GOS-4&5) in 45 (48.4%) patients. Our results are comparable with other studies. Gaetane Gouello et al [26] found favourable outcome in 50% of cases. Barbara M.Eberle et al [3] found in their study 25.6% mortality (11of43), 32.5% (14 of 43) remained in vegetative state or severely disabled and favourable outcome (GOS-4&5) in 41.9% (18 of 43) patients. Salvatore Chibbaro et al [15] found in their study that 6 (12.5%) patients were died, 7 (15%) were discharged with a GOS of 5, 18 (40%) showed a favourable outcome after rehabilitation with GOS of 4 & 5, 6 (12.5%) had a severe disability (GOS-3), 9 (20%) were in a vegetative state (GOS-2).

In our study, statistical significant correlation was present between final outcome and preop and postop GCS. Patients had poor preop and postop GCS had unfavourable outcome and those patients who had good preop and postop GCS had favourable outcome. There was also statistical significant correlation between final outcome with external cerebral herniation and CSF leak. Those patients had complication of external cerebral herniation and CSF leak had unfavourable outcome. In our study, there was no statistical significant correlation between final outcome and complications with age, as we excluded patients below 18 years and above 60 years. Other studies showed increase incidence of complications and poor outcome with older age.

CONCLUSION

Trauma is the commonest cause of death in young population worldwide. Decompressive craniectomy is widely used neurosurgical procedure for traumatic brain injury. This study has concluded that DC is associated with a spectrum of complications. This study also concluded that to what extent these complications affect the final outcome after DC. We conclude that those patients had poor preop and postop GCS they had more incidence of unfavourable outcome. Patients who had external cerebral herniation and CSF leak also had unfavourable outcome. Overall, the survival rate of 83.9% is promising and 48.4% had favourable outcome. These results should help neurosurgeons to anticipate the complications and we recommend to adopt management strategies that reduce the risk of complications, and to improve clinical outcomes.

Conflict of interest: None

REFERENCES

1. Winter CD, Adamides A, Rosenfeld JV. The role of decompressive craniectomy in the management of traumatic brain injury: a critical review. Journal of clinical neuroscience. 2005 Aug31;12(6):619-23.
2. Accidental Death and Suicides in India 2015. New Delhi: National Crime Records Bureau(IN); 2016 Sep.117 p.
3. Eberle BM, Schnüriger B, Inaba K, Gruen JP, Demetriades D, Belzberg H. Decompressive craniectomy: Surgical control of traumatic intracranial hypertension may improve outcome. Injury. 2010 Sep30;41(9):894-8.
4. Su FW, Ho JT, Wang HC. Acute contralateral subdural hygroma following craniectomy. Journal of Clinical Neuroscience. 2008 Mar31;15(3):305-7.
5. Honeybul S. Complications of decompressive craniectomy for head injury. Journal of Clinical Neuroscience. 2010 Apr30;17(4):430-5.
6. Wick J, Wade J, Rohrer D, O'Neill O. Use of decompressive craniectomy after severe head trauma. AORN journal. 1999 Mar 31;69(3):517-29.
7. Timofeev I, Hutchinson PJ. Outcome after surgical decompression of severe traumatic brain injury. Injury. 2006 Dec31; 37(12):1125-32.

