COLLEGE OF MEDICINE AND HEALTH SCIENCES

DEPARTMENT OF SURGERY

NEURO SURGERY DIVISION

OUTCOME DETERMINANTS OF DECOMPRESSIVE CRANIECTOMY IN TRAUMATIC BRAIN INJURY PATIENTS: MULTICENTRIC PROSPECTIVE COHORT STUDY, ADDIS ABABA, ETHIOPIA, 2024.

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A RESEARCH THESIS TO BE SUBMITTED TO DEPARTMENT OF SURGERY, NEUROSURGERY DIVISION FOR PARTIAL FULFILLMENT OF NEUROSURGERY SPECIALTY CERTIFICATE

ADDIS ABABA UNIVERSITY.

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Summary:

Background: Many local as well as global figures portends neurotrauma as a commonest cause of trauma mortality and brain trauma foundation designed a tier system to maximize care and reduce mortality. From those protocol, decompressive craniectomy (DC) is the last tier and likely potentially viable option in Low- and middle-income (LMIC) country like Ethiopia as there is lack of invasive neuromonitoring and control of intracranial pressure. We hope our study will make a room in our future patient selection and optimal care.

Objectives: The main objective of this study was to assess the outcome and Determinants of outcome in 94 patients undergoing DC for trauma patients over 21 months and possibly propose Clinico-radiologic outcome predicting scores among patients undergoing DC during study period.

Methodology: A multi-centric prospective cohort study was conducted from January 2023 to September 2024. 94 patients fulfilling inclusion criteria were included in the study and patients were followed till 90 days post operatively and death, favorable and unfavorable outcome using Extended Glasgow Outcome Score (EGOS) were studied at discharge, 30 days and 90 days. SPSS version 29 is used, margin of errors of 5% and CI=95% is utilized first in Chi-square, variables with p-value less than 0.05 is further analyzed using binomial logistic regression after outcome is dichotomized into favorable and unfavorable outcome, Univariate of each variable and multivariate logistic regression was done and Variables with p-value of <0.25 in the bivariable analysis entered to multivariable analysis. The statistical significance is declared at p-value <0.05. We used the measure of association Odd Ratio (OR) with 95% confidence interval.

Result: Out of 94 there were 80 male and 14 female with mean age of, 41.5% of them were severe TB with GCS of <9 and at 3 months follow up after DC 29(30.9%) died and 55.3% had favorable outcome and 13.8% had unfavorable outcome. Univariate analysis of GCS at emergency less than 5(p<0.001), non-reactive pupil(p-0.007), Deranged vital sign at emergency(p-0.018), patient non responding to osmotic diuretic(p-0.001), presence of intra-operative hypotension(p-0.002) and requirement of intra-operative pressor support(p-0.008), immediate post -op GCS (p-0.007) where found to be statistically significant factor of poor outcome.

Conclusion: DC is found as viable option for TBI in LMIC and low GCS (<5) at emergency and immediate post op, non-reactive pupil, deranged peri-operative hemodynamic status, use of peri-operative pressor support and patient not improving to osmotic diuretics were found to die and have poor outcome.

Keywords: decompressive craniectomy, GCS, EGOS, Favorable and Unfavorable outcome.

Acknowledgment

I wish to extend my sincerest gratitude to my esteemed mentors, Dr. Abat and Dr. Mersha, for their invaluable guidance and unwavering support throughout the development of this research project. Their expertise and encouragement have been instrumental in shaping this endeavor.

Furthermore, I am deeply indebted to Addis Ababa University college of health sciences for providing me with the invaluable opportunity and necessary resources/funds to conduct this research in a timely and efficient manner and the University's commitment to academic excellence has been a cornerstone of my success.

Lastly, I would like to acknowledge the indispensable contributions of my family, friends, and most notably, my wife. Their unwavering support and unwavering encouragement have been the bedrock of my perseverance. I am eternally grateful for their belief in me and their steadfast support throughout this journey.

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Acronyms and Abbreviations

ALERT: All Africa Leprosy TB Rehabilitation and training center

BFDC: Bifrontal Decompressive Craniectomy

BLH/TASH: Black Lion Hospital/Tikur Anbessa Hospital

DECRA trials: Decompressive Craniectomy in Patients *with Severe Traumatic Brain Injury*

DC: Decompressive craniectomy

DHC: Decompressive Hemicraniectomy

EGOS: Extended Glasgow Outcome Score.

GOS: Glasgow outcome score

GCS: Glasgow Outcome Score

ICH: Intra Cerebral Hematoma

ICP: Intra cranial pressure

MCM: Mysung Christian Medical Hospital

MMM: Maximal Medical Management

PFDC: Posterior fossa Decompressive craniectomy

RCT: Randomized controlled trials

RESCUE-ICP trials: Trial of Decompressive Craniectomy for Traumatic Intracranial Hypertension)

OR: Odd Ratio

SAH: Subarachnoid Hemorrhage

TBI: Traumatic brain injury

ZMH: Zewditu Memorial Hospital

1. Introduction.

1.1. Background

A retrospective hospital-based study (2002-2006) at TASH revealed that head injuries constituted approximately 60% of trauma-related fatalities among surgical inpatients [1]. This finding aligns with national trends, establishing traumatic brain injury (TBI) as a leading cause of trauma mortality in Ethiopia. Neurotrauma poses a significant public health burden in Ethiopia, characterized by high mortality and disability rates. A meta-analysis further underscores the prevalence of TBI within the Ethiopian trauma population, with 20% of patients sustaining this injury [2, 3].

Following TBI, elevated intracranial pressure (ICP) can arise from various factors, including intracranial hematomas, contusions, diffuse brain swelling, and hydrocephalus. This elevated ICP can compromise cerebral perfusion pressure, leading to brain ischemia. Numerous studies have demonstrated a strong association between post-traumatic intracranial hypertension and increased mortality risk [4-9]. While the management of patients with severe TBI often involves ICP monitoring and interventions to lower ICP, it's crucial to acknowledge the limited availability of level 1 evidence supporting these practices. Effectively managing elevated ICP is paramount in the treatment of severe TBI [6-9]. TBI can lead to an increase in intracranial volume due to hemorrhage, cerebral edema, and hydrocephalus. This increased volume within the confined space of the skull can result in brain herniation, a potentially life-threatening condition.

The Brain Trauma Foundation guidelines outline a tiered approach to managing elevated ICP [6-14]. General measures include head elevation (30-45 degrees), appropriate ventilation, analgesia, and sedation. First-tier interventions encompass hyperosmolar therapy (mannitol or hypertonic saline), hypothermia, and cerebrospinal fluid diversion via ventriculostomy. Second-tier interventions include barbiturate coma or decompressive craniectomy. Notably, the guidelines recommend performing large frontal-temporal-parietal decompressive craniectomies (at least 12

× 15 cm or 15 cm diameter) for optimal ICP management and mortality reduction when this surgical intervention is deemed necessary

Decompressive craniectomy is a neurosurgical intervention involving the removal of a segment of the skull bone and dural opening to alleviate elevated intracranial pressure (ICP) secondary to traumatic brain injury (TBI) [6]. While evidence suggests a beneficial effect of this procedure on mortality and functional outcomes, the specific factors that predict surgical success in trauma patients undergoing decompressive craniectomy remain poorly defined, especially in resource-limited centers. This thesis aims to conduct a comprehensive review and analysis of potential prognostic factors that may influence the surgical outcome of decompressive craniectomy in this patient population.

1.2. Statement of the problem

Traumatic brain injury (TBI) constitutes a significant global health burden, characterized by high morbidity and mortality rates. Global estimates indicate an annual mortality rate of 10.4 per 100,000 individuals. [1] The Centers for Disease Control and Prevention (CDC) reports over 1.7 million new TBI cases annually within the United States, with an estimated 275,000 hospitalizations and 52,000 fatalities. [21,22] Furthermore, the global TBI incidence rate, currently at 106 per 100,000, is on the rise, likely attributed to increased motorization and urbanization in developing nations. [21,22]

Globally, injuries surpass HIV, tuberculosis, and malaria combined in terms of annual mortality. The World Health Organization (WHO) estimates 5.8 million injury-related deaths annually, with a disproportionate burden in low- and middle-income countries (LMICs), accounting for approximately 90% of these fatalities. [1] Head injuries specifically contribute substantially to morbidity and mortality among injured individuals in LMICs. In Africa, a substantial proportion (one-third) of head injury patients experience unfavorable outcomes, and individuals with severe head injuries exhibit nearly twice the mortality risk compared to their counterparts in high-income countries. [4,5] These outcomes are significantly influenced by resource constraints within the healthcare systems of these regions. Enhancing access to pre-hospital care, emergency services, and specialized surgical interventions has the potential to improve patient outcomes. [6]

In Ethiopia, Tikur Anbessa Specialized Hospital (TASH), a major public hospital and the sole neurosurgical and trauma referral center affiliated with Addis Ababa University, serves as a crucial hub for trauma care. Head injuries represent a leading cause of mortality within this institution. A retrospective review conducted at TASH revealed that head injuries accounted for approximately 60% of all trauma-related deaths among surgical service admissions between 2002 and 2006. [10] Moreover, a more recent review of mortality within the emergency department demonstrated that head injuries contributed to 21.5% of all deaths occurring within 72 hours of presentation. [1-3]

Ethiopia exhibits a youthful demographic profile, with 70% of the population below the age of 30. Trauma emerges as the leading cause of mortality within this age group, posing a significant economic challenge due to the loss of productive members of society. Notably, Ethiopia is characterized by high rates of motorization and urbanization, further contributing to the burden of trauma. [2,3]

This research endeavors to identify patient subgroups that may benefit most from surgical decompression and to elucidate key predictors of favorable outcomes following this intervention

1.3. Significance of the study

While decompressive craniectomy has shown promising results in reducing morbidity and mortality in TBI patients, there is still a lack of consensus on the optimal timing, patient selection, and other factors that can influence the surgical outcome to create more confusion, nonetheless, there are conflicting data regarding the effectiveness of decompressive craniectomy in elating post operative good functional outcome.

