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NEUROSURGERY UNIT

A Research THESIS ON

OUTCOMES OF DECOMPRESSIVE CRANIECTOMY IN ADULTS WITH SEVERE TRAUMATIC BRAIN INJURY

Investigator: Samson Assefa, MD, Final Year Neurosurgery Resident
Neurosurgery Unit, Department of Surgery, AAU.

Advisor: Hagos Biluts, MD, Associate professor,
Neurosurgery Unit, Department of surgery, Tikur Anbessa Specialized Hospital, Addis Ababa, Ethiopia

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Addis Ababa University, College of Health Sciences, School of Medicine
Department of Surgery, Neurosurgery Unit

Principal investigator: Samson Assefa, MD
Neurosurgical Resident
Department of Surgery
College of Health Sciences, AAU
Addis Ababa, Ethiopia
E-mail; samiasf05@gmail.com

Advisors: Hagos Biluts, MD
Assistant professor of Neurosurgery
Head, Neurosurgery Unit
Department of Surgery
College of Health Sciences, AAU
Addis Ababa, Ethiopia
E-mail; hagosisnow@yahoo.com

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ABBREVIATIONS

AAU	Addis Ababa University
ALERT	All African Leprosy and Rehabilitation Training
BTF	Brain Trauma Foundation Guidelines
DC	Decompressive Craniectomy
FMOH	Federal Ministry of Health
GCS	Glasgow Coma Score
GOS	Glasgow Outcome Scale
GOS-E	Extended Glasgow Outcome Scale
ICP	Intra Cranial Pressure
ICU	Intensive Care Unit
LMICs	Low- and middle-income countries
MCM	Myung sung Christian Medical Center
TBI	Traumatic Brain Injury
TASH	Tikur Anbessa Specialized Hospital
TBI	Traumatic Brain Injury

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ABSTRACT

Objective: The aim of this study is to assess the outcome of decompressive craniectomy in adult patients with severe traumatic brain injury and to identify factors responsible for poor outcome

Methodology: A retrospective study of 36 patients with severe TBI who had undergone decompressive craniectomy in a period of 40 months (May 2017 to March 2020). Adult patients, aged between 15 and 73 years of both genders undergoing DC were selected. Variables assessed were Sex, age, presence of comorbid illness, mechanism of injury, presence of associated injury, pre-operative GCS and motor score, pupillary reaction, CT finding, degree of midline shift, the status of the basal cisterns, Rotterdam score, and timing of surgery. The outcome of patients was assessed using the Extended Glasgow Outcome Scale. Student's t-test and Chi-square test were used to identify possible factors responsible for poor outcome.

Results: 36 patients (31males and 5 females) underwent surgical decompressive craniectomy with a mean time of 25.6 hours (SD=26.2) after trauma. Mean age of patients was 33.39 years (SD=13.92), old (range: 15 to 73 years). The mean duration of follow up was 5.78months. 33.3% of patients had a favorable outcome (GOSE=5-8), 66.7% had unfavorable outcomes (GOSE= 1-4) and the mortality rate was 52.8%. Among patients that survived, 70% had a favorable outcome and 30% had an unfavorable outcomes. Cranioplasty was done in 11 of the discharged patients (61%). The mean timing of cranioplasty was 6.2 months post craniectomy. Patients with the following conditions had significantly worse outcomes; presence of associated extracranial injury, preoperative GCS $\leq$ 5, motor score of 2 to 3, abnormal pupillary reaction, absent basal cisterns on CT scan, and high Rotterdam score. There was also a significantly significant association between older age and mortality. Complications included hydrocephalus (one patient), surgical site infection (SSI) in nine patients, six of the SSI were infection of the bone flap kept in the abdomen.

Conclusion: The result of this study indicates that the majority of survivors after decompressive craniectomy have a good functional outcome as analyzed by GOSE. Poor functional outcome and death were observed in patients having poor prognosticators. Improving patient selection may further improve outcome in these very severely brain-injured patients.

1. INTRODUCTION

1.1 Background

Severe Traumatic Brain Injury is defined as injuries to the brain presenting with a GCS of 8 or less. Head injury specifically is a leading cause of death and disability among the injured in Low- and middle-income countries (LMICs). In Africa, one-third of all head injury patients suffer poor outcomes, and those patients with a severe head injury have almost twice the risk of dying compared to those in high-income countries. [1]

The management of severe traumatic brain injury (STBI) has been aided by the Brain Trauma Foundation (BTF) guidelines. [2] Accordingly, these guidelines outline an approach to the management of STBI using a combination of medical and surgical treatments. Surgical interventions used in the management of STBI include ventriculostomy for drainage, craniotomy for evacuation of a mass lesion, and decompressive craniectomy for refractory increased intracranial pressure (ICP).

Decompressive craniectomy is the surgical removal of a large part of the skull to reduce intracranial pressure that is otherwise intractable. It forms the last tier in the BTF and other guidelines in the management of severe traumatic brain injuries, for management of medically refractory increased ICP.

Evidence of surgical decompression performed to treat TBI goes as far back as Ancient Egypt and Greece, and the indications for its use included TBI, epilepsy, headache, and mental illness.

The first description of indications and techniques of DC was written by Berengario da Carpi who was an Italian physician and teacher of Anatomy at the Bologna University in 1880 [3].

The concept of using surgical decompression to treat elevated intracranial pressure (ICP) was introduced to modern neurosurgery by Kocher and Cushing at the beginning of the 20th century[4]. Discussion of surgical decompression for TBI in the literature did not become widespread until the late 1960s and 1970s after a series of studies examining surgical decompression for various TBI-related entities

STBI is a common neurosurgical problem that can cause massive brain swelling leading to uncontrolled raised intracranial pressure (ICP), resulting in severe brain damage or even death.

Therefore, the reduction of raised ICP is an important factor in the treatment of STBI. One means of reduction of raised ICP is through Decompressive craniectomy.

This study aims to evaluate the outcomes and procedure-related complications of DC after STBI in the adult population.

