Decompressive craniectomy versus craniotomy for acute subdural hematoma: A systematic review and meta-analysis with an adjusted subgroup analysis

Journal of Central Nervous System Disease
Volume 16: 1–10

DOI: 10.1177/11795735241297250

Syed Hasham Ali[1], Zoaib Habib Tharwani[1], Asad Ali Siddiqui[1], Fizza Iqbal[1], Mahnoor Sadiq[1], Ali Abdullah[2], Abdullah Khalid[1], Huzaifa Ul Haq Ansari[1], Muhammad Usman[1], Shurjeel Uddin Qazi[1], Uzair Munaf[1], Ibtehaj Ul Haque[1] and Shayan Marsia[3]

[1]Department of Medicine, Dow Medical College, Dow University of Health Sciences, Karachi, Sindh, Pakistan. [2]Department of Medicine, Sindh Medical College, Jinnah Sindh Medical University, Karachi, Sindh, Pakistan. [3]Department of Neurology, Corewell Health West, Michigan State University, Grand Rapids, MI, USA.

ABSTRACT

INTRODUCTION: Acute subdural hematomas are major causes of morbidity which warrant immediate treatment. If surgical intervention is warranted, craniotomy (CO) and decompressive craniectomy (DC) are employed, largely based on a loosely defined criteria and the neurosurgeon's best judgment. The primacy of one approach over another is a matter of dispute.

OBJECTIVE: We attempt to further clarify any advantages in the two techniques, and include a propensity score matched (PSM) subgroup analysis to eliminate bias.

DESIGN: This meta-analysis was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.

DATA SOURCES AND METHODS: A literature review was conducted on PubMed/Medline, Cochrane Central, and Google Scholar from inception to September 2023. 15 studies were extracted, and three outcomes were meta-analyzed: Mortality, Glasgow Outcome Scale (GOS) scores and patients undergoing re-operations/revisions. Odds Ratios (OR) and Mean Difference (MD) were used in dichotomous and continuous variables respectively. PSM data was used wherever possible. A subgroup analysis was conducted with 5 PSM studies and a trial. Heterogeneity was addressed if above 40% and the *P*-value is significant (≤ .05).

RESULTS: A total of 15 studies were meta-analyzed with a total of 2327 and 2171 patients undergoing CO and DC respectively. Patients undergoing DC had a significantly worse GOS 5 outcome (OR: .63 [95% CI: .45-.87]; $P = .005$; I2 = 0%) and higher mortality (OR: 1.58 [95% CI: 1.20-2.08]; $P = .001$; I2 = 67%). In subgroup analysis of adjusted studies, DC still had significantly higher mortality. (OR: 1.50 [95% CI: 1.03-2.18]; $P = .001$; I2 = 83%).

CONCLUSIONS: This meta-analysis determines that CO is more viable than DC as a surgical option due to its less invasive nature. DC can be employed, albeit under strict preprocedural patient selection and for highly specific indications.

KEYWORDS: Craniotomy, craniectomy, subdural hematoma, decompression, traumatic brain injury

RECEIVED: October 25, 2023. **ACCEPTED:** October 7, 2024.

TYPE: Meta-analysis

DECLARATION OF CONFLICTING INTERESTS: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

FUNDING: The author(s) received no financial support for the research, authorship, and/or publication of this article.

CONSENT FOR PUBLICATION: All authors consent to publishing this manuscript.

SUPPLEMENTAL MATERIAL: Supplemental material for this article is available online.

CORRESPONDING AUTHOR: Syed Hasham Ali, Department of Medicine, Dow Medical College, Dow University of Health Sciences, Baba-e-Urdu Road, Karachi V246+X8C, Pakistan.
Email: Syedhashamali00@gmail.com

Introduction

Acute subdural hematoma (ASDH) is a critical neurosurgical emergency characterized by the abnormal accumulation of blood under the dura mater, leading to irreversible brain injury and death caused by hematoma expansion, elevated intracranial pressure (ICP), or brain herniation. The Brain Trauma Foundation guidelines advocate for immediate surgical intervention in cases of ASDH exceeding a diameter of 10 mm or displaying a midline shift exceeding 5 mm, regardless of the patient's clinical state or patient characteristics. In instances where the patient's Glasgow Coma Scale (GCS) score falls below 9, evacuation may be warranted even for smaller ASDHs.