To the best of our knowledge, there was no prospective and conclusive study conducted which cleared confusion in our clinical practice and decompressive craniectomy is being done irrespectively; this paper will hopefully resolve those contentions and come up with an algorithm that will smoothen and advance our neurotrauma care.

Understanding the determinants of surgical outcome is crucial to improving patient selection, minimizing complications, and optimizing the overall outcomes of decompressive craniectomy in trauma patients in this paper, we will try to come up with recommendations and possibly scoring systems that will help us in predicting the outcome of decompressive craniectomy which will be base and foundation of clinical practice for local guidelines and /or global faculties.

1.4.Research Question(s):

1.4.1. Is decompressive craniectomy worth doing in our setup for traumatic brain injury patients?

1.4.2. If it is worth doing, what are the predictors of good outcome?

1.4.3. What are the predictors of bad outcomes?

2. Literature Review

2.1. Measurements of Outcome:

The Glasgow Outcome Scale (GOS) and its extended version (GOSE) are widely recognized as the gold standard for assessing outcomes following major trauma, including head injuries. The GOS's enduring popularity stems from its simplicity, brevity, reliability, validity, versatility (face-to-face, telephone, or mail administration), and cost-effectiveness. These advantages extend to derivatives such as the Glasgow Outcome at Discharge Scale (GODS) and the pediatric GOS revision. While the GOS primarily focuses on social recovery, there's growing recognition of the multidimensional nature of TBI outcomes. In this study, we utilized the GOSE to assess outcomes at both discharge and follow-up, aligning with established best practices.

2.2. Outcomes After Decompressive Craniectomy for TBI:

Decompressive craniectomy is a surgical intervention for TBI, but its efficacy remains controversial despite extensive research. While numerous studies have investigated its potential benefits, conclusive evidence supporting its routine use remains elusive.

- **Early Studies:**
    - Piek et al. (1971-2001) reported cumulative mortality of 30% and poor outcomes (GOS 1-3) in 14.7% of patients undergoing decompressive craniectomy. [2]
    - Howard et al. observed a 55% mortality rate in a cohort of 40 patients, but among survivors, 66% achieved good outcomes (GOS 4 or 5). [3]
- **The DECRA Trial (2011):** This landmark randomized controlled trial compared decompressive craniectomy with maximal medical management in 155 adult TBI patients. While mortality rates were similar between groups, the decompressive craniectomy group exhibited worse functional outcomes. [4]

- **Critiques of DECRA:**
  - High crossover rates from medical management to decompressive craniectomy might have skewed the results.
  - Inclusion criteria limited the study population, and potential imbalances in patient characteristics between groups were noted.

- **The RESCUEICP Trial (2016):** This second randomized controlled trial involving 408 patients demonstrated improved functional outcomes and reduced mortality in the decompressive craniectomy group compared to medical management. [13]

Decompressive craniectomy remains a subject of ongoing debate. While early studies offered mixed results, the recent RESCUEICP trial provides evidence supporting its potential benefits in carefully selected TBI patients with refractory intracranial hypertension. However, further research is crucial to refine patient selection criteria and optimize treatment protocols.

1.3. REVIEWING GUIDELINES: [10-17]

- Updated Summary of Guidelines and Recommendations from RCTs and Others on Decompressive Craniectomy (DC)

A. Impact on Mortality and Overall Outcome:

- **Late Refractory ICP:** Secondary DC performed to address persistent, high intracranial pressure (ICP) that doesn't respond to other treatments (late refractory ICP) is recommended. This approach has been shown to improve survival rates and overall patient outcomes.

- **Early Refractory ICP:** Secondary DC is **not** recommended for early-onset, treatment-resistant ICP. Evidence suggests it may not improve survival or lead to better patient outcomes in these cases.

- **Craniotomy Size Matters:** A larger craniotomy (at least 12 x 15 cm or 15 cm in diameter) is generally favored over smaller ones. This approach has been linked to lower mortality rates and improved neurological recovery in patients with severe traumatic brain injury (TBI).

B. ICP Control:

- **Secondary DC:** Regardless of whether it's performed for early or late refractory ICP, secondary DC can effectively reduce ICP and shorten the duration of intensive care. However, the direct link between these effects and improved patient outcomes remains uncertain.

C. Modifications and Considerations:

- **Bifrontal DC:** For patients with diffuse brain injuries (without localized masses) and significantly elevated ICP (above 20 mmHg for more than 15 minutes within an hour) that doesn't respond to initial treatments, bifrontal DC is **not** recommended. This approach has been shown to reduce ICP and shorten ICU stays, but its impact on overall patient outcomes (measured by the GOSE score) at 6 months post-injury is not significant.

- **Craniotomy Size:** As mentioned earlier, a larger craniotomy (at least 12 x 15 cm or 15 cm in diameter) is generally preferred for better outcomes

- **Meta-analysis findings on Decompressive Craniectomy (DC) for Traumatic Brain Injury (TBI)[16-20]:**

- **Aljishi et al. (2011):** This study compared primary and secondary DC in a smaller cohort. While pre-operative characteristics differed between the groups, secondary DC was associated with significantly better mortality (15.4%) and a higher proportion of good neurological outcomes (73.1%) compared to primary DC
- **Garg et al. (2019):** This meta-analysis of 28 RCTs involving 573 patients examined the impact of DC on mortality and adverse outcomes. The study found a significant reduction in mortality rates (nearly 50%) among patients who underwent DC. However, survivors of DC were more likely to experience poor neurological outcomes compared to those receiving medical management.
- **Zhang et al. (2023):** This recent meta-analysis of 8 RCTs (1458 patients) demonstrated a statistically significant reduction in ICP levels (-4.01 mmHg) and a 31% decrease in mortality rates in the DC group compared to the control group.

Table-I. Summary of Factors affecting outcome in DC:

SN.	Author, year and place	Sample size and characteristics	Poor outcome rate (%)	Factors identified
1.	Gouello etal[24], 2014; France	60, mean age=33, Male=77% mean GCS=7	38.3	GCS
2.	Sharda etal [25] 2014; Malaysia	110, mean age=36, 86%-Male; 31.8%-GCS<8	32.7, death	Post-op Hypoxia, CPP and BP (MAP)
3.	Saade etal [26.] 2014; Brazil	56, 31-40; 80%-M; 52%-GCS4/5	78.6	Dilated, Unreactive pupil, GCS<5; MLS>15r and presence of Intracranial lesion
4.	Grille and Tommasino[27] 2015; Uruguay	64, mean age=31, 79%=M GCS=7+/-3	66	Post-op ICP and Low GCS* @admission
5.	Sinha etal[28] 2015; India	1236, mean age=32, 81%=M, GCS=6,	41.7, death	Age, GCS, Pupillary reaction, Pre-op Hypotension, MLS, brain swelling, EDH, SA infarction, polytrauma, duraplasty/ slit duroto bilateral DC, Length of stay
6.	Bagheri etal[29] 2017; Iran	61, mean age=36, 59%=M,18%-GCS,5	45.9	GCS*(<5), Age*(>60), DNRP, MLS (>10)
7.	Dhakre etal 2019; India	96, mean age 67.7% (18-40), 84%-M, 22.6% -GCS<8	50	Pre- and post-op GCS and Neurologic status.
8.	Silva etal [30] 2020; Brazil	131, 57.3%(19-39), 90%-M, 49%-GCS<8	74	GCS@Admission
9.	Shukla etal [31] 2020; India	83, mean age=32, 82%-M, GCS=7+/-3.4	49	GCS, Hydrocephalus, Older age

10.	Tau etal [32] 2020, South Africa	62, mean age=36.1, 82%-M, 58%-GCS<8	53	Mechanism of trauma, GCS, Time lapse trau to hospital admission
11	Gopolan etal [33],2021; India	164, most 18-40 84%-GCS<8	69.5;39 dead	GCS(Motor*), pupillary reactivity, type of DC(Primary=40% and Secondary=37%) and op hypotension
12.	Ogundale etal[37] 2018; USA	50, mean age=22.4+/-3, 86%-Male; all GCS<9	12% mortality@30day	GCS @arrival(<5), type of surgery(cranioton vs craniectomy), effacement of basal cisterns/MLS, closed TBI.
13.	Celi etal [38] 2020; Peru	32, mean age=52.2, 82%-M, mean GCS=9, and 73% Anisocoric	12% mortality	Size of the flap and MLS>5mm
14.	Balaj etal [39]2023, India	126, 65.1%<60 GCS<9	12.6%	Age>50, Brain stem involvement, redo surge for recollection, meningitis, Hypernatremia, Hydrocephalus and DAI

- Finally, Decompressive Craniectomy (DC) for Traumatic Brain Injury (TBI) remains a highly debated surgical intervention. The two pivotal randomized controlled trials (RCTs), DECRA and RESCUEICP, while offering valuable insights, have not definitively established the efficacy of DC. Both trials present complex and nuanced data, making definitive conclusions challenging. A key takeaway from these studies is that the decision to proceed with DC is not straightforward. It requires a careful and individualized assessment, weighing potential benefits against the risks of complications and the likely patient-specific outcomes.
- Despite significant advancements in prognostic models for severe TBI at the population level, predicting individual patient outcomes with high accuracy remains a significant challenge**.**
- While the consensus is that DC should be performed before irreversible neurological damage occurs, the optimal timing for the procedure remains a subject of ongoing debate. Some

advocate for ultra-early DC (within 4 hours) or early DC (within 12 hours) of injury, while other studies suggest that the timing of DC may not significantly impact outcomes