1.2 Statement of The Problem

The World Health Organization (WHO) estimates 5.8 million annual injury-related deaths and that 90% of them occur in low- and middle-income countries (LMICs). In Africa, one-third of all head-injured patients suffer poor outcomes, and those patients with a severe head injury have almost twice the risk of dying compared to those in high-income countries.

A retrospective review done at Addis Ababa University's Tikur Anbessa Specialized Hospital (TASH) found head injury accounted for almost 60% of deaths among trauma patients admitted to the surgical service from 2002 to 2006.

Over the past two decades, there has been a global resurgence of interest in the use of decompressive craniectomy in the management of severe head injury. Several studies have demonstrated that these procedures are effective in reducing intracranial pressure.

More recently, there has been renewed interested in defining the use and benefits of decompressive craniectomy, with an ever-increasing number of publications on the topic over the past 20 years.

It has been shown that intracranial hypertension resistant to treatment is responsible for 80% of deaths resulting from a severe head injury[5]. There is clear evidence that decompressive craniectomy decreases intracranial pressure (ICP). However, the doubts that are raised, are whether doing a decompressive craniectomy improves not just neurological-, but functional- and psychological- outcome, or whether it may lead to an increased burden on family and the medical system by leaving a patient, who would otherwise have died, in a persistent vegetative state.

Knowledge of DC in Africa is woefully inadequate and data in sub-Saharan Africa, especially in Ethiopia, are spares.

1.3 Significance of The Study

Much of the literature on this subject is from developed countries with cutting-edge neurocritical care systems. In such advanced health systems, posttraumatic raised ICP in the absence of any immediately obvious surgically evacuable mass lesions are first treated medically under highly technologically advanced intensive care multimodal monitoring. Decompressive craniectomy is then usually deployed as a second-tier, perhaps even a last-ditch, effort in the management of post-traumatic raised ICP. Even so, some experts are now of the opinion that DC should more and more be considered early whenever it is indicated in this clinical setting.

In our practice, for instance, there is no dedicated neurointensive care unit. There is also no facility for ICP monitoring. Hence our ICP-targeted care of TBI is virtually limited to the empiric use of mannitol and furosemide and the basic physical/nursing management practices.

In this study, we have tried to assess the functional outcome and factors associated with poor outcomes for DC. The study will try to show the outcome in this setup and can be used to compare with results from other countries.

The result of this study can be used in formulating institution-based and national guidelines for better management and improved outcome with reduced treatment-induced and incurred morbidity and mortality. The result of this study can be of great help for resource-limited setups like Ethiopia in deciding which patient to operate and which not to operate.

2. LITERATURE REVIEW

A retrospective review done In Ethiopia, Addis Ababa University's Tikur Anbessa Specialized Hospital (TASH) found head injury accounted for almost 60% of deaths among trauma patients admitted to the surgical service from 2002 to 2006[6].

2.1 Measurements of Outcome After TBI

The Glasgow Outcome Scale [6] was first published in 1975 by Bryan Jennett and Michael Bond[7, 8]. With over 4,000 citations to the original paper, it is the most highly cited outcome measure in studies of brain injury and the second most-cited paper in clinical neurosurgery.
The original GOS and the subsequently developed extended GOS (GOSE) are recommended by several national bodies as the outcome measure for major trauma and a head injury. The enduring appeal of the GOS is linked to its simplicity, short administration time, reliability and validity, stability, the flexibility of administration (face-to-face, over the telephone, and by post), cost-free availability, and ease of access. [9] These benefits apply to other derivatives of the scale, including the Glasgow Outcome at Discharge Scale (GODS) and the GOS pediatric revision. The GOS was devised to provide an overview of the outcome and to focus on social recovery. Since the initial development of the GOS, there has been an increasing focus on the multidimensional nature of outcome after head injury.

For these reasons, we have used GOSE to measure the outcome of patients in our study at discharge and at last follow up.

2.2 Outcomes After Decompressive Craniectomy

Studies and case series are published every year on different center's outcomes in patients with severe TBI that underwent decompressive craniectomy. This reflects the controversy and interest there is in the salvage of severe TBI patients.

However, there is still a lack of conclusive evidence for, or against, decompressive craniectomy as a management option in TBI.

In a summary of studies done between 1971 and 2001, Piek et al. found cumulative mortality of 30%, poor outcomes (GOS 1-3) of 14.7%, and found good outcomes (GOS 4 or 5) in 46% of patients[10].

Howard et al. studied a cohort of forty patients that underwent decompressive craniectomy after TBI and did a six-month follow-up telephonic interview. Twenty-four of their patients underwent primary decompressive craniectomy. The mortality rate was 55%, but in the survivors, 12 of the 18 patients (66%) had a good outcome (GOS 4 or 5)[11].

In 2011, Cooper, et al. published the DECRA trial[12]. This study is the first randomized controlled trial done in adults with a large cohort of 155 patients, evenly randomized into a maximal medical therapy group or a group where decompressive craniectomy is allowed to salvage patients with severely elevated ICP. From this study, it was shown that the mortality rate at six months follow-up did not differ between the two groups (19% in decompression group vs. 18% in the medical group), and the functional outcome was worse in the DC group (71% poor), compared to the medically managed group (51% poor outcome) (p=0.02). After adjusting for initial pupil size changes in the study there was no significant difference in the outcomes, however. This study is criticized for the high number of "walkovers" to the decompressive group. This may lead to the patients with worse injury severity, and a therefore higher likelihood of a poor outcome, to be better represented in the decompression group, thereby skewing the randomization of results. The other critique of the DECRA study is that only patients without any mass lesions were included, the group only performed bifrontal decompressive craniectomies and it appears as if the decompressive craniectomy cohort had more patients with nonreactive pupils than the medical management group (nineteen versus ten). With the criticism as discussed in these two studies, there is a great need for a large multicenter randomized controlled trial such as RESCUEICP.