Data Availability Statement included at the end of the article

However, the evidence for either is low-quality, with small studies in highly specific populations. This leaves room for a neurosurgeon's intuition and experience in choosing the treatment modality.[1]

Craniotomy (CO) and decompressive craniectomy (DC) have emerged as primary surgical options for ASDH.[2] Craniotomy entails the elevation of a bone flap, the evacuation of the SDH, and repositioning of the removed bone flap. Contrary to it, the decompressive craniectomy entails the removal of a bone flap to allow for brain swelling without constraint. Subsequently, the bone flap is preserved, allowing space for accommodating the expansion of swollen cerebral tissue and facilitating ICP management. The repositioning of the bone flap is conducted several weeks later through a procedure known as cranioplasty, which is linked with its own set of risks and complications.[3] (Figure 1).

While some neurosurgeons prefer craniotomy due to its precise hematoma removal, potential for concurrent brain lesion treatment, this approach does not require a secondary cranioplasty procedure. Others opt for decompressive craniectomy owing to its capacity to reduce ICP over a larger surface area, which may be advantageous in cases of severe cerebral edema but can lead to increase in length of hospital stay and potential risk of surgical site infection, elevating the burden of mortality.[4]

Therefore, a comprehensive evaluation of existing evidence is warranted. This systematic review and meta-analysis are undertaken to assess the comparative efficacy and safety of decompressive craniectomy vs craniotomy in managing ASDH. By integrating findings from multiple studies, this meta-analysis aims to provide an evidence-based, objective assessment of the outcomes associated with each procedure. Its approach to include and then isolate and analyze adjusted data separately means that outcomes can be judged and discussed without the traditional confounders associated with each approach such as GCS.

Methods

This meta-analysis was conducted following the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) guidelines.[5] As this is a compilation of publicly accessible results, no institutional review board permission or patient informed consent was required.

Search Strategy and Eligibility Criteria

An electronic search was conducted on several databases and registers like PubMed/Medline, the Cochrane Central), and Google Scholar from date of inception to September 2023, with no filters applied. The search string used varied on all databases, but included keywords and MeSH terms such as '(subdural hematoma)', '(decompressive craniectomy)', and '(craniotomy)'. (Supplemental Table 1) All articles retrieved were reviewed on the title, abstract, and full-text level and finally those that were in accord with the exclusion and inclusion criteria were selected. A further breakdown of our strategy is detailed in a flowchart fashioned according to the guidelines set by PRISMA (Figure 2). A robust inclusion and exclusion criteria were decided upon to ensure a satisfactory degree of accuracy (Table 1).

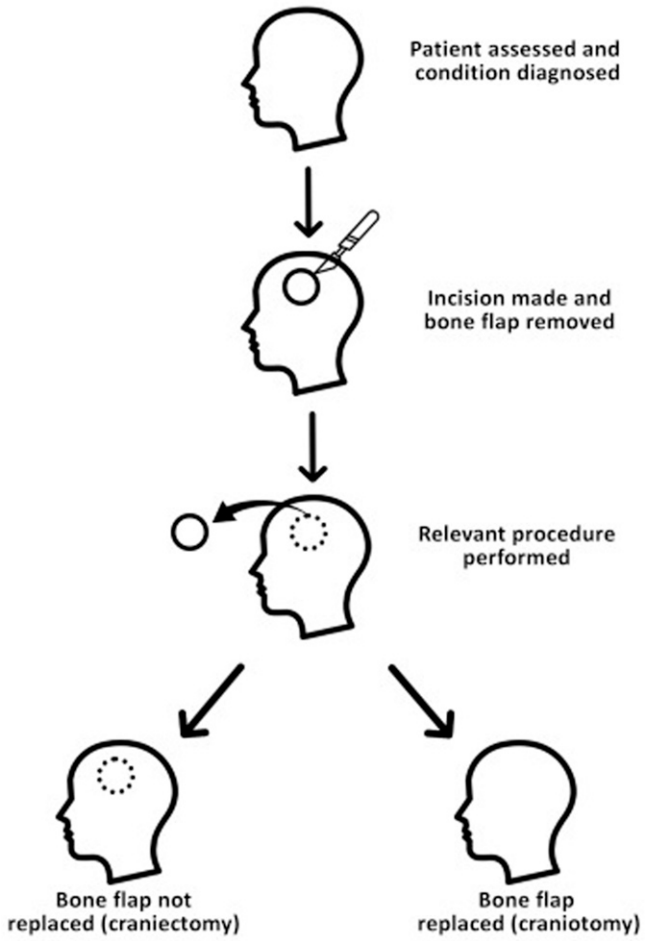

Figure 1. Didactic illustration of each procedure.