- 2.4. Conceptual framework

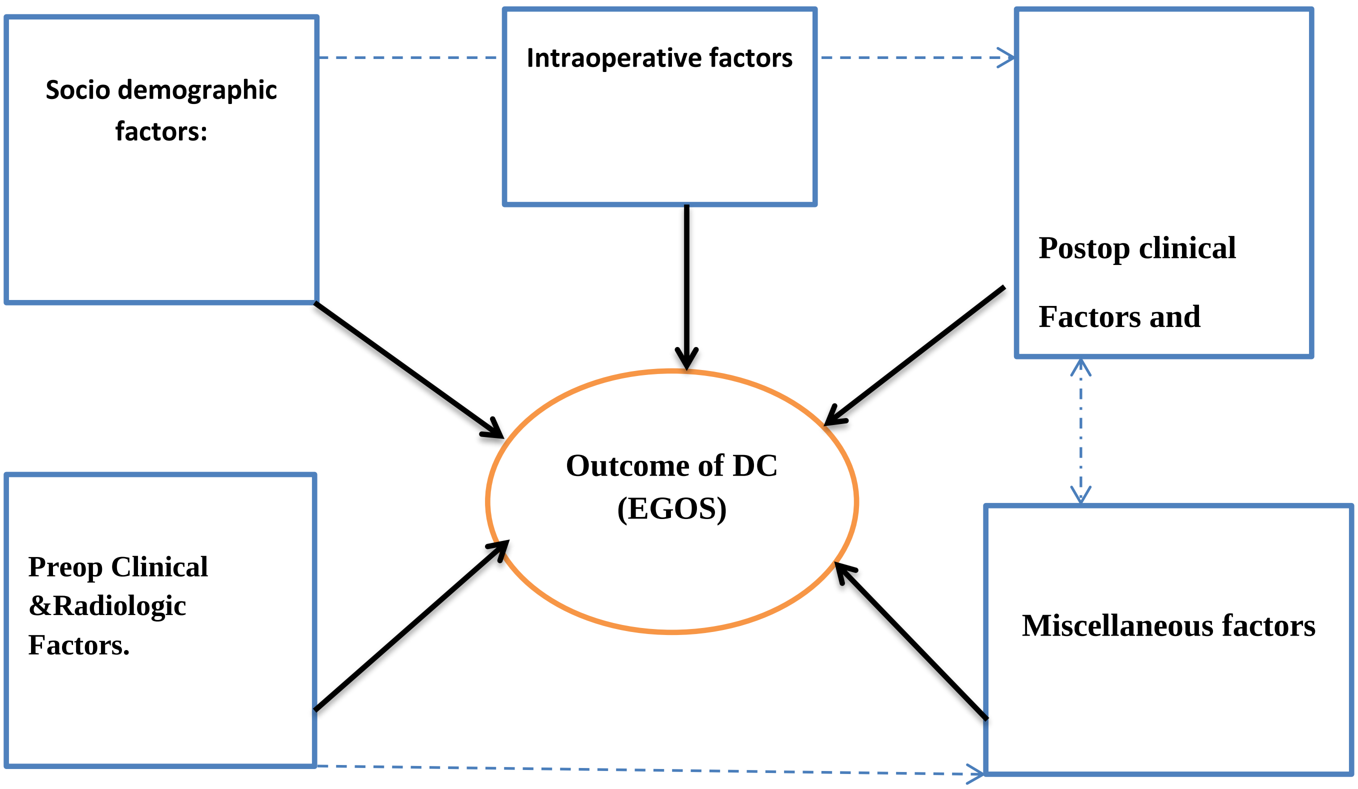


Figure-I: Conceptual frame work showing the relation between the outcome and different factors

1. Objectives

3.1. General objective

- To assess the outcome determining factors in DC for trauma patients and propose clinico-radiologic outcome predicting scores among patients undergoing DC at BLH, ALERT, ZMH and MCM from January 2023 to September 2024.

3.2. Specific objective

- To assess good outcome predicting factors: pre-op, intra-op and post-op
- To assess worse outcome predicting factors: pre-op, intra-op and post-op
- To design outcome predicting scores in DC.

4. Methodology

4.1. Study design and period

A Facility based prospective cohort study will be conducted on patients undergoing DC for traumatic brain injury in the study period.

4.2. Study setting

The study will be conducted at four (4) teaching hospitals of Addis Ababa University: Alert, BLH, MCM and ZMH.

4.3. Source Population

All patients who sustained traumatic brain injury and has an indication for surgery at 4 teaching hospitals during study period.

4.4. Study Population

All patients undergoing DC at 4 of AAU affiliate teaching hospitals: ALERT, BLH, MCM, ZMH fulfilling the inclusion criteria with in the study period.

4.5. Inclusion and Exclusion criteria

4.5.1. Inclusion criteria:

All patients undergoing DHC for TBI during the study period.

4.5.1. Exclusion criteria:

Patients/family/attendant who refused consent will be omitted in the study.

4.6. Sample size determination

Using sample size calculation formula: n=population/sample size, p=standard deviation (50%), e=margin of error (5%), Z=z-score (1.96),

$$\text{Unlimited population:} \quad n = \frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2}$$

$$\text{Finite population:} \quad n' = \frac{n}{1+\frac{z^2 \times \hat{p}(1-\hat{p})}{\varepsilon^2 N}}$$

The sample size for the study is determined using:

Where: n = required sample

Z-α/2_= Critical value=1.96

p= 50%.

d= precision (marginal error) =0.05

Therefore: n = (1.96)2 (0.5X0.50)/ (0.05)2 = 384

The study population is less than 10K, the final sample size will be

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

nf $=384/\ [1+\frac{384}{105}]$ = 82, we added a 10% non-respondent rate, making a sample size = <u>90</u>

→ nf=> Final sample size; N- Average number of patients who will undergo Decompressive craniectomy over 21 months study period in the four study hospitals as there was an average of 5 DC in a month in total (min 2 and maximum 8) which will be 105.

4.7. Sampling procedures

All eligible subjects will be included in the study.

4.8. Variables of the study

4.8.1. Dependent variables

The outcome variable is outcome of DHC using EGOS. EGOS is classified into Death, good (4-8) and bad outcome (1-3) for this study. EGOS will be assessed up on discharge, at first month and 3rd month post-operatively.

4.8.2. Independent Variables

A. Sociodemographic factors

- Preop comorbidity
- Mechanism of trauma
- Sociodemogrphic factors

B. Preop Clinico-radiological factors

- Clinical:
- Other site(s) trauma
- Emergency Vital Sign
- GCS
- Pupillary size and reaction
- Motor weakness
- Use of osmotic diuretics and its response
- Radiological:
- Type of lesion: ASDH, EDH, contusion
- Site: Supratentorial: Frontal, Lateral: Infratentorial-PF; Right, Left
- Brain CT: Rotterdam Score

C. Intra-operative factors

- Type and site of DC: Primary, Secondary
- Size of Craniectomy flap
- Duration of surgery
- Estimated Blood loss
- Type of dural opening and tissue used for duraplasty
- Any hypotensive record and use of vasopressor(s)
- Brain swelling
- Type of anesthesia used

D. Post op Discourse.

- Post op disposal: ICU, Ward
- Use of MV
- Immediate post-op GCS

- Infection
- Recollection and /Re-do surgery.

4.9. Operational definitions

- **Primary Decompressive craniectomy:** refers to the leaving off of the craniotomy flap during an emergency procedure for evacuating a traumatic collection or post traumatic edema.

- **Secondary Decompressive craniectomy:** DC after failed Medical Management.

- **GOSE:** 8 category functional outcome score: 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+). See index for reference.

- **Rotterdam BRAIN CT score:** Brain CT scan scoring system which predicts mortality at 6 months using 4 components: MLS, Basal cistern, EDH, IVH/tSAH Scored out of 6, higher score suggesting higher mortality.

4.10. Data collection tools and procedures

Data will be collected by neurosurgical residents prospectively. Each of the study populations will be followed on the scheduled time intervals outlined in the methodology. The data will be collected from the patient's/attendants, emergency, neurosurgical team and Critical care unit and documented electronically using pretested questionnaires using google doc.

4.11. Data quality control

Two days intensive training will be given to the data collectors on how to conduct the data collection. Data quality will be managed by training and appropriate supervision of data collectors. Overall supervision will be made by the supervisor and principal investigator. And the collected data will be checked its completeness, clarity and accuracy. This quality checking will also be done daily after data collection and correction will be made before the next data collection measures. Data clean up, cross checking and double entry will be done before analysis.

4.12. Data processing and analysis

The coded data containing demographic, preop imaging factors, post op factors will be exported to SPSS version 27 statistical software for further management, cleaning and analysis. Descriptive statistics, frequencies and percentages for categorical variables and summary statistics for continuous data (mean with standard deviation in normally distributed data or median with IQR if the data is not normally distributed) will be used to characterize the study population.

This outcome will be assessed in patients who underwent DHC at Discharge, 1^{th} and 3^{rd} month post operatively.

Bivariable analysis will be done to see the association of each predictor variables with patient neurologic outcome postoperatively using EGOS. Variables with p-value of <0.25 in the bivariable analysis will be entered to multivariable analysis. The statistical significance will be declared at p-value <0.05. The measure of association will be Risk Ratio (RR) with 95% confidence interval, for the study design is prospective follow up study design.

4.13. Ethical considerations

Ethical approval will be obtained from the Ethical Review Committee of Addis Ababa University. Confidentiality of the information will be assured by omitting personal identifiers like names. The research involves no more than minimal risk to the subjects and the waiver or alteration will not adversely affect the rights and welfare of the subjects.

4.14. Dissemination plan

The finding of this research will be shared to the neurosurgery unit so that it can serve as a baseline data to the attending neurosurgeons and fellow residents. Similarly, it will be presented in annual neurosurgical society of Ethiopia and other international scientific conferences across the world. Last but not least, the finding of this research finding will be published in a reputable high impact neurosurgical journal so that its visibility and usefulness can be escalated in the scientific community.

5. RESULT

A total of 94 Decompressive craniectomy (DC) is done for traumatic head injury (TBI) in four Addis Ababa university affiliate hospitals over the period of 21 months which meets inclusion criteria. Out of 94 patients undergoing DC during study period 11(11.7%) were female and 83(88.3%) is male. The age range is between 18-78 and with mean age of 38.9+/-15.048

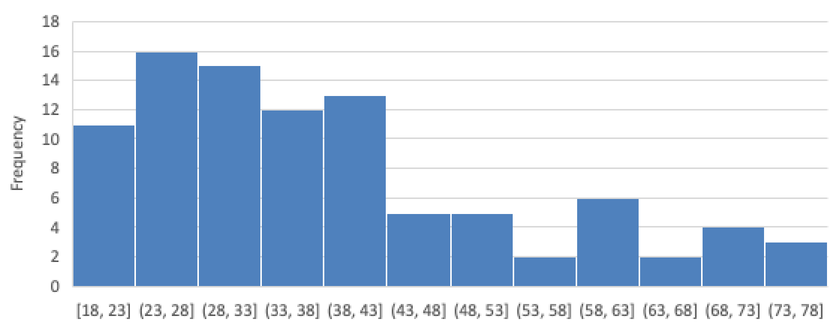


fig. showing age frequency distribution.