The second randomized prospective trial on Decompressive craniectomy was published by Hutchinson PJ, Kolias AG, Timofeev IS, et al in 2016, The RESCUEICP Trial[13]. They randomly assigned 408 patients, 10 to 65 years of age, with traumatic brain injury and refractory elevated intracranial pressure (>25 mm Hg) to undergo decompressive craniectomy or receive ongoing medical care. At 6 months, the GOS-E distributions were as follows: death, 26.9% among 201 patients in the surgical group versus 48.9% among 188 patients in the medical group; vegetative state, 8.5% versus 2.1%; lower severe disability (dependent on others for care), 21.9% versus 14.4%; upper severe disability (independent at home), 15.4% versus 8.0%; moderate disability, 23.4% versus 19.7%; and good recovery, 4.0% versus 6.9%.
At 12 months, the GOS-E distributions were as follows: death, 30.4% among 194 surgical patients versus 52.0% among 179 medical patients; vegetative state, 6.2% versus 1.7%; lower severe disability, 18.0% versus 14.0%; upper severe disability, 13.4% versus 3.9%; moderate disability, 22.2% versus 20.1%; and good recovery, 9.8% versus 8.4%. Surgical patients had fewer hours than medical patients with intracranial pressure above 25 mm Hg after randomization (median, 5.0 vs. 17.0 hours; P<0.001) but had a higher rate of adverse events (16.3% vs. 9.2%, P=0.03).

Clavijo A, Khan AA et. al published a literature review. The Role of Decompressive Craniectomy in Limited Resource Environments in 2019[14]. The most common publications

include case reports, case series, and observational studies describing the benefits of the procedure on different pathologies. In most of the observational studies, there is a common trend of benefit from the procedure, but the low methodological quality of these studies and a high risk of publication bias does not allow any type of conclusions valid for transferability of knowledge in other regions of the world.

Five studies were found from Sub-Saharan Africa, including two from Nigeria, two from South Africa, and one from Cameroon.

A Nigerian prospective study was done by Ojo OA, Bankole OB et al in 2015[15]. They published a one-year prospective study of patients with severe brain injury with CT and clinical evidence of increasing ICP who had DC as the main modality of management. Ten patients were recruited into the study based on deterioration in the level of consciousness and CT evidence of raised intracranial pressure. Out of the ten patients, 4 (40%) died after DC. Six (60%) of the patients survived and had cranioplasty with bone flap replacement (3), titanium (2), and acrylic (1). Two (20%) were discharged with GOS of 5, another 2 (20%) with 4, and the last 2 (20%) with GOS of 3.

In another study done in South Africa by Enslin J[16]. on the Outcomes of Decompressive Craniectomy in Adults with Severe Traumatic Brain Injury, patients that underwent decompressive craniectomy for TBI in an attempt to lower raised intracranial pressure (ICP) were reviewed. At six months follow up 24 patients (33.3%) had a good outcome (GOS 4 or 5) and 48 patients (66.7%) had a poor outcome (GOS 1-3). 32 patients (44.4%) died (GOS 1). There were 16 survivors in the poor group. Sixty percent of survivors had a good outcome after decompressive craniectomy. Eighteen patients underwent secondary decompressive craniectomies and 54 (75%) primary decompressive craniectomies. Mortality was slightly higher in the primary decompression group than the secondary group.

Another African study was done in Cameroon by Motah Mathieu et. al[17]. Patients included were those who underwent decompressive craniectomy as a result of nonresponsiveness to conservative management of blunt trauma to the brain with CT scan evidence of cerebral herniation. Patients' outcome was reassessed two to ten months following decompressive craniectomy using the Glasgow outcome scale [6] score. Thirteen patients were studied. Ten patients (76.93%) had good outcomes (GOS 1-2). One patient (7.69%) remained in a vegetative state (GOS 4) and two patients (15.38%) died (GOS 5)

2.3 Factors Influencing Outcomes in Decompressive Craniectomy

In this study, we have tried to assess factors influencing the outcome of DC in severee TBI patents. Many publications have tried to assess the outcome predictors.

Howard et al found certain factors that did seem to predict a better outcome after decompressive craniectomy in TBI[11]. Similar to other studies[18, 19], the presence of unreactive pupils or other signs of brainstem dysfunction on admission correlates accurately with poor outcomes.

Higher admission GCS does lead to better outcomes[11]. This finding is supported by Williams et al. [20], and Guerra et al.[21] showed that patients with an admission motor score of 5 or 6, were 4.2 times more likely to have a good GOS at three months follow up.

The timing of decompressive craniectomy does seem to be important. Czosnyka et al[22]. showed that persistently elevated ICP for more than six hours results in worse outcomes. Early decompressive craniectomy had a favorable outcome (GOS 4 or 5) in 78.6% of patients, compared to the 47.1% in patients that underwent secondary decompression in a study by Aarabi et al[23]. and Polin et al[24] agreed that earlier intervention (decompressive craniectomy within 48 hours) led to improved outcomes compared to later decompression.

The size of the craniectomy is important in the outcomes of patients[10, 25]. The authors recommend a cranial defect of at least 12cm to 15.3cm in diameter[26, 27]. Herniation and strangulation of cerebral tissue occur if the defect is too small. In a study by Jiang et al, published in 2008, it is clear that patients, in whom a limited craniotomy was performed, fared worse than those in whom a standard decompressive craniectomy was done. The reduction of ICP was also more marked in the group that underwent a standard decompressive craniectomy[28].

3. OBJECTIVES

3.1 General Objectives

- ✓ To assess the functional outcome of DC using GOSE

3.2 Specific Objectives

- ✓ To assess indications used for a decompressive craniectomy.
- ✓ Determine timing from admission to decision to do decompressive craniectomy.
- ✓ Determine the mortality rate of patients undergoing DC for severe TBI.
- ✓ To find out factors responsible for poor functional outcome and mortality, including GCS, pupillary reaction to light, age, the timing of DC, and radiologic findings.
- ✓ To describe the common complications encountered during the hospital stay

4. METHOD

4.1 Study setting and design

It is a hospital-based study conducted at Tikur Anbessa Specialized Hospital (TASH), All African Leprosy and Rehabilitation Training (ALERT) Trauma center, and Myung sung Christian Medical center (MCM). These hospitals have a neurosurgical unit which is under the Department of Surgery, AAU, college of health science. It is a multi-center retrospective Cross-sectional study on the outcome of DC for severe TBI.