Outcomes of Interest, Data Extraction, and Risk of Bias Assessment

Outcomes were selected for analysis if they had been reported by three or more studies. The outcomes of interest selected were mortality, Glasgow Outcome Scale (GOS) data of patient cohorts, and the number of patients who underwent re-operations/revisions. Outcomes are defined as reported in the studies and data at the maximum available follow-up time was used. Data were extracted from relevant texts, figures, and tables, and were subsequently reviewed by two independent reviewers (S.H.A and F.I). Inconsistencies and conflicts were resolved post-discussion with a third reviewer (S.M), and then tabulated in a pre-designed Microsoft Excel spreadsheet. Assessment of risk of bias was carried out by using the Cochrane Risk of Bias tool for trials, and the Newcastle-Ottawa Scale for

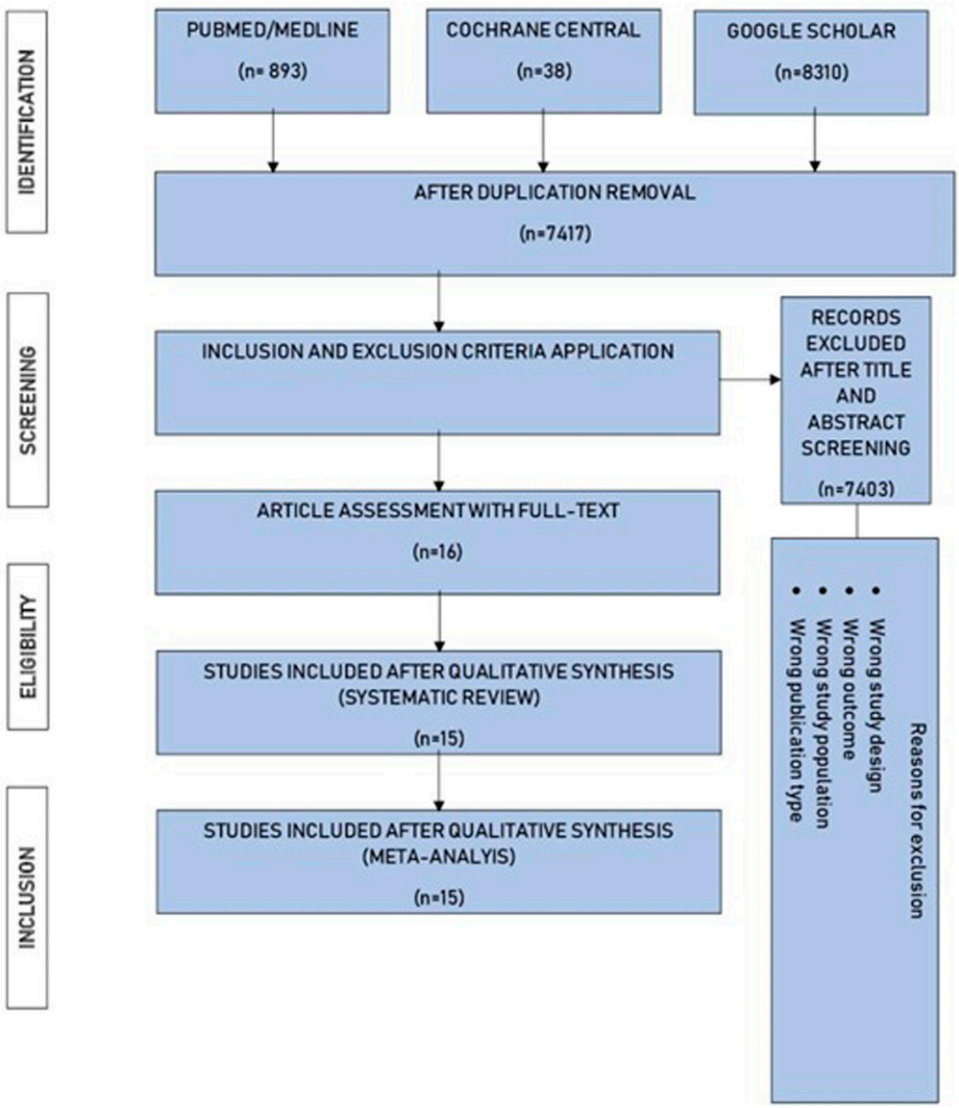

Figure 2. Prisma flowchart.

Table 1. Inclusion and exclusion criteria employed.

Inclusion criteria	Randomized control trials, national datasets and observational studies with data comparing decompressive craniectomy to craniotomy in patients with acute subdural hematoma/hemorrhage, regardless of patient demographics.
Exclusion criteria	Unpublished and unfinished studies, abstracts, single-arm studies, case reports, reviews, and technical notes, book chapters, cost-analyses, epidemiological studies, along with any study which did not report the relevant outcomes selected for analysis

observational studies, with the results being reviewed by the senior author.