Figure 1: age frequency distribution.

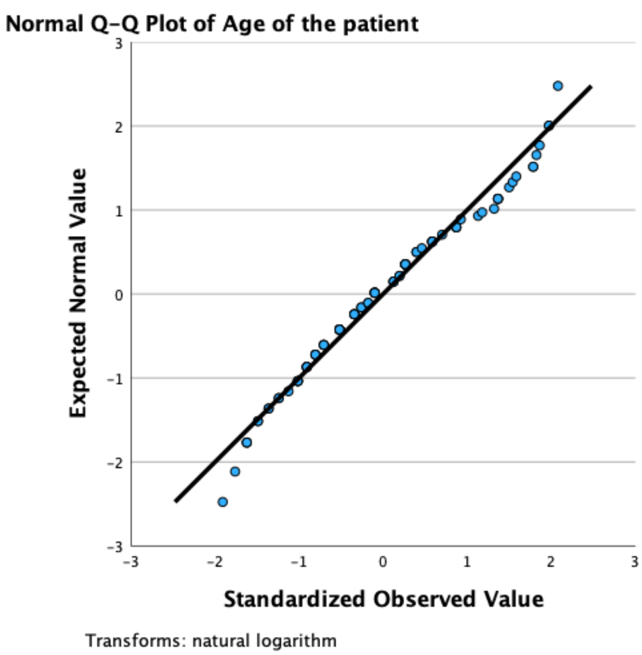


Figure 2: Q-Q plot of age.

Road traffic accident (RTA) is the commonest trauma mechanism accounting 51(54.3%) followed by assault 21(21.3%) and 2(2.1%) patients came after sustaining penetrating injury as detailed in below pie chart.

Figure 3: Mechanism of trauma

While most of the patient which means 29(30.9%) of them arrives to emergency neurosurgical centers in less than 4hrs of trauma, 3(3.2%) came after 72hours of trauma. totally 86(91.49%) of patients come to emergency neurosurgical centers in 24hs while only 8(8.51%) come after 24 hours of sustaining trauma in study period

.

Figure 4: Duration of trauma

Out of 94 patients undergoing DC, 14(14.9%) had GCS less than 5, which is critical head injury 25(26.6%) had GCS Between 5-8, which mean 39(41.5%) had severe TBI, 36(38.3%) had moderate TBI with GCS of 9-12 and 19(20.2%) had mild TBI with GCS of 13-15 as described in figure below.

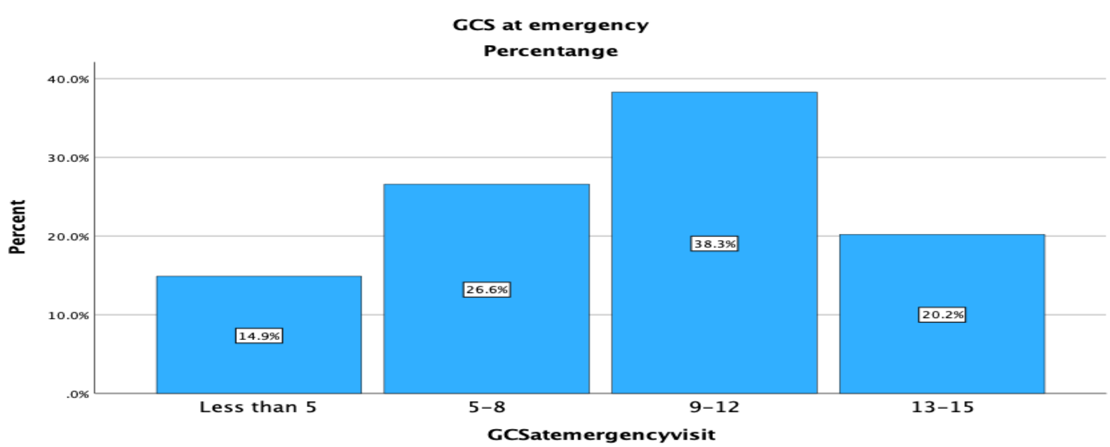


Figure 5: Severity of TBI at Emergency using GCS.

Regarding pre-operative pupillary reflex status finding, 9(9.6%) had bilaterally fixed and dilated pupil while majority 59(62.8%) had mid-sized and reactive, 11(11.7%) had anisocoric and non-reactive and 13(13.8%) had anisocoric and reactive pupillary light reflex preoperatively as tabulated in figure below.

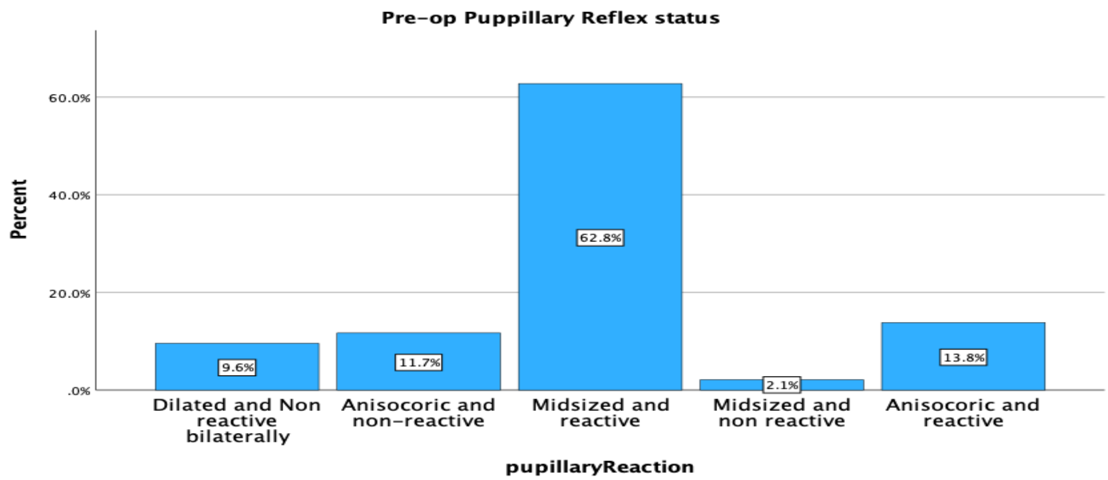


Figure 6: pre-op Pupillary reflex status

The pre-operative motor weakness status of the patient defined as motor power less 4 for this study, 45(47.9%) had no weakness, 34(36.2%) had contralateral weakness to the site of lesion and 4(4.3%) had bilateral lower extremity weakness as depicted in table below.

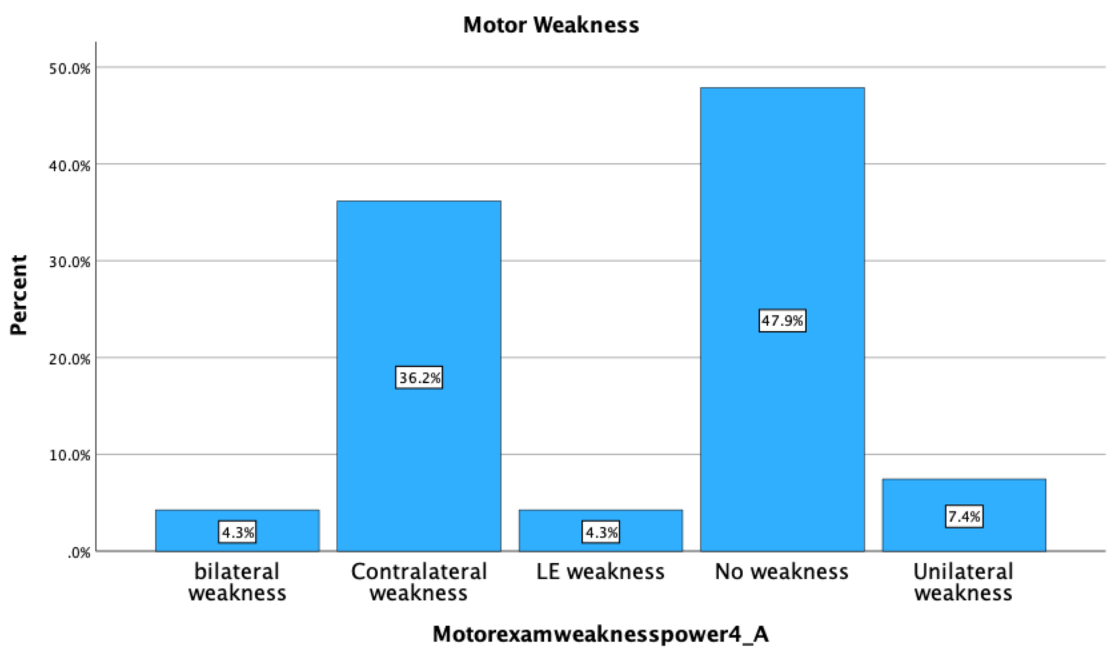


Figure 7: pre-op Motor exam

During emergency visit 11(11.7%) patient had vital sign derangement with 9(9.6%) cases having Hypotension with systolic blood pressure (SBP) of less than 90. One (1.1%) patient having cardiac arrest and surgery done after resuscitation. Only 4(4.3%) had known comorbidity out of which 2(50%) patients had known hypertension on drug (Amilodipine) and another one is a patient with ischemic heart disease (IHD) taking aspirin while the other patient is hemophilic on factor replacement.

Preoperatively 92(97.9%) has taken mannitol and 45(48.9%) improved in neurologic condition and 47(51.1) stayed the same after challenging with mannitol.