4.2 Study Population

All patients undergoing decompressive craniectomy after Sever traumatic brain injury at the study area mentioned above between May 2017 and March 2020 were included in this study.

4.2.1 **Inclusion Criteria**

- ➢ All patients, age ≥14, Sever TBI patient undergoing Decompressive Craniectomy
- ➢ GCS ≤ 8 and >3

4.2.2 **Exclusion Criteria**

- ➢ The patients undergoing decompressive craniectomies for non-trauma related reasons

- Patients with incomplete medical records
- Patients who are lost from follow up

4.3 Study Variables

4.3.1 **Independent Variables**

- Age, sex, GCS, pupillary size, mechanism of injury, indication for DC, the timing of DC (<24hr or >24hrs from time of trauma), findings on computed tomography [3], length of ICU stays, length of hospital stay.

4.3.2 **Dependent Variables**

- Extended Glasgow coma outcome scale (GOS-E)

4.4 Operational Definitions

Traumatic Brain Injury (TBI): refers to any insult to the brain that is not acquired or degenerative. This insult is caused by an external force and may lead to an altered state of consciousness. This may lead to impaired physical and cognitive functioning.

Severe TBI: An initial post-resuscitation GCS of less than 9.

Decompressive craniectomy: is the term used to describe the surgical procedure wherein a craniectomy is performed to reduce intracranial pressure. This craniectomy has to fulfill a certain size and position criteria to be effective. There are two anatomical area's where a decompressive craniectomy is performed, namely **bifrontal craniectomy** – where the bone covering both frontal lobes, as well as both temporal poles, are removed from posterior to the coronal suture, up to the middle- and anterior-cranial fossa floor bilaterally, usually as a single piece of bone. The other common procedure is **hemicraniectomy**. Here the craniectomy is performed on a single side and the bone covering the parietal-, frontal-, as well as temporal pole is removed.

Decompressive craniectomy can be divided into different categories, according to the timing and rationale for performing the procedure: primary (or prophylactic) craniectomy and secondary (or therapeutic) craniectomy.

Primary Decompressive craniectomy refers to the leaving off of the craniotomy flap during an emergency procedure for evacuating a subdural hematoma or intracerebral hematoma. This decision is made by the surgeon due to very high intracranial pressure (ICP) measured, or the inability to replace the bone flap due to brain swelling. This procedure can also be done prophylactically, where the bone is left off to avoid an unexpected raise in postoperatively measured ICP.

Secondary Decompressive craniectomy is usually performed in patients without surgical mass lesions in whom the intracranial pressure is raised and becomes refractory to maximal medical therapy. Surgery to remove a mass lesion may already have been performed in this group. The goal here is to control raised ICP.

The Glasgow coma Scale (GCS) is a clinical assessment tool to determine the level of consciousness by assessment of eye-opening, speech, and motor function.

The Extended Glasgow Outcome Scale (GOSE) is a global scale for the functional outcome that rates patient status into one of eigth categories: Dead, Vegetative state (VS) Lower severe disability (SD-), Upper severe disability (SD+), Lower moderate disability (MD-), Upper moderate disability (MD+), Lower good recovery (GR-), Upper good recovery (GR+).

Unfavorable GOSE includes patients having a GOSE of 1 to 4 (Dead, Vegetative state (VS) Lower severe disability (SD-), Upper severe disability (SD+))

Favorable GOSE includes patients having a GOSE of 5 to 8 (Upper moderate disability (MD+), Lower good recovery (GR-), Upper good recovery (GR+).

4.5 Data Collection and analysis

The principal investigator was the main data collector. The data was collected using a standardized questionnaire prepared by the principal investigator. Sources of data include the patients' medical chart, outpatients' and inpatients' registry books, OR logbook, and radiologic archives.
Assessment of outcome at discharge from hospital and at last follow was done by chart reviewing, interviewing, and examining the patient, or interviewing the attendant or caregiver.

The collected data was cleaned, coded, and entered into IBM/SPSS 25.0 statistics software for analysis. Categorical variables were analyzed using frequencies and percentages. Whereas continuous variables like age and timing of surgery were summarized using means ± standard deviation. Inferential analysis was done Eleven potential predictors of outcome (Sex, age, presence of comorbid illness, mechanism of injury, presence of associated injury, pre-operative GCS and motor score, pupillary reaction, CT finding, degree of midline shift, the status of the basal cisterns, Rotterdam score and timing of surgery). A Chi-square test was used to compare the outcomes in different strata. $P < 0.05$ was considered statistically significant. The differences between numerical variables like age and timing of DC were tested with student's t-test. P-value of less than 0.05 was taken as significant at 95% Confidence Interval (CI).

4.6 Sample size determination

The sample size for the study was determined using:

$$n = \frac{(Z\alpha/2)^2 P(1-p)}{d^2}$$

Where: n = required sample size

Z α/2= Critical value=1.961.

p= 50%. P-value is taken as 50% since there is no similar study published in our country as to the knowledge of the investigator.

d= precision (marginal error) =0.05

Therefore: $n = \frac{(1.96)2\ (0.5X0.50)}{(0.05)^2} = 384$

Since the study population is less than 10,000 the final sample size will be

$$nf = \frac{n}{[1 + n/N]}$$

$$nf = \frac{384}{[1 + 384/150]} = \mathbf{108}$$

→ nf - Final sample size; N- Average number of patients who have undergone Decompressive craniectomy over five-year period in the three study hospitals which I found by looking at the OR log book.

5. RESULTS

5.1 Baseline characteristics of the patients

The study includes 36 Emergency decompressive craniectomies were done at three teaching hospitals in Addis Ababa that fulfilled the inclusion criteria. Among 36 cases constituting the series, 31 patients (86.1%) were male and 5 patients (13.9%) were female. The mean age is 33.39 years (SD=13.92), the age range of 15-73 years. 64% of the patients were under the age of 30 years and 19.4% of patients were older than 50 years.