8. Guerra WK, Gaab MR, Dietz H, Mueller JU, Piek J, Fritsch MJ. Surgical decompression for traumatic brain swelling: indications and results. Journal of neurosurgery. 1999Feb;90(2):187-96..
9. Wagner S, Schnippering H, Aschoff A, Koziol JA, Schwab S, Steiner T. Suboptimum hemicraniectomyasacauseofadditionalcerebrallesionsinpatientswithmalignant infarction of the middle cerebral artery. Journal of Neurosurgery. 2001 May;94(5):693-6.
10. Polin RS, Shaffrey ME, Bogaev CA, Tisdale N, Germanson T, Bocchicchio B, Jane JA. Decompressive bifrontal craniectomy in the treatment of severe refractory posttraumatic cerebral edema. Neurosurgery. 1997 Jul1;41(1):84-94.
11. Morrow SE, Pearson M. Management strategies for severe closed head injuries in children. In Seminars in pediatric surgery 2010 Nov 30 (Vol. 19, No. 4, pp. 279-285). WBSaunders.
12. Rosenfeld JV, Cooper J. What is the role for decompressive craniectomy in severe traumatic brain injury? Re: Decompressive craniectomy: surgical control of intracranial hypertension may improve Outcome.Injury.2010Sep;41(9):899-900.
13. Ban SP, Son YJ, Yang HJ, Chung YS, Lee SH, Han DH. Analysis of complications following decompressive craniectomy for traumatic brain injury. Journal of Korean Neurosurgical Society. 2010 Sep1;48(3):244-50.
14. Grille P, Tommasino N. Decompressive craniectomy in severe traumatic brain injury: prognostic factors and complications. RevistaBrasileira de terapiaintensiva. 2015 Jun;27(2):113-8.
15. Chibbaro S, Tacconi L. Role of decompressive craniectomy in the management of severe head injury with refractory cerebral edema and intractable intracranial pressure. Our experience with 48 cases. Surgical neurology. 2007 Dec 31;68(6):632- 8.
16. Aarabi B, Hesdorffer DC, Ahn ES, Aresco C, Scalea TM, Eisenberg HM. Outcome following decompressive craniectomy for malignant swelling due to severe head injury. Journal of Neurosurgery. 2006. Apr;104(4):469-79.
17. Flint AC, Manley GT, Gean AD, Hemphill III JC, Rosenthal G. Post-operative expansion of hemorrhagic contusions after unilateral decompressive hemicraniectomy in severe traumatic brain injury. Journal of Neurotrauma. 2008 May1;25(5):503-12.
18. Huang AP, Tu YK, Tsai YH, Chen YS, Hong WC, Yang CC, Kuo LT, Su IC, Huang SH, Huang SJ. Decompressive craniectomy as the primary surgical intervention for hemorrhagic contusion. Journal of Neurotrauma. 2008 Nov1;25(11): 1347-54.
19. Jiang JY, Xu W, Li WP, Xu WH, Zhang J, Bao YH, Ying YH, Luo QZ. Efficacy of standard trauma craniectomy for refractory intracranial hypertension with severe traumatic brain injury: a multicenter, prospective, randomized controlled study. Journal of Neurotrauma. 2005 Jun 1;22(6): 623-8.
20. Yang XF, Wen L, Shen F, Li G, Lou R, Liu WG, Zhan RY. Surgical complications secondary to decompressive craniectomy in patients with a head injury: a series of 108 consecutive cases. ActaNeurochirurgica. 2008 Dec1;150(12):1241-8.
21. GH., BardtT., Lanksch W.R., Unterberg A. (2002)Decompressive Craniectomy Following Traumatic Brain Injury: ICP, CPP and Neurological Outcome. In: Czosnyka M., Pickard J.D., Kirkpatrick P.J., SmielewskiP., HutchinsonP. (eds) Intracranial Pressure and Brain Biochemical Monitoring. Acta Neurochirurgica Supplements, vol 81.pp 77-79.
22. Zhang GL, Yang WZ, Jiang YW, Tao ZE. Extensive duraplasty with autologous graft in decompressive craniectomy and subsequent early cranioplasty for severe head trauma. Chinese Journal of Traumatology (English Edition). 2010 Oct1;13(5):259-64.
23. Yang XJ, Hong GL, Su SB, Yang SY. Complications induced by decompressive craniectomies after traumatic brain injury. Chinese journal of traumatology. Zhonghuachuangshangzazhi. 2003Apr; 6(2): 99-103.
24. StiverSI. Complications of decompressive craniectomy for traumatic brain injury. Neurosurg Focus.2009;26:E7.
25. Choi I, Park HK, Chang JC, Cho SJ, Choi SK, Byun BJ. Clinical factors for the development of posttraumatic hydrocephalus after decompressive craniectomy. Journal of Korean

Neurosurgical Society. 2008 May1;43(5): 227-31.
26. Gouello G, Hamel O, Asehnoune K, Bord E, Robert R, Buffenoir K. Study of the long-term results of decompressive craniectomy after severe traumatic brain injury based on a series of 60 consecutive cases. The Scientific World Journal. 2014 Feb 24;2014.
27. Lang JK, Ludwig HC, Mursch K, Zimmerer B, Markakis E. Elevated cerebral perfusion pressure and low colloid osmotic pressure as a risk factor for subdural space-occupying hygromas? Surgical neurology. 1999 Dec 31;52(6):630-7.

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