Rotterdam CT scan score is utilized to classify them into 6 categories using: Status of basal cistern (Normal, compressed or absent), presence or absence of midline shift (MLS), Epidural hematoma (EDH) or intraventricular hemorrhage (IVH) and +1 point added after scoring above variables and classified into 6 categories to measure association with our desired outcome. Accordingly, 29(30.9%) where Class-III, 25(26.6%) is class-II and 27(28.7%) is Class-IV as described in bar chart below.

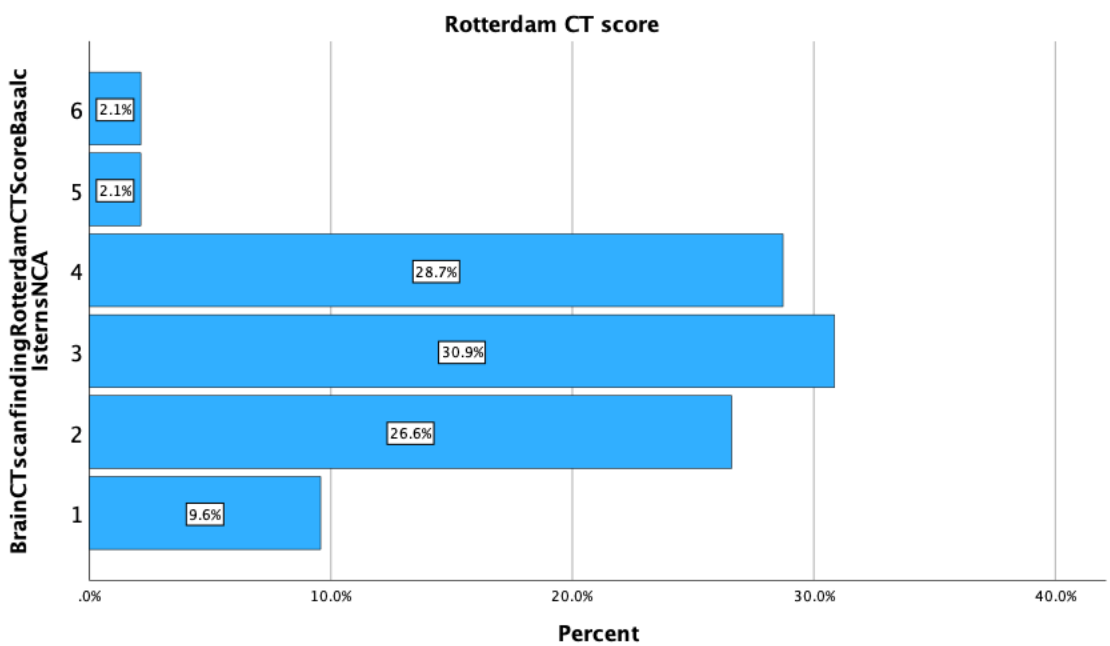


Figure 8: Rotterdam CT score

Acute subdural hematoma (ASDH) is the commonest imaging finding accounting 28 (29.8%) while ASDH with underlying contusion accounts for 11(11.7%) followed by traumatic contusion making 10(10.6%), contusion with traumatic intracerebral hemorrhage (TICH) accounts 8(8.5%) details of lesions are described in table below.

Type of Lesion.	Frequency	Percent
ASDH	28	29.8
ASDH, CONTUSION	11	11.7
Bilateral ASDH	1	1.1
CONTUSION	10	10.6
EDH	1	1.1
Multiple ST Lesion	28	29.8
PTBI	1	1.1
TICH	6	6.4
TICH, CONTUSION	8	8.5
Total	94	100.0

Table 1: Type of Lesion.

Location.	Frequency	Percent
ST-Frontal	20	21.3
ST-Frontal, Infratentorial	1	1.1
ST-Frontal, ST-Lateral	17	18.1
ST-Lateral	54	57.4
ST-Lateral, Infratentorial-	2	2.1
Total	94	100.0

Table 2: Location of lesion.

Most of the lesions are in supratentorial lateral (Parieto-temporo-occipital) 30(31.9%) and 20(21.3%) patients had isolated supratentorial frontal lesion and 2(2.1) patients had both supra and infratentorial lesion requiring DC surgery 1 patient having both posterior fossa lesion which required DC and and supratentorial EDH requiring surgery (Craniotomy).

Only 6 patients had extracranial additional trauma where 3(3.2%) had associated spine lesion, 2(2.1%) had other Head and Neck lesion and 1(1.1%) had abdominal lesion.

Surgery is done in 46(48.9%) with in 24 hours of trauma and in 10(10.6%) it is done after 72hours of trauma and the remaining 38(40.4%) in between.

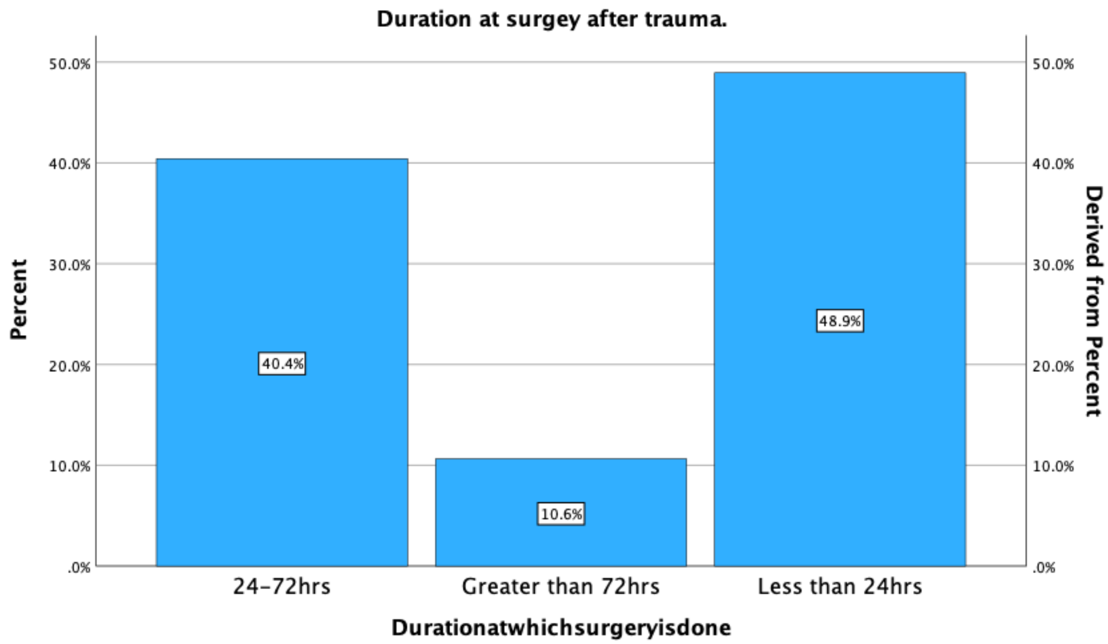


Figure 9: Surgery Trauma Interval.

Type and location of DC is characterized and 69(73.4%) underwent lateral DHC and 22(23.4%) underwent BFDC and 2(2.1%) had combined SODC and DHC and 1(1.1%) had SODC alone. From DHC 37(39.4%) surgery is performed on the left side and 34(36.2%) had DHC on the right.

There were 80(85.1%) primary DC and 14(14.9%) Secondary DC done for refractory increased Intracranial pressure (ICP) after trials of maximum medical treatment and to those patients who deteriorated on medical management of ICP.

	Frequency	Percent	Percent
Primary	80	85.1	85.1
Secondary	14	14.9	14.9
Total	94	100.0	100.0

Table 3: Type of Decompression.

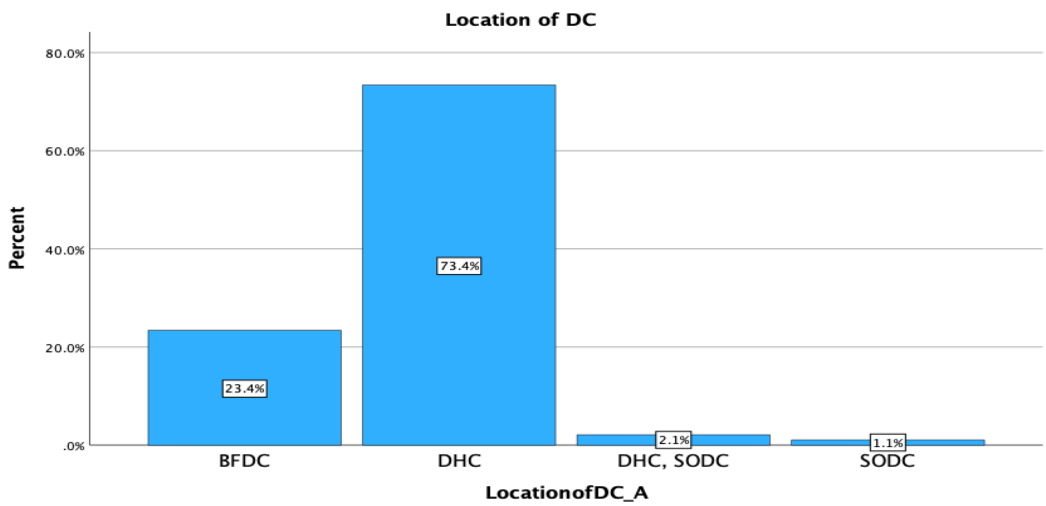


Figure 10: Type of Decompressive Craniectomy.

Location of DC.	Frequency	Percent
BFDC	22	23.4
DHC	69	73.4
DHC, SODC	2	2.1
SODC	1	1.1
Total	94	100.0
Site of DC.	Frequency	Percent
BFDC	22	23.4
Left	37	39.4
Right	34	36.2
SODC	1	1.1
Total	94	100.0

Table 4: Location and Site of Decompressive Craniectomy

Duration of surgery is further categorized to check for association with outcome in which fast surgery is considered surgery taking less than 90min for this study and prolonged surgery is greater than 180min for a single decompressive surgery. Accordingly, in only 2(2.1%) of patient surgery is performed in less than 90min out of which one had intra-operative arrest.