Nearly half (55.6%) of patients were from Addis Ababa, 30.6% of patients came from the Oromia region. The source of referral was predominantly from outside referral sources comprising of 28 cases (78%), followed by direct admission from the emergency department of 8 cases (22%).

Table 1 - Epidemiology

		Frequency	Percentage
Sex	Male	5	13.9
	Female	31	86.1
Age in years	≤30	23	63.9
	31-49	6	16.7
	≥50	7	19.4
Address	Addis Ababa	20	55.6
	Oromia	11	30.6
	Amhara	1	2.8
	SNNP	1	2.8
	Somalia	1	2.8
	Other	1	2.8
ER presentation	Direct	8	22.2
	Referred	28	77.8

Table 2- Mechanism of injury

	Frequency	Percentage
RTA pedestrian	16	44.4
RTA passenger	4	11.1
Penetrating head injury	3	8.3
Assault	6	16.7
Fall down	5	13.9
Unknown	2	5.6

The commonest mechanism of injury was the road traffic accident (55.5%), whereby pedestrian-car accidents accounted for the greatest number of injuries in 16 cases (44.4%), followed by assault (16.7%) with stick or stone injury to the head. 3 patients had a penetrating head injury with a bullet. The mechanism of injury was unknown in 2 patients.

The majority (N=32, 61.1%) had no other extracranial injuries. 14 patients (33.9%) had an extracranial injury, orthopedic and chest injury being the most common ones. 5 patients had more than 2 sites of injury.
6 (12.9%) patients had a preexisting comorbid illness, 5 patients were known hypertensive patients on antihypertensive medications, and 1 patient was both hypertensive and diabetic on medication.

In analyzing the timing of injury, we found that the mean time from accident to ED was 18.4 hours (SD=24.3), and the mean time from trauma to surgery was 25.6 hours (SD=26.2). Only 19.4% of patients were operated on 6hrs of the trauma. A significant number of patients (47.2%) were operated on between 6-24hrs of the trauma. The remaining 33.3% of patients were operated on after 24hrs of the trauma.

The Glasgow coma scale (GCS) was measured and tabulated as a summation of eye, verbal, and motor component post-resuscitation, and further categorized into two groups. A separate motor response was also taken.

All patients had a preoperative GCS of 4 to 8. The median (IQR) GCS at presentation was 6 (4-8). Nearly half (55.6%) of patients had GCS of six to eight and the remaining 44.4% of patients had a GCS of four and five. The motor score was ranging from 2 to 5 and the median motor score was 3.

A total of 11 patients (30.6%) had a normal pupillary reaction, and 25 patients (69.4%) had an abnormal pupillary reaction, of these 20 patients (50.6%) were anisocoric and 5 (13.9%) patients had bilaterally non-reactive pupils.

Table 3 - Preoperative neurologic status

	Frequency	Percentage
Pre-operative GCS		
3-5	16	44.4
6-8	20	55.6
Motor score		
Extension (2)	9	25.0
Flexion (3)	10	27.8
Withdrawal (4)	5	13.9
Localization (5)	12	33.3
Pupillary reaction		
Neither pupil reactive	5	13.9
One pupil reactive	20	55.6
Both pupil reactive	11	30.6

All patients had a preoperative CT scan done. ASDH was the most common finding seen on the CT scan of 80.6% of the patients. Contusions, ICH, and IVH were other findings seen on the imaging studies (17.8%, 15.1%, and 15.1% respectively). The degree of midline shift and the status of basal cisterns was also studied from the CT scans. 83.3% of the patients had a midline shift of >5mm. Half of the patients had completely effaced basal cisterns. The remaining nearly

half of patients (47.2%) had a partially effaced basal cistern. Only 2.8% of patients had normal basal cisterns. Rotterdam CT score for traumatic brain injury was calculated based on the CT findings.

Table 4 - Radiologic findings

		Frequency	Percentage (%)
Radiologic finding	ASDH	29	80.6
	Contusion	13	36.1
	ICH	11	30.6
	AEDH	1	2.8
	Diffuse brain swelling	5	13.9
	DAI	1	2.8
	DSF	2	5.6
	IVH	11	30.6
Midline shift	<5mm	6	16.7
	>5mm	30	83.3
Basal cisterns	Normal	1	2.8
	Compressed	17	47.2
	Absent	18	50.0
Rotterdam score	3	5	13.9
	4	14	38.9
	5	8	22.2
	6	9	25.0

ASDH was the most common primary indication for DC in 24 patients (66.7%). 4 patients (11.1%) had bifrontal hemorrhagic contusions and bifrontal DC was done. In another 4 patients (11.1%) post-op brain swelling was the primary indication for DC. These patients initially had a craniotomy, evacuation of a mass lesion with expansile duraplasty done and postoperatively there was deterioration in GCS and CT scan showed postoperative brain swelling. All patients were reoperated and bone flap removal with the placement of the bone flap in the abdominal subcutaneous was done.

FTP Hemicraniectomy was done in 32 patients (90%), and bifrontal DC was done in the remaining 4 patients (11.1%). Duraplasty using Pericranial tissue was done for all patients. The bone flap was kept in abdominal subcutaneous tissue in 32 patients (88.9%), 4 bone flaps were preserved in a refrigerator.

5.2 Complications and short-term outcome

Post-operatively all patients were transferred to ICU. The mean length of ICU stay was 16.44 days (SD=14.99). The mean duration on MV was 11.33 days (SD=9.8) and it ranged from 0 to 40 days. Overall hospital stay ranged from 3 to 81 days with a mean of 24.67 days (SD=22.31 days).