Statistical Analyses

All statistical analysis was performed on Review Manager (Version 5.4.1, Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration, 2014). A random-effects model was utilized to account for the anticipated heterogeneity, procedural discrepancies, and certain outcome definitions. Propensity score matched (PSM) data or data which underwent multivariate regression (MR) were analyzed wherever available to reduce confounding bias. Forest plots were generated to visually display results of meta-analysis of outcomes. Baseline meta-analysis was tabulated in Table 2.

GOS outcomes were first analyzed as a large pool of all available studies and then a subgroup analysis of only PSM/MR and trial data was conducted to maximally eliminate confounding bias.[6-11]

Weightage of dichotomous variables was assigned using the inverse variance method, with Odds Ratio (OR) and the corresponding 95% Confidence Interval (CI) being extracted and

Table 2. Meta-analysis of baseline characteristics summarized.

BASELINE CHARACTERISTIC	NO. OF STUDIES	PATIENTS IN CO GROUP (N/%)	PATIENTS IN DC GROUP (N/%)	POOLED OR/ MD (DC VS CO)	*P*-VALUE	HETEROGENEITY (%)	CAUSE OF HETEROGENEITY
Baseline GCS in mean/SD	8[3,6,7,9-11,15,17]	1897	1735	MD −.73, 95% CI [−2.07, .61]	.29	96	Insignificant
Age in mean/SD	8[3,6-11,15]	1997	1817	MD −1.23, 95% CI [−3.76, 1.30]	.34	72	Insignificant
Midline shift in mean/ SD	4[3,6,11,17]	474	610	MD 1.75, 95% CI [−1.21, 4.71]	.25	92	Insignificant
Females	11[2,3,7-11,15-17,20]	651	492	OR .65, 95% CI [.45,.94]	.02	80	Vilcinis et al, exclusion leads to 11%

analyzed from all relevant studies. For continuous baseline characteristics, we used inverse variance and extracted Mean Differences (MD) with corresponding standard deviations.

The Higgins (I^2) statistic was used to evaluate heterogeneity and a value of 25%-50% was considered mild, 50%-75% as moderate, and >75% as severe heterogeneity. The tolerated level of heterogeneity, meriting little further discussion, is set at less than or equal to 40%, a benchmark decided upon by reviewing the Cochrane Handbook.[12] Heterogeneity was considered insignificant if the *P*-value of any pooled outcome analysis was insignificant, and thus was not discussed in these cases.

Publication bias was assessed through visual inspection of funnel plots (Supplemental Figure 2, 2(a) and 3). *P*-value ≤ .05 was regarded as significant for all analyses. No unpublished data was sought. Outcomes at maximum follow-up times reported in each study were analyzed to provide a more representative picture.

Data can be made available on reasonable request to corresponding author.

Efforts to Achieve Standardization. A lack of standardization was a challenge, whereby some studies had different ways of reporting one outcome. For instance, some reported mean GOS for each cohort and thus treating it like a continuous variable whereas others treated GOS as a dichotomous value and reported the number of patients who presented with each score. Others still, simply reported patient mortality.[13]

We took the decision to treat GOS as a dichotomous variable, excluding studies which reported means or reported patient numbers across a range of GOS scores (eg, GOS 3-5: 14 patients). Studies which reported GOS-E as an outcome were made to conform to the GOS rubric by adding patient numbers across similar subgroups after ensuring no population doubling took place.[6,7] (eg, Upper Good Recovery: 1, Lower Good Recovery: 1 would be imputed to 2 patients reporting a good outcome of GOS 5). To increase representation and present a fuller picture, for continuous values in the meta-analysis of baseline characteristics, we imputed medians and interquartile ranges where available to means and standard deviations using Wan et al.'s method.[14] Any continuous outcome which reported either just the mean or median, or medians without a Quartile 1 and Quartile 3 value were excluded from analysis as they could not be analyzed with the methods employed.

Results

Literature Search Synthesis

Our literature search yielded a total of 7417 articles across databases, which was reduced to 16 articles upon application of exclusion and inclusion criteria.[2,3,6-11,13,15-21] Castano-Leon et al was excluded from analysis as the data given took conservative treatment as a reference instead of either operation.[18] Therefore, we meta-analyzed 15 studies, with 2327 and 2171 patients undergoing CO and DC respectively. The PRISMA flow chart summarizes our process (Figure 2). A full list of included studies and their characteristics are tabulated in Supplemental Table 3.

Quality Assessment and Risk of Bias evaluation

Quality assessment was conducted via the Newcastle-Ottawa scale for observational studies and the Cochrane Risk of Bias tool for trials. A detailed evaluation has been tabulated. (Supplemental Table 2, Supplemental Figure 1).