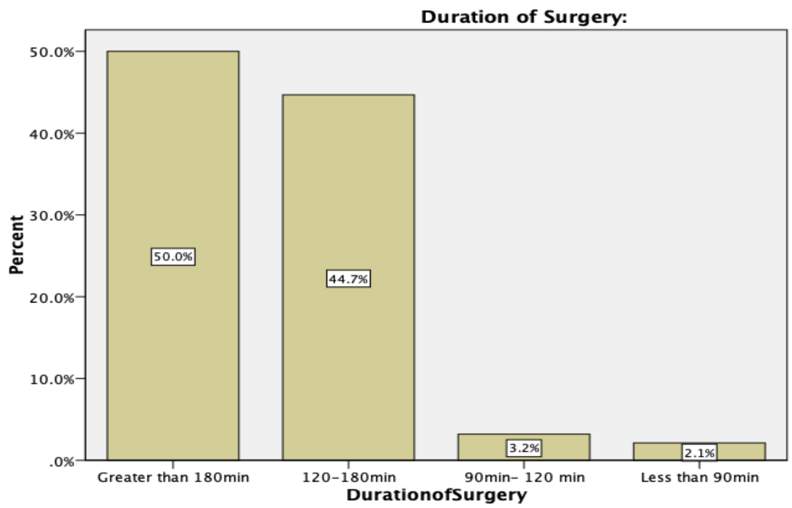
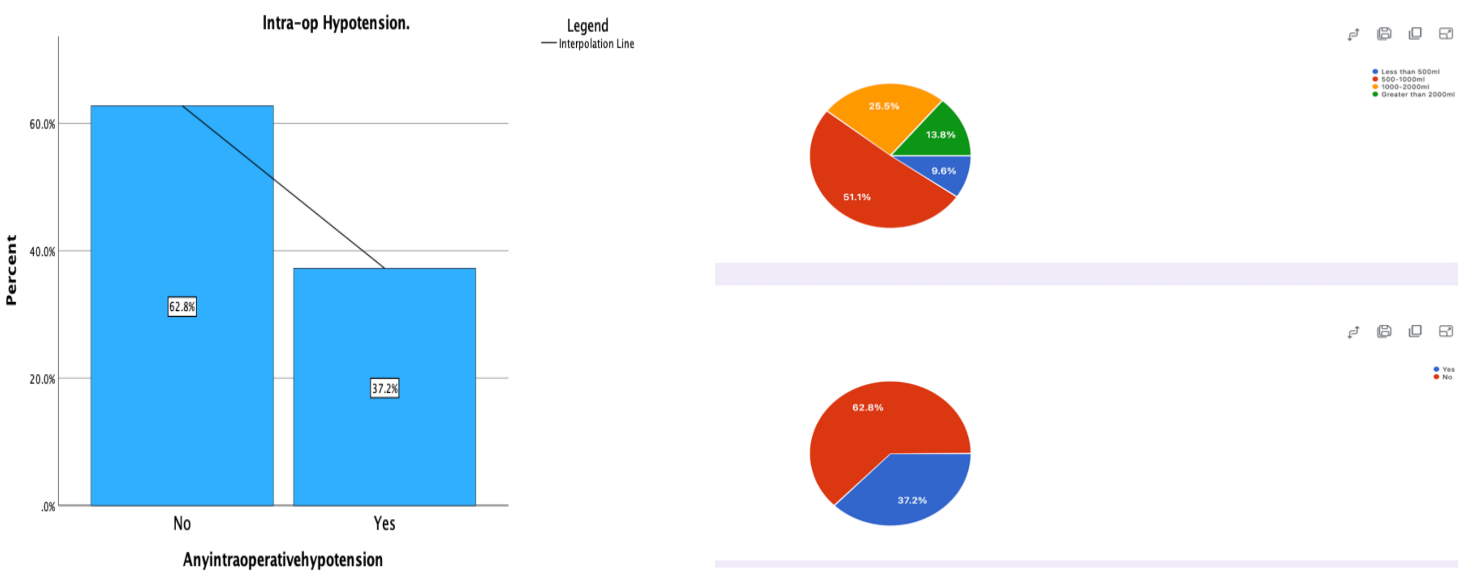


Figure 11: Duration of Surgery in min

Intra operatively 35(37.2%) of our patients had hypotension out of which 23(24.5%) required vasopressor support as described below meanwhile 13(13.8%) had intra-operative blood loss greater than 2000ml while 9(9.6%) had blood loss than



500ml.

Figure 12: Estimated blood loss and Intra-op Hypotension.

Post operative discourse of most of our patient was ICU 74(79.8%) while there was 2(2.1%) intra-operative arrest and others transferred to recovery and then ward.

Outcome:

Outcome of all patients who underwent surgery was assessed using extended Glasgow outcome (EGOS) score and score of 1-Death, 2-4, unfavorable and 5-8 assigned as favorable outcome. Up on discharge 17(18.1%) died and 22(23.4%) had unfavorable outcome and 55(58.5%) had good outcome. Subsequently these patients are also followed at 1 month and 3 months where mortality increased to 21(22.3%) and 29(30.9%) respectively and at 3 months 52(55.3%) had favorable outcome and 39(44.7%) had unfavorable outcome (both death and unfavorable) and details is described in table below. (See below for reference)

Post Op Discourse.	Frequency	Percent	**Discharge EGOS**	Frequency	Percent
ICU + MV	75		Death	17	18.1
ICU no MV	17	18.1	Unfavorable	22	23.4
Intra-Operative arrest	2	2.1	Favorable	55	58.5
Total	94	100.0	Total	94	100.0

Table 5: Post op discourse and Discharge EGOS.

1 Month EGOS	Frequency	Percent	**3Month EGOS**	Frequency	Percent
Death	21	22.3	Death	29	30.9
Unfavorable	23	24.5	Unfavorable	13	13.8
Favorable	50	53.2	Favorable	52	55.3
Total	94	100.0	Total	94	100.0

Table 6: One month and 3 months EGOS.

Commonest cause of intra-hospital mortality was refractory increased intracranial pressure 9(47.4%) followed by respiratory related complication accounting 7(36.8%) and there was 2(10.5%) intra-operative death.

GCS-E*	EGOS-3mo*				Total
		Death	Unfavorable	Favorable	
	<5	8	2	4	14
	5-8	13	6	6	25
	9-13	6	5	25	36
	14-15	2	0	17	19
Total		29	13	52	94

Table 7: GCS- at emergency with 3 months outcome Using EGOS.

*Table 8: **Summary Table****: Analysis of **Predictor Factors** and degree of significance*

SN	Predictor variables (Independent variables) **	Pearson Chi-square p-value			Univariate and Multivariate Reg.		
		Discharge	1month	3months	Univar-1m	Univar-3m	Multi-V3
1.	GCS at emergency	p<0.001	p<0.001	p<0.001	p<0.001	p<0.001	p-0.007
2.	Pupillary reflex	p<0.001	p=0.003	p=0.022	p-0.01	p-0.027	*
3.	Pre-op V/S derangement	p<0.001	p=0.013	p<0.001	p-0.025	p-0.018	*
4.	Motor weakness	p-0.212*	p=0.015	p-0.148*	*	*	*
5.	Response to Osmotic Diuretic	p<0.001	p<0.001	p<0.001	p<0.001	p-0.001	p<0.001
6.	Rotterdam CT score	p<0.001	p=0.005	p=0.146*	*		
7.	Type of lesion	p=0.05	p-0.061	p-0.064	*		
8.	Location of lesion	p=0.05	p-0.195*	p-137*	*		
9.	Trauma-surgery interval	p-0.141*	p=0.021	p=0.012	*		
10.	Duration of surgery	p-0.007	p-0.03	p-0.189*	*		
11.	Intra-op hypotension	p<0.001	p<0.001	p<0.001	p-0.018	p-0.002	*
12.	Requirement/use of pressor	p<0.001	p-0.006	p-0.002	p-0.046	p-0.008	*
13.	Post op discourse	p<0.001	p-0.006	p-0.002	*	*	*
14.	Immediate post-op GCS	p<0.001	p-0.006	p-0.002	p-0.008	p-0.296	*

***14 variables are identified to be associated with outcome at discharge, 1 month and 3 months showing statistical significance of p<0.05 as shown in table above, and further inferential analysis using logistic regression is done where 7-variables/6-variables showed statistical significance in univariate logistic regression with p<0.05 at 1 month, and 3 months respectively and 2-variables showing statistical significance of p<0.005 at multivariate analysis as shown in table above. *=> Not associated; Univar-1m/3m; =>univariate analysis at 1 month and 3 months respectively, multi-V3=>Multivariate analysis at 3 months.*

After confirming normal distribution using skewness and kurtosis, Independent T-test of age is done and mean age of favorable outcome is 3.7 years younger than unfavorable group (40.9 vs 37.2) but doesn't show statistical significance(p-0.23).

6. Discussion and Recommendation

Decompressive craniectomy(DC), a surgical procedure involving the removal of a portion of the skull and opening of the dura mater to alleviate elevated intracranial pressure (ICP), has a long history. First described by Kocher in 1901 and further popularized by Cushing, it has become an established neurosurgical intervention for managing refractory ICP in severe TBI. However, despite its increasing utilization, the optimal timing, indications, and long-term outcomes of DC remain areas of active investigation.

Literature Review and Regional Context:

Published data on the determinants of short- and long-term functional outcomes following DC for TBI in sub-Saharan Africa, particularly in our specific region, is limited. To the best of our knowledge, no prospective studies have comprehensively examined the factors influencing DC outcomes in this context.

Historical Perspective:

The evolution of DC reflects advancements in neurocritical care. While early reports, such as Cooper et al. (1976), 53 documented high mortality rates (90%) following hemicraniectomy for acute subdural hematomas, subsequent studies, including those by Polin et al. (1990) 55 and Williams et al., 54 demonstrated significant improvements in outcomes, with mortality rates decreasing to 11-23% and 33%, respectively.

Contemporary Outcomes:

Numerous retrospective studies have evaluated DC outcomes, reporting variable mortality rates ranging from 11% to 59%. 39-42 Our study observed mortality rates of 18.1%, 22.3%, and 30.9% at discharge, 1 month, and 3 months, respectively, which align with the findings of many other studies.