16 patients (44.4%) had aspiration pneumonia either before the hospital presentation or during their hospital stay. Hospital-acquired infections like VAP, UTI, sepsis of unknown focus and SSI

was one of the common complications seen during the hospital stay of 15 patients (41.7%). SSI occurred in 9 patients. 3 patients had superficial SSI at the craniotomy site and they were all treated with antibiotics and wound irrigation and debridement. Six patients (16.7%) had an infection of the bone flap kept in the abdominal subcutaneous tissue and all of the bone flaps were discarded. Bedsore of grade II and above were seen in 6 patients (16.7%). Post-traumatic hydrocephalus was seen in one patient. EVD was initially inserted and later changed to VPS and the patient was discharged from the hospital. There were two reoperations. One was for a patient who developed acute epidural hematoma contralateral to the craniectomy, the other was for a patient who developed ICH on the side of the craniectomy.

In-hospital mortality occurred in 16 patients (44.4%). Half of the deaths occurred in the first week of the admission, and 3/4th of deaths occurred in the first 11 days. The mean duration of hospital stay of the dead patients was 11.38 days (SD=11.15 days) with a range of 3 to 42 days.

20 patients (55.6%) were discharged alive. A tracheostomy tube was inserted in 8 of the discharged patients (40%). 5 patients (25%) were discharged feeding gastrostomy tube. 3 patients needed an NG tube for feeding. The remaining 12 patients (60%) were able to feed orally by themselves or assisted.

Table 5 - Complications

	Frequency	Percentage (%)
Aspiration Pneumonia	16	44.4
HAI*	15	41.7
SSI	9	25.0
Bone flap infection	6	16.7
Hydrocephalus	1	2.8
Reoperation	2	0.5
Bedsores	6	16.7
Death (In-patient)	16	44.4

* *HAI includes VAP, UTI, sepsis of unknown focus, and SSI.*

Table 6 - Condition at discharge

		Frequency	Percentage (%)
GCS	8-10	5	25
	11-13	8	40
	14-15	7	35
Feeding	Self or assisted	12	60.0
	NG tube feeding	3	15.0
	Gastrostomy	5	25.0
Breathing	Not on tracheostomy	12	60.0
	On tracheostomy	8	40.0

5.3 Follow up and long-term outcome

The mean duration of follow up of the 20 discharged patients was 5.78mons (Range = 3 to 12 mons). Three patients died at home within the first month of discharge. Cranioplasty was done in 11 of the discharged patients (61%). The mean timing of cranioplasty was 6.2 months post craniectomy. Autologous bone was used in 9 cranioplasties and synthetic material was used in the remaining 2 patients.

Patients having a GOSE of 1 (death) to 4 (Upper severe disability) are considered to have a favorable outcomes. The favorable outcome is from GOSE 5 (Lower moderate disability) to 8 (Upper good recovery).

Overall, 66.7% of patients have an unfavorable outcomes and 33.3% of patients have a favorable outcome, with three patients (8.3%) having a full functional recovery (GOSE=8). The overall mortality rate on mean duration of follow-up of 5.8 months was 52.8%.

Table 7 - Outcome

	Outcome	Frequency	Percentage (%)
Overall mortality	Dead (GOSE=1)	19	52.8
	Survived (GOSE=2-8)	17	47.2
GOSE (Grouped)	Favorable	12	33.3
	Unfavorable	24	66.7
GOSE	Vegetative state (VS)	2	5.6
	Lower severe disability (SD-)	1	2.8
	Upper severe disability (SD+)	2	5.6
	Lower moderate disability (MD-)	2	5.6
	Upper moderate disability (MD+)	2	5.6
	Lower good recovery (GR-)	5	13.9
	Upper good recovery (GR+)	3	8.3

5.4 Predictors of outcome

The outcome of the study was dichotomized into two, favorable GOSE and unfavorable GOSE. Eleven potential predictors of outcome were selected for analysis (Sex, age, presence of comorbid illness, mechanism of injury, presence of associated injury, pre-operative GCS and motor score, pupillary reaction, CT finding, degree of midline shift, the status of the basal cisterns, Rotterdam score and timing of surgery). Bivariate correlational analysis assuming a normal distribution of variables (Pearson correlation) was done at a 5% level of significance. Among these 11 potential predictors of outcome, seven predictors have a statistically significant association with the outcome. This includes the presence of associated injury, pre-operative GCS and motor score, pupillary reaction, CT finding of IVH, the status of the basal cisterns, and the Rotterdam score. (Table 8)

Table 8 – Predictors of outcome

		Favorable N (%)	Unfavorable N (%)	P-value
Sex	F	2(40%)	3(60%)	.549*
	M	10(83.3%)	21(87.5%)	
Age	<30	9(39.1%)	14(60.9%)	.527*
	30-50	2(33.3%)	4(66.7%)	
	>50	1(14.3%)	7(85.7%)	
Comorbid illness	No	11(36.7%)	19(63.3%)	.640*
	Yes	1(16.7%)	5(83.3%)	
Associated injury	No	11(50.0%)	11(50.0%)	**.011***
	Yes	1(7.1%)	13(92.9%)	
Pre-operative GCS	4-5	0(0.0%)	16(100.0%)	**<.001***
	6-8	12(60.0%)	8(40.0%)	
Motor score	2	0(0.0%)	9(100.0%)	**.006***
	3	2(20.0%)	8(80.0%)	
	4	2(40.0%)	3(60.0%)	
	5	8(66.7%)	4(33.3%)	
Pupillary reaction	Neither reactive	0(0.0%)	5(100.0%)	**<.001***
	One reactive	3(15.0%)	17(85.0%)	
	Both reactive	9(81.8%)	2(18.2%)	
CT finding (IVH)**	No	12(48.0%)	13(52.0%)	**.006***
	Yes	0(0.0%)	11(100.0%)	
Degree of midline shift	<5mm	2(33.3%)	4(66.7%)	.691*
	>5mm	10(33.3%)	20(66.7%)	
Basal cisterns	Normal/partially effaced	12(66.7%)	6(33.3%)	**<.001**
	Absent	0(0.0%)	*(100.0%)	
Rotterdam score	3-4	12(63.2%)	7(36.8%)	**<.001**
	5-6	0(0%)	17(100&)	
timing of surgery	<6hrs	1(14.3%)	6(85.7%)	. 276
	6-24hrs	5(29.4%)	12(70.6%)	
	>24hrs	6(50.0%)	6(50.0%)	

** Fisher's Exact Test*

***Among the radiologic findings (ASDH, contusion, ICH, DSF, DAI & IVH), IVH was the only finding with statistical significance*

Student's T-test was performed to see the difference in the mean age of patients with favorable and unfavorable outcome. On average patients with favorable outcomes were five years younger than patients with unfavorable outcomes, but this age difference was not statistically significant (P=0.301). Similarly, there was no difference in the mean time of surgery between the two groups of outcomes. But when we compare the mean age of patients that survived and patients that died, survivors were 10 years younger. This difference in age was statistically significant (t=2.2, SE=4.4, 95% CI=0.8-18.7, P=0.