Baseline Characteristics

Four baseline characteristics were chiefly analyzed. While no significant differences were found in patient ages, mean midline shift, and mean baseline GCS scores across studies, the number of females was significantly lesser in the DC group (OR .65, 95% CI [.45,.94] P = .02). Meta-analysis of baseline characteristics has been comprehensively summarized in Table 2.

Results of the Meta-analysis of Outcomes

Glasgow Outcome Scale (GOS) (Figure 3(a)): 13 studies contained data on the GOS. The data was divided into five subgroups based on the levels of GOS reported. Pooled analysis showed a significant difference between the procedures with DC having a significantly lower proportion of patients with a "Good outcome" (CO; 120 events DC; 80 events) (GOS 5). (OR: .63 [95% CI: .45- .87]; P = .005; I2 = 0%), The burden of mortality (GOS 1) was significantly higher in the DC group. (CO; 737 events DC; 844 events) (OR: 1.58 [95% CI: 1.20-2.08]; P = .001; I2 = 67%). Leave-one-out analysis shows that heterogeneity is high due to Vilcinis et al and Shibahashi et al, exclusion of which reduced the heterogeneity to an acceptable 2%. No significant differences were observed in the "Moderately disabled" (CO; 75 events DC; 78 events) (GOS 4) (P = .84), "Severely disabled" (CO; 98 events DC; 90 events) (GOS 3) (P = .52), and "Vegetative state" (CO; 404 events DC; 388 events) (GOS 2) (P = .67) subgroups (Figure 3).

A sub-group analysis of the 5 PSM/MR studies and a trial resulted in "Good Outcome" being an insignificant outcome (OR:.56 [95% CI:.25-1.22]; P = .14, I2 = 46%), but with mortality remaining significantly high in the DC cohort. (OR: 1.50 [95% CI: 1.03-2.18]; P = .001; I2 = 83%) (Figure 3(a)). The high heterogeneity here was again caused by Vilcinis et al and Shibahashi et al as determined by successive leave-one-out analyses.

Patients undergoing re-operations/revisions (Figure 4): 5 studies reported data on the number of patients undergoing reoperations/revisions. There was no significant difference observed in this outcome when comparing the two procedures (CO; 54 events DC; 63 events) (OR: .87 [95% CI: .55, 1.38]; P = .56; I2 = 0%).

Discussion

Acute subdural hematomas are generally traumatic in etiology, and have exceptionally high mortality rates, with GCS at admission, time to treatment, age, and nature of injury being significant risk predictors. Craniotomy is largely preferred as a surgical solution to evacuate such hematomas, however decompressive craniectomies have been carried out too, mostly as a last-resort procedure to counter raised ICP and brain swelling.[8,22] Evidence both for, and against DC exists with recent studies showing safety outcomes to be insignificant, and with DC even being a viable option for certain subgroups of patients.

This meta-analysis builds upon the previous one conducted by Phan et al. in 2017 by adding additional studies, a large scale observational (CENTER-TBI) and RESCUE-ASDH: the first randomized, multicenter clinical trial comparing the two approaches.[6,7,10,23] A trial significantly improves our understanding and sheds more light on procedural outcomes by bridging a gap in literature which was identified in the previous analysis as a limiting factor.

Our analysis at first, considering all data, confirms and further solidifies the findings of Phan, showing that patients undergoing craniotomy have better outcomes and a lower mortality rate than their counterparts. This may be due to most patient cohorts undergoing DC having poorer admission characteristics like herniation, pupillary reflex, or higher severity scores, as reported by almost all studies in our analysis. Although our analysis showed no difference in baseline GCS between cohorts, our standardization efforts meant that only 8 out of 15 studies could be included in GCS analysis. Individually, most studies reported a worse baseline GCS score for the DC cohort. These characteristics are established as worsening outcomes post-DC.[24] Additionally, it has been posited that DC could cause axonal stretching, as well as elevate the risks of cerebral ischemia.[25-27] Furthermore, the very 'open-box' nature of a DC procedure requires longer exposure of brain tissue and an increased risk of SSIs, which may contribute to complications like meningitis, as well as a higher post-procedural mortality risk.[7,28] Another challenge in controlling for infections is the long incision required and the scalp flap being based on a limited frontal blood supply, leading to compromised healing.[29] Literature also suggests a risk of remote hematomas, and hydrocephalus.[30-32]

Our analysis of both adjusted and unadjusted mortality data did harbor significant heterogeneity, which was caused by the inclusion of Vilcinis et al and Shibahashi et al.[10,11] Their exclusion led to a much more acceptable heterogeneity of 2%. We hypothesize a few reasons why this is so: 1) Vilcinis et al and Shibahashi et al are two large studies in our dataset, leading to a greater patient population and potential data skewing 2) the non-randomized, observational nature of the studies, or 3) the expected confounding factors that are severity of trauma, patient comorbidities, operative technique and perioperative complications. The MR model in Vilcinis et al only adjusted for age, GCS, midline shift and ASDH thickness. Sibahashi's model, although more comprehensive, does not adjust for perioperative factors and certain baselines like pupillary reactions to light. Furthermore, Shibahashi et al, much like us, pooled results from different centers which may have had different indications for a DC over CO.