Functional Outcome Assessment:

The Extended Glasgow Outcome Scale (EGOS) is currently the most widely used and reliable measure of functional status following DC, ensuring greater inter-rater reliability compared to other outcome measures. Studies conducted in recent decades have reported good outcomes in 25-77% of patients, with mortality rates ranging from 11.7% to 59%.

Our Study Findings:

In our study, 53.2% and 55.3% of patients achieved favorable outcomes at 1 month and 3 months, respectively. Conversely, 46.8% (with 22.3% mortality) and 44.7% (with 30.9% mortality) experienced unfavorable outcomes at these time points.

Regional Comparison:

While limited data exists from the African continent, a retrospective study from South Africa reported favorable outcomes in 33.3% of patients and an unfavorable outcome rate of 66.7%, with a mortality rate of 44%. 52 Our study's mortality rates (22.3% and 30.9% at 30 and 90 days, respectively) appear to be lower than those observed in some local unpublished findings (as high as 52.8%), 6 potentially attributable to the inclusion of a higher proportion of patients with moderate-to-mild TBI (58.5%) in our study compared to other studies that primarily focused on severe TBI. However, our mortality rates remain higher than those reported in another study of severe TBI patients, which observed a 30-day mortality rate of 12%. [41]

RTA is the commonest mechanism of trauma in our study 54.3% which is consistent with other local and regional findings[2,3,6,7], taking some corrective measures to alleviate this tragedy and proposing local traffic or transportation guideline might contribute to lowering the prevalence and detrimental effects it has in overall country's socio-economic wellbeing.

In our study age, sex, mechanism of trauma, Prescence or absence of comorbidity, type and location of DC, type and location of lesion didn't show statistical significance with functional outcome unlike other articles[6,31,32] which substantiated the correlation may be because of small sample size and disproportionate representation.

GCS at emergency, pupillary reactivity, motor weakness, pre/Intra-op Hypotension, Rotterdam CT scan, response to osmotic diuretic used, use of intra-op pressor support and immediate post -op GCS was found to be statistically associated with functional outcome at discharge, 1 month and 3 months consistently with other studies.[40-42,]

It has been a popular saying as GCS at emergency is important factor in the decision to perform a decompressive craniectomy. In a literature review of more than 15 articles (listed in table below) admission GCS has significantly affected outcomes. In our study also pre-operative GCS was one of the strongest predictors of poor outcome at discharge, 1 month and 3 months respectively with p<0.001. Different studies have shown unfavorable outcomes in 70-90% of patients with GCS of 3-5. In our study, 14 patients (14.5% of the total) had a GCS of 3-5, where 6(42.9%) died at discharge, 8(57.1%) of them died at 3 months, 2(14.3%) of them had unfavorable outcome at 3months and 4(28.6%) had favorable outcome at 3 months out of which 3(75%) of the had reactive pupil and 1(25%) had non-reactive pupil. This finding is inconsistent with many previous notion and findings, where almost all are expected to be in persistent vegetative state or Severe disability range. The result might be because surgery is done before secondary brain injury occurred and all of them where young less than the age of 30 which is independent predictor for good outcome, though not statistically significant in our study. only 2(7%) patients died who were in the range of GCS 13-15, because of respiratory complication, which is consistently predictor of good outcome at discharge, 1 month and 3 months. In general, in our study a patient with GCS at emergency <5 is more likely to die or have poor outcome 3.2 times (p-0.023) compared to mild TBI in binary logistic regression.

Since the emergence of DC as surgical tool to treat TBI, various pupillary changes were ascribed to poor outcome where the poorest outcome was reported with bilateral dilated [6,37,38,41,42,50-55]and fixed pupils or with dilated fixed pupil and contralateral pinpoint pupil,[52-55] with mortality rates ranging 45-75% and 55-85%, respectively. in early study done in Akira et al, in Japan[55] Only 3(9%) among 32 patients with such pupils recovered up to the level of functional recovery and all of them were younger than 30 years. In this study reactivity of the pupils was a statistically significant determinant of outcome (p<0.001, pearson chi-square test) and p-0.026, OR=16 logistic regression showing dilated and non-reactive pupil is 16 times more likely to die than reactive pupil. 2(22.2%) of non- reactive pupil had favorable out-come at 3 months in our study which is also consistent with the study of Göksu et al[56] where 4/28 (14.3%) had favorable outcome. It's likely commendable to consider DC for a patient with non-reactive pupil if the patient is young and arrives early as chance of surviving is not daunting.

In this study, this study investigated the prognostic value of the Rotterdam Computed Tomography (CT) Score, a validated radiologic predictor of outcome in patients undergoing decompressive craniectomy (DC) for traumatic brain injury (TBI). While previous research, such as the study by Asefa et al., 6 demonstrated a strong association between high Rotterdam CT scores [5 and 6] and unfavorable outcomes, including high mortality rates, our findings did not fully support these observations.

In our study, the Rotterdam CT Score showed a significant association with mortality and outcome at discharge and one-month post-DC, as determined by Pearson chi-square analysis. However, this significance was not maintained at three months, and logistic regression analysis did not reveal a statistically significant predictive relationship.

Furthermore, our analysis suggests that the Rotterdam CT Score may have limited predictive value in patients undergoing bifrontal DC. We hypothesize that the Rotterdam CT Score might be a more robust predictor of outcome in patients with severe TBI (less than 15% of our study population) and in cases of hemicraniectomy compared to other types of DC.

This study investigated the impact of the timing of decompressive craniectomy (DC) on patient outcomes following traumatic brain injury (TBI).

- **Early Intervention:** Consistent with findings from previous research by Guerra et al. and others, 43,48 the study suggests that early DC, performed within a short interval after injury (ideally within 4 hours), may be associated with improved outcomes. This was supported by statistically significant differences in outcomes at 1 and 3 months (p=0.021 and p=0.012, respectively).

- **Study Observations:** In the current study, 46% of patients underwent DC within 24 hours of injury. Among this group, 9% died and 65.2% had good outcomes.

- **Limitations:** While early DC showed a trend towards improved outcomes, the study did not find a statistically significant association with outcome at discharge and failed to demonstrate a strong correlation in logistic regression analysis.

- **Factors Influencing Outcome:** The study suggests that factors such as the severity of trauma and neurological status may be more significant determinants of outcome than the timing of DC alone. Furthermore, patients who undergo DC within 24 hours often present with more severe TBI, which may influence their overall prognosis.

Another important predictor of outcome is pre/intra-operative hypotension, use of vasopressor intraoperatively, duration of surgery, and immediate post-operative GCS(p<0.05). comparison with other literature is tabulated in the table below. (See for reference)

Table 9: A Summary table of literature for comparison.

SN.	Author, year and place	Sample size and characteristics	Poor outcome rate (%)	Factors identified
1.	Gouello etal[24], 2014; France	60, mean age=33, Male=77% mean GCS=7	38.3	GCS
2.	Sharda etal [25] 2014; Malaysia	110, mean age=36, 86%-Male; 31.8%- GCS<8	32.7, death	Post-op Hypoxia, CPP and BP (MAP)
3.	Saade etal [26.] 2014; Brazil	56, 31-40; 80%-M; 52%-GCS4/5	78.6	Dilated, Unreactive pupil, GCS<5; MLS>15mm and presence of Intracranial lesion
4.	Grille and Tommasino[27] 2015; Uruguay	64, mean age=31, 79%=M GCS=7+/-3	66	Post-op ICP and Low GCS* @admission
5.	Sinha etal[28] 2015; India	1236, mean age=32, 81%=M, GCS=6,	41.7, death	Age, GCS, Pupillary reaction, Pre-op Hypotension, MLS, brain swelling, EDH, SAH, infarction, polytrauma, duraplasty/ slit durotomy, bilateral DC, Length of stay
6.	Bagheri etal[29] 2017; Iran	61, mean age=36, 59%=M,18%-GCS,5	45.9	GCS*(<5), Age*(>60), DNRP, MLS (>10)
7.	Dhakre etal 2019; India	96, mean age 67.7% (18-40), 84%-M, 22.6% -GCS<8	50	Pre- and post-op GCS and Neurologic status.
8.	Silva etal [30] 2020; Brazil	131, 57.3%(19-39), 90%-M, 49%-GCS<8	74	GCS@Admission
9.	Shukla etal [31] 2020; India	83, mean age=32, 82%-M, GCS=7+/-3.4	49	GCS, Hydrocephalus, Older age
10.	Tau etal [32] 2020, South Africa	62, mean age=36.1, 82%-M, 58%-GCS<8	53	Mechanism of trauma, GCS, Time lapse trauma to hospital admission
11	Gopolan etal [33],2021; India	164, most 18-40 84%-GCS<8	69.5;39 dead	GCS(Motor*), pupillary reactivity, type of DC(Primary=40% and Secondary=37%) and pre-op hypotension
12.	Ogundale etal[37] 2018; USA	50, mean age=22.4+/-3, 86%-Male; all GCS<9	12% mortality@30day	GCS @arrival(<5), type of surgery(craniotomy vs craniectomy), effacement of basal cisterns/MLS, closed TBI.
13.	Celi etal [38] 2020; Peru	32, mean age=52.2, 82%-M, mean GCS=9, and 73% Anisocoric	12% mortality	Size of the flap and MLS>5mm
14.	Balaj etal [39]2023, India	126, 65.1%<60 GCS<9	12.6%	Age>50, Brain stem involvement, redo surgery for recollection, meningitis, Hypernatremia, Hydrocephalus and DAI
15.	Jiang JY,[19]2005, China	241, Severe TBI; RCT	MR=26% Favorable: 40%	Size of DHC
16.	Enslin,[52]2011, South Africa	N=72	MR=44.4, FAV=33.3	
17.	Ojo OA[58] 2015, Nigeria	N=10	MR=40, FAV=60%	
18	Motah etal[59] 2014, Cameroon	N=13	MR=0.7, FAV: 77%	
19	DECRA(2011)[16]	N=77	MR=19; FAV=30%	
20	RESCUE-ICP(2016)[17]	N=201	MR=27; FAV=27%	
21	Asefa, 2020[6], Ethiopia	N=36, GCS<8	MR=52.8% Favorable: 33.7%	
22*	OUR STUDY*	94, mean age=38.9+/-15.05, Male=83(88.3%) 41.5%-GCS<9	Death=>30.9% Unfavorable (44.7%)	GCS@-E<5, non-reactive pupil, peri-operative Hypotension, Response to Osmotic Therapy, Requirement of intra-op pressor support, and

			Favorable (55.3%)	Immediate post-op GCS.