6. DISCUSSION

Decompressive craniectomy is the surgical removal of a large part of the skull to reduce intracranial pressure that is otherwise intractable. It forms the last tier in the BTF and other guidelines in the management of severe traumatic brain injuries. There are only a few published papers in sub-Saharan Africa regarding the long-term functional outcome of DC for severe TBI. In our country, there is no published study that shows the outcome of DC as to the knowledge of the authors.

In this study, road traffic accident (RTA) involving pedestrian-car accidents was the most common mechanism of injury seen in the most productive age group of 30 years and younger (64%) followed by falls and assaults. The World Health Organization (WHO) estimates that the African region has the highest RTA-related mortality rate in the world (24.1 per 100,000 population vs. 10.3 per 100,000 in Europe) and that 38% of these deaths occurring among ‘‘vulnerable road users” (i.e. pedestrians and cyclists)[29]. Attention to road safety would greatly impact the burden of injury in our country.

This study did not find any significance in gender in predicting outcomes. However, our sample-size was not significantly strong as only 5 females were included in our study as compared to the 31 males.

TBI affects the young and productive portion of the population, causing enormous medical and socioeconomic repercussions, because this population is more exposed to traumatic incidents. In our study 75% of the patients were young people up to the fourth decade of life, being consistent with that reported in other series[30]. In his study, we found that older age is significantly associated with the risk of mortality. Patients that survived were 10 years younger than patients that died (P=0.034). The mean age difference between patients with favorable and unfavorable outcomes was not statistically significant on the student’s t-test. Different studies in the literature have shown age to be a strong predictor of outcome[18]. Many studies consider age as a strong exclusion criterion for doing decompressive craniectomy in TBI. Upper limits in recommendations vary from as low as 30 years to 50 years in the literature[18, 31].

The presence of associated extracranial injury is one factor for poor outcome[32]. 33.9% of the patients in the study had another extracranial injury, orthopedic and chest injury being the most common ones. Our study showed that patients having one or more extracranial injuries were more likely to have an unfavorable outcomes (P=0.011, Fisher's Exact Test).

Admission GCS is important in the decision to perform a decompressive craniectomy. Studies by Aarabi, et al.[23, 33] as well as Howard and colleagues[11]. stated that admission GCS significantly affects outcomes. Different studies have shown unfavorable outcomes in 70-90% of patients with GCS of 3-5[34, 35]. In our study, all 16 patients (44.4% of the total) who had a GCS of 4-5 had

unfavorable outcomes, with only one survivor who was in a vegetative state at 5 months of follow-up. On the other hand, 60% of patients with GCS of 6-8 had a favorable outcome.

Reactivity of the pupils to light is another important factor that influences a patient's outcome. In this study reactivity of the pupils was a statistically significant determinant of outcome ($p<0.001$, Fisher's Exact Test). All five patients (13.9%) who had bilaterally non-reactive pupils have died (GOSE=1). 20 patients had one pupil reactive, among these 17 patients (85%) had unfavorable outcomes, and 3 patients (15%) had a favorable outcomes. The mortality rate of patients with one pupil reactive was 70%. 11 patients included in this study had normal pupillary reactivity to light, 9 patients (85%) had a favorable outcome. Pupil reactivity to light stimulus correlated to outcomes that have been reported in several reports. Bilaterally absent pupillary light reflex was associated with a 56–90% mortality[36]. In another study by Jinn-Rung Kuo[37], the percentage of unfavorable outcomes was 28.6% when both pupils were reactive, 52.6% if one pupil was fixed and 91.3% if both pupils were fixed ($p < 0.001$) the percentage of an unfavorable outcome. According to the study of Göksu *et al* , the outcome in patients with bilateral non-reactive dilated pupil after severe TBI may not always be fatal or poor[38]. Rapid DC may increase the chance of functional survival, especially in patients with admission GCS scores of 6 or 7, if surgery is performed within four hours of the trauma. Due to the delayed presentation of our patients, we have a worse outcomes in patients with abnormal pupillary reactions compared to other literature.

Radiology statistically important findings were the presence of traumatic IVH, the status of the basal cisterns, and the Rotterdam score. ASDH was the most common radiologic finding (86%) and the most common indication for surgery followed by ICH and contusion. IVH was present in 11% of the CT scans of the patients and its presence was a statistically significant indicator of poor outcome ($p=0.006$, Fisher's Exact Test). According to reports in the literature up to 9% of patients with blunt head trauma have IVH on CT. Another study indicated that up to 70% of patients with traumatic IVH had a poor outcomes that seems to be the consequence of associated injuries[39].

A study that assessed the appearance of basal cisterns in 218 patients with severe traumatic head injury showed that mortality rates were 77%, 39%, and 22% among those with absent, compressed, and normal basal cisterns, respectively[40]. In our series, all 18 patients with absent basal cisterns on CT had unfavorable outcomes (100%), in contrast to 33% with normal or compressed basal cisterns having unfavorable outcomes. Hence the status of the basal cisterns on the preoperative CT scan is a significant predictor of outcome ($P<0.001$).