It is worth noting, that on pooling MR/PSM and clinical trial data, although the odds of a good outcome became insignificant, DC was still associated with higher mortality. This held true even after exclusion of the studies causing heterogeneity. This hints at DC being intrinsically disadvantageous, perhaps due to the aforementioned factors independent of baselines like axonal stretching, danger of cerebral ischemia, or an increased exposure leading to higher SSIs.

Our analysis also saw no significant difference in the rates of reoperations or revisions between the two methods, even after accounting for any further cranial procedures. This can be due to most studies not recording reoperation data, or the fact that both patient cohorts have some sort of secondary procedure. CO patients may have to undergo DC as a secondary procedure to

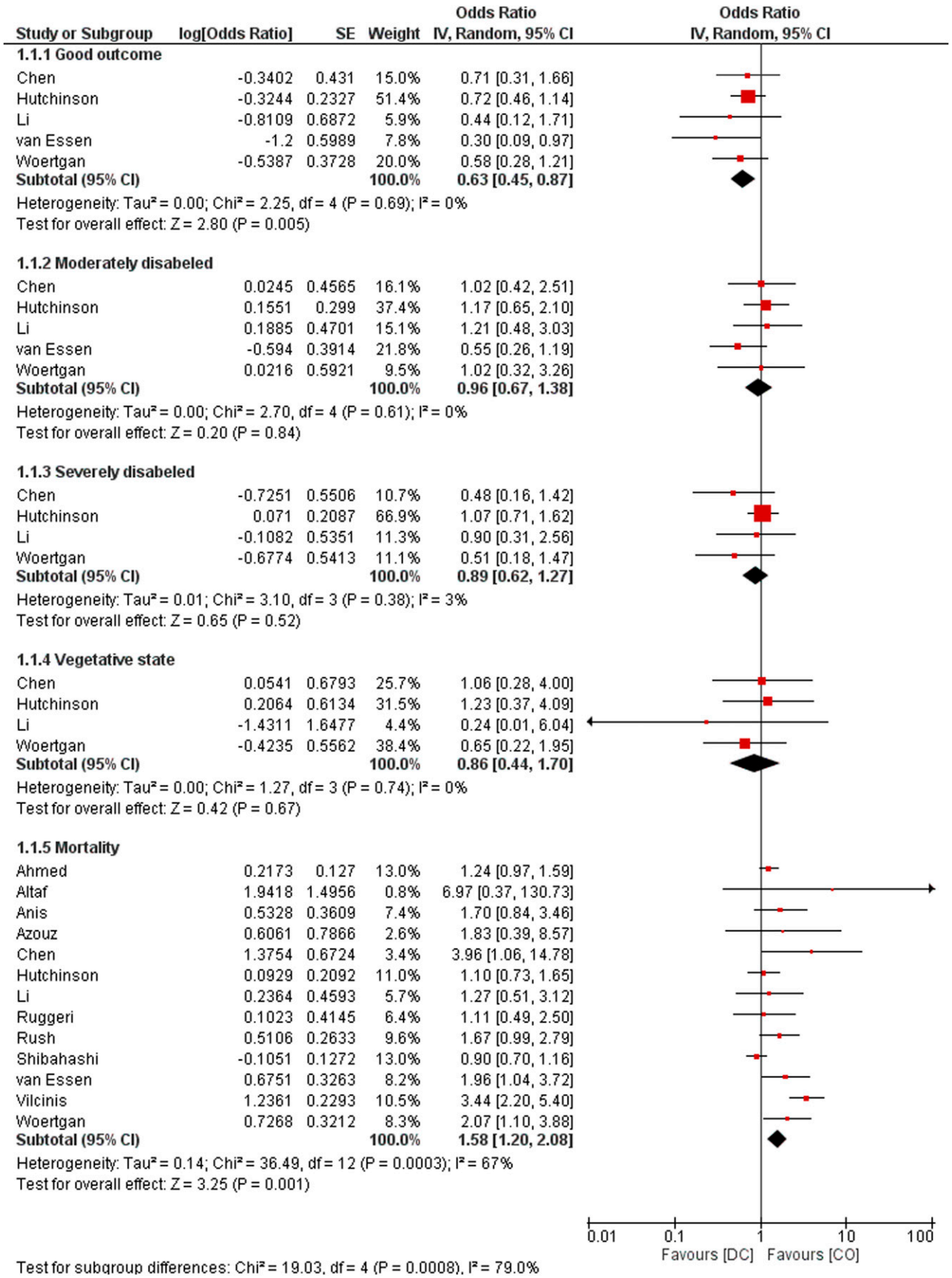

Figure 3. (a) Forest Plot comparing unadjusted GOS outcomes. (b) Forest Plot comparing adjusted GOS outcomes.