Conclusion

There is still inconclusive statement and no level -I recommendation for DC in trauma patients, Both DECRA and RESCUE-ICP asserted that DC inevitably decrease intra-cranial pressure though their functional outcome is not substantiative of one another. Another local study objected DC for some selected patients and found higher mortality in nearly more than half, in our study of 94 patients who underwent DC with in study period we've found that at 3 months, 29(30.9%) died, 55.3% had good outcome (EGOS>/=5) and remaining (13.8%) had poor outcome;(i.e., ~55%-good vs 45%-poor outcome). Many of our study groups were, however, from mild and moderate than severe head injury categories (58.5% vs 41.5%). it's found that favorable outcome at 3 months is better in contrary to the notion which claims the role of surgery is to increase survival of persistent vegetative states as described in randomized control trials and other series.

Another important striking finding was duration at which surgery is done which is likely the other potential reason for better outcome in our study where most of our patients had surgery in less than 24hrs of trauma (48.9%) as a primary decompressive craniectomy unlike previous local narrative of our patient late arrival to neurosurgical center.

While it is still difficult to imperatively recommend, our research answers our questions and proved DC can be done as a viable option for trauma patients with acceptable and comparable outcome when surgery is considered in individualized and systematic manner and patient is selected and managed properly peri-operatively in organized team manner keeping secured patient hemodynamic status. Accordingly, we found that individual with GCS<5 and non-reactive pupil (ipsilateral or bilateral), we had deranged vital sign pre-operatively and intra-operatively, and those who doesn't improve to osmotic diuretics were found to statistically fare unfavorable outcome and the reverse is true.

Strength and Limitation of the study:

This prospective study represents a rare, if not unique, investigation into the determinants of decompressive craniectomy across a broad spectrum of traumatic brain injury (TBI) patients on a national and regional scale. The sample size, while moderately sized, is sufficiently robust to warrant generalization and global recommendations, albeit with prudent caution.

Although minor discrepancies in outcomes were observed between surgical centers, these differences were not statistically significant and may be attributable to variations in care practices.

Despite the ability to present and analyze the surgical outcomes of numerous patients within a three-month timeframe, the relatively short follow-up period compared to other prospective studies (6 months and 1 year) and the moderate sample size limit the strength of the recommendations due to reduced statistical power and model limitations

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8. Annex I:

Questionnaire: https://docs.google.com/forms/d/e/1FAIpQLSfzlMBwEerjM2xny-SO9Sgw85870ZfuBybXLVv8NO7FJisF_w/viewform

***Rotterdam CT-Score**

Feature		Points	Score
basal cisterns (p.1109)	normal	0	(0 - 2)
	compressed	1	
	absent	2	
midline shift (MLS) (p.1110)	0–5 mm	0	(0 - 1)
	>5 mm	1	
epidural mass lesion	absent	0	(0 - 1)
	present	1	
intraventricular blood or traumatic SAH (tSAH)	absent	0	(0 - 1)
	present	1	
add 1 point[a]			+1
Rotterdam score → TOTAL			(1 - 6)

[a]one point is added to all scores to bring the range from 1 to 6 in a nod to the original Marshall score

Score	Mortality number & %[a]
1	0/36 (0%)
2	41/600 (6.8%)
3	122/773 (16%)
4	121/465 (26%)
5	138/261 (53%)
6	69/114 (61%)

[a]6-month mortality

***Extended Glasgow Outcome Score (EGOS)**

GOS	GOSE	Interpretation
1 = Dead	1 = Dead	Dead
2 = Vegetative state	2 = Vegetative state	Absence of awareness of self and environment
3 = Severe disability	3 = Lower severe disability	Needs full assistance in ADL
	4 = Upper severe disability	Needs partial assistance in ADL
4 = Moderate disability	5 = Lower moderate disability	Independent, but cannot resume work/school or all previous social activities
	6 = Upper moderate disability	Some disability exists, but can partly resume work or previous activities
5 = Good recovery	7 = Lower good recovery	Minor physical or mental deficits that affects daily life
	8 = Upper good recovery	Full recovery or minor symptoms that do not affect daily life

ADL = activities of daily living.

TABLE 2. Continued

Reference, study topic	Study design, N, and outcomes	Data class	Results conclusion
"late refractory ICP elevation"	Unfavorable = 1-3 Lower severe disability or worse		ICP reduction Median duration of ICP > 25 mm Hg after randomization—5.0 vs 17.0 ($P < .001$) Median intracranial hypertension index 20 18.1 vs 31.4 ($P < .001$) Median intracranial hypertension index 25 6.6 vs 11.8 ($P < .001$) GOS-E 12 mo (DC N = 185 %; Medical N = 175 %) Death 30.4; 52.0 Vegetative 6.2; 1.7 Lower severe disability 18.0; 14.0 Upper severe disability 13.4; 3.9 Lower moderate disability 10.3; 7.8 Upper moderate disability 11.9; 12.3 Lower good recovery 19.7; 3.9 Upper good recovery 2.6; 4.5 DC "patients had fewer hours than medical patients with ICP above 25 mm Hg after randomization (median, 5.0 vs 17.0 h; $P < .001$) but had a higher rate of adverse events (16.3% vs 9.2%", $P = .03$).
Size of DC			
Jiang, 2005[19] Comparison of the influence of standard, larger trauma craniectomy ([STC] unilateral frontotemporoparietal bone flap [12 × 15 cm]) vs a limited, smaller craniectomy ([LC] temporoparietal bone flap [6 × 8 cm])	RCT N = 486 STC:245 LC: 241 GOS at 6 mo Complications	Class 2 Concern about baseline differences between eligible/excluded and eligible/included	STC vs LC GOS 4 or 5: good recovery or moderate deficit 96 (39.8%) vs 70 (28.6%), $P = .05$ GOS 2 or 3: severe deficit or vegetative state 82 (34.0%) vs 89 (36.3%), $P = .05$ GOS 1: death 63 (26.2%) vs 86 (35.1%), $P < .05$. Significantly greater mortality in the LC group; incidence of delayed hematoma and incision cerebrospinal fluid fistula significantly lower in the STC group, while other complications did not differ
Qiu, 2009[34] Unilateral DC (larger = 15 cm diameter) vs unilateral routine temporoparietal craniectomy	RCT N = 74 Unilateral DC = 37 Unilateral routine temporoparietal craniectomy (control group) = 37 Mortality at 1 mo; GOS at 1 yr Complications	Class 2 Concern about baseline differences between eligible/excluded and eligible/included	Mortality at 1 mo 27% in the large DC group 57% in the smaller DC control, $P = .010$ Good neurological outcome (GOS score of 4-5) at 1 yr 56.8% in the large DC group vs 32.4% in the smaller DC control, $P = .035$. Incidences of delayed intracranial hematoma: 21.6% in the large DC group vs 10.8% in the smaller DC group, $P = .041$ Subdural effusion: 5.4% in the large DC group vs 0% in the smaller DC group, $P = .040$ Larger DC improved outcomes (mortality and function), but resulted in higher rates of complications

Reference, study topic	Study design, N, and outcomes	Data class	Results conclusion
DC compared to medical management			
Cooper, 2011, 2020[9,10] (DECRA) DC vs medical management Patients with ICP > 20 mmHg for 15 min over a 1-h period within the first 72 h of care– "early refractory ICP elevation"	RCT N = 155 DC = 73 No DC = 82 Mortality Extended GOS Favorable = 5-8 Lower moderate disability or better Unfavorable = 1-4 Upper severe disability or worse ICU days	Class I 29.8% potentially eligible patients not randomized and no comparison of included to not included (21: no consent; 344: excluded with no reason reported)	Mortality DC vs medical management 6 mo. 19% vs 18% 12 mo 21% vs19% GOS-E unadjusted ORs for DC group (no DC is the reference group) Worse functional outcome: 6 mo: 1.84 (95% CI 1.05-3.24), $P = .03$ 12 mo: 1.68 (95% CI 0.96-2.93), $P = .07$ More unfavorable outcomes: 6 mo: 2.21 (95% CI 1.14-4.26), $P = .02$ 12 mo: 1.58 (95% CI 0.84-2.99), $P = .15$) ICP reduction Number of hours of ICP > 20 mm Hg (median) 9.2 vs 30.0 ($P < .001$) Intracranial hypertension index (median) 11.5 vs19.9 ($P < .001$) GOS-E 12 mo (DC N = 73 %; Medical N = 82 %) Death 21; 19 Vegetative 11; 3 Low severe disability 19; 16 Upper severe disability 8; 10 Low moderate disability 14; 12 Upper moderate disability 19; 19 Lower good rec 5; 16 Upper good rec 3; 5 DC fewer ICU days during hospitalization 3(10-18) vs 18(13-24), $P < .001$. 12 mo exploratory analyses: Fewer good outcomes in survivors with DC: 0.33 (95% CI, 0.12 to 0.91) $P = .03$ More vegetative outcomes in survivors with DC: 5.12 (95% CI 1.04 to 25.2) $P = .04$
Hutchinson, 2016[11] (RESCUEicp) DC vs medical management Patients with TBI and refractory elevated ICP (>25 mm Hg for 1-12 h) within 30 d of	RCT N = 398 DC = 202 No DC = 196 Mortality Extended GOS Favorable = 4-8 Upper severe	Class 1 Modified intention to treat (excluded loss to follow-up and withdrawal of consent)	Mortality: DC vs medical management 6 mo 16.9% vs 48.9% 12 mo 30.4% vs 52.0% GOS-E Favorable outcome: DC vs medical 6 mo 42.8% vs 34.6% ($P = .12$) 12 mo 45.4% vs 32.4% ($P = .01$) GOS-E distribution

RCT SUMMARY