In this study, we used Rotterdam Computed Tomography Score as a predictor of outcome. Rotterdam CT score has been validated and it provides great prognostic discrimination and is an independent predictor of unfavorable outcomes[41]. In a study done to examine the prognostic discrimination and prediction of the Rotterdam CT score in the case of patients undergoing decompressive craniectomy (DC) for TBI, 80% of patients with a score of 3 and 4 had a

favorable GOSE, as compared to patients with a score of 5 and 6 having only 20% favorable GOSE[42]. In our study, this scoring system is a strong predictor of outcome and mortality (P<0.001), with 100% rate of unfavorable outcome and 94% mortality in patients with Rotterdam score of 5 and 6. 63% of patients with a score of 3 and 4 had a favorable outcome.

The timing of decompressive craniectomy is likely to be important in determining the outcome. Guerra et al. maintained that decompressive craniectomy should be performed early in the course of STBI before brain tissue hypoxia and irreversible damage has occurred[21]. Despite the result of some studies[43, 44] which showed that early surgical intervention results in a more favorable outcome, our study didn't show any difference in outcome in the timing of DC. This could be because of the delayed hospital presentation of our patients. The mean time from accident to ED was 18.4 hours (SD=24.3), and the mean time from trauma to surgery was 25.6 hours (SD=26.2).

Infectious complications are described in the literature in 2-10% of cases of DC[44]. Our infection complication rate was 25%, which is higher than most literature. SSI occurred in 9 patients. 3 patients had superficial SSI at the craniotomy site and they were all treated with antibiotics and wound irrigation and debridement. Six patients (16.7%) had an infection of the bone flap kept in the abdominal subcutaneous tissue. We have a high bone flap infection rate compared to other studies. In a study done on bone flap preservation in the abdominal wall after decompressive craniectomy in head injury patients, they found a 10.6% infection rate. Poor nutrition, poor GCS (5-8), patient with bifrontal decompressive craniectomy, and associated comorbid conditions were found to be risk factors for bone flap infection[45].

The Glasgow Outcome Scale is the most widely used system for evaluation of a patients' functional status after decompressive craniectomy. The GOSE is the most reliable, the most reproducible and it ensures the most inter-rater reliability of all outcome measures. Multiple reports have been generated regarding the outcome after decompressive craniectomy. In general, studies after 1999 show good outcomes in 26 to 66% of patients, with mortality rates of 14.7% to 52%. The outcomes of studies that reported outcomes after decompressive craniectomy is summarized in *table 9*. The results of this study show that 33.7% of patients undergoing DC for severe TBI had a favorable outcomes and 66.7% had an unfavorable outcomes. The mortality rate was 52.8%. Among patients that survived, 12 patients (70%) have a favorable outcomes and 5 patients (30%) have an unfavorable outcomes. There are few published papers in sub-Saharan Africa. A study done in South Africa showed a favorable outcome in 33.3%, an unfavorable outcomes in 66.7%, and mortality in 44%[16]. 60% of survivors in this study had a favorable outcome. The result of our study is comparable to the South African and some other studies done in developing countries.

Table 9 - Literature review on predictors of outcome

	N	Favorable[1] %	Unfavorable[2] %	Mortality %
USA, 1991[24]	35	37	40	23
German, 2002[31]	62	29	48	23
France, 2003[18]	40	25	32.5	42.5
China, 2005[28]	241	40	34	26
USA, 2006[33]	50	40	32	28
UK, 2006[13]	49	61	21	18
US, 2008[11]	40	30	15	55
Thailand, 2008[46]	150	25.3	16.7	51.3
DECRA, 2011[12]	77	30	51	19
RESCUIicp, 2016[13]	201	27	46	27
South Africa, 2011[16]	72	33.3	22.2	44.4
Nigeria, 2015[15]	10	60	-	40
Cameroon, 2014[17]	13	77	23	0.7
Total	1025	34.5	33.3	32
Our study	**36**	**33.7**	**13.8**	**52.8**

1 – Favorable outcome includes GOS of 4-5 or GOSE of 5-8

2 – Unfavorable outcome includes GOS of 2-3 or GOSE of 2-4

7. CONCLUSION

The role of primary DC in TBI remains controversial. Despite the conclusion of the two largest RCTs, DECRA and RESCUEicp, comparing the efficacy of DC vs. medical management for patients with TBI, there is still controversy regarding the role of DC in the management of refractory ICH. Some proponents against DC for TBI suggest that the procedure reduces mortality but at the same time may increase the poor outcome group.

This study describes 36 patients who underwent unilateral DC for TBI. Overall, a favorable functional outcome was observed in 33.7% of cases is in keeping with other reports. Our study demonstrated that most survivors after decompressive craniectomy had a favorable long-term functional outcome. A higher rate (60-80%) of favorable functional outcomes was observed for patients with higher preoperative GCS (6-8) and motor score (4-5), normal pupillary reaction, normal basal cisterns, and a lower Rotterdam's score (3-4). On the other hand, patients with GCS ≤5, and bilateral non-reactive pupils have a uniformly poor outcome with almost 100% mortality.

The result of this and other retrospective trials shows that decompressive craniectomy could still have a role to play in carefully selected patients with severe TBI.

8. LIMITATIONS AND RECOMMENDATIONS

There are some limitations observed in this study. The major limitation of this study is that it is retrospective and observational and the sample size is small. As this is a retrospective trial, measurements of outcomes were also made from patient folders and phone calls in a retrospective way. No randomization or blinding of study participants was done. Due to our small sample size, we were not able to perform multivariate analysis, thereby making it difficult to draw any powerful conclusion. There is no clear comparison possible between the sizes of craniectomy performed as all were done by the attending surgeon on duty. The study, therefore, cannot be generalized to all patients with severe brain injury.

Due to the retrospective nature of our study and the small sample size, it is difficult to make a strong recommendation, but the results of this study encourage us to perform fewer decompressive craniectomies in patients with a very severe traumatic brain injury (initial Glasgow score ≤5 and bilateral fixed dilated pupils).

Despite its limitations, the result of this study can be of great help for resource-limited setups like Ethiopia. The result of this study can serve as a baseline data for future studies to be done in this subject matter.

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