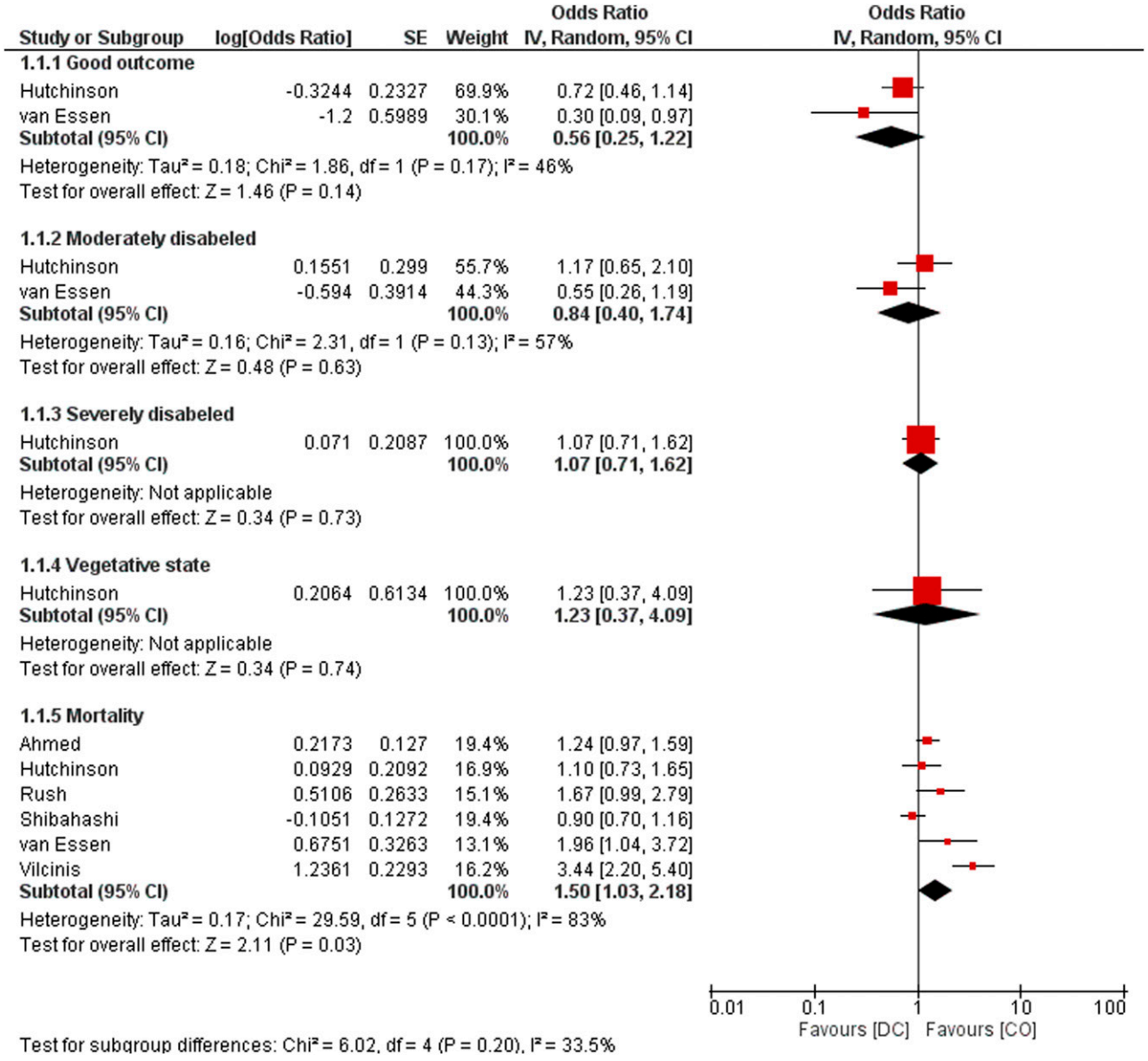

Figure 3. Continued.

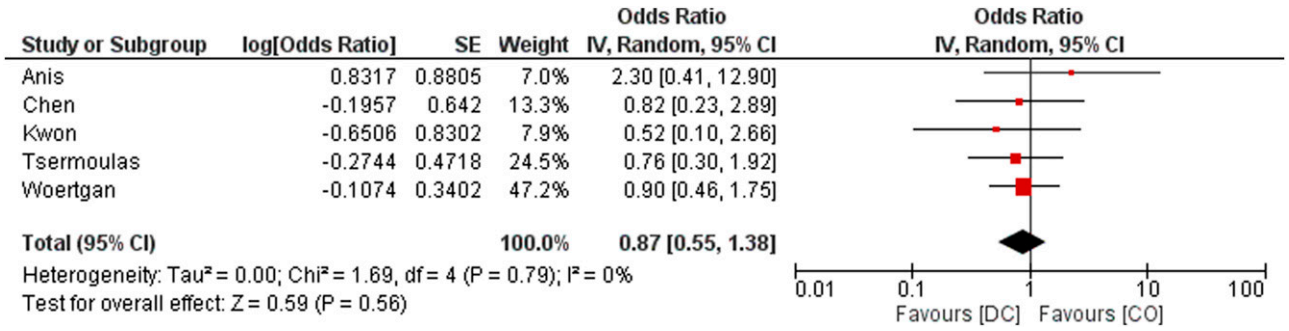

Figure 4. Forest Plot comparing patients undergoing revisions/reoperations.

alleviate brain swelling, and a DC necessitates a cranioplasty for aesthetic and neuroprotective purposes.[7,33,34]

A cranioplasty, being a second procedure after craniectomy, exposes a patient to further risk of infection, with studies reporting infections in 8.2% to 26.4% of cohorts.[35,36] Resorption of the bone plate can also be a serious issue. Although not reported in the studies selected for meta-analysis, post-cranioplasty hemorrhages and seizures have been reported in several studies, caused by a myriad of mechanisms like a scalp artery bleed and perioperative disturbance of the cerebral parenchyma respectively.[37-39] Adhesions between layers during cranioplasty may increase operation time, and heighten the risk of CSF leakages and epidural hemorrhage.[40] These in themselves could also be contributors to the worse outcomes seen in DC procedures, especially on late follow-up.

Future Prospects

There are prospects which hold merit in reducing the mortality and morbidity associated with DC and its subsequent procedures. Keeping in view that the traditional reverse question mark incision for a DC requires sacrificing the occipital and posterior auricular arteries, Abecassis et al propose the alternative Kempe incision. The latter technique is a T-shaped incision which has been shown to permit a larger cranial decompression.[41]

Similarly novel approaches have been proposed for cranioplasties both in operative technique and materials to repair the cranial defect. Decompressive cranioplasty, a procedure pioneered by Hsu et al, has a range of positives that differentiate it from a standard cranioplasty. Chiefly, it achieves markedly better 1) cosmetic, 2) financial, and 3) morbidity outcomes. Cosmetically, its sparing of the temporalis muscle means a better look post-surgery as judged by the neurosurgical team. Financially, this approach preserves the bone flap, nullifying any storage and acquisition costs of a cranial implant. The procedure also resulted in less mastication dysfunction, and a larger decompressive volume which may reduce ICP.[42] This procedure may be especially pertinent in low-to-middle income countries like Pakistan owing to it being cheaper and simpler and the country's notoriously high TBI rate.

A 2021 study describes the use of a silicone elastomer sheet as a non-adhesive to be placed between the musculocutaneous flap layer and the dura to reduce operation time and perioperative complications like the ones mentioned above. Their results showed that the cohort treated with the elastomer sheet had a significantly less operation time, estimated blood loss, and no instances of infection or adhesion even on delayed surgery.[43] Several materials have also been shown to be conducive to viable cranioplasties when compared to the standard autologous bone grafts. Polyetheretherketone (PEEK) is a synthetic polymer with good histocompatibility, chemical stability, and stability in the face of temperature changes.[44,45] It has been seen lowering the risk of re-operation when compared to titanium mesh in some studies, while others also show it as conducive to reducing post-operative pneumocephalus and epidural effusion.[45] However, literature is still divided on its overall efficacy, safety, and cost-benefit when compared to titanium or polymethyl methacrylate[46,47] It is possible, therefore, that with the incorporation of some of these practices in future, DC could emerge as a viable alternative.

We reiterate the need to properly define guidelines which dictate the use of either operative technique according to the patient population that would most benefit from it. As Shibahashi suggests, in their study patients with a GCS<9 and a probability of survival < .64 and inflicted with high-energy trauma do show greater benefits with DC.[10] With this in view, further subgroup analyses based on patient characteristics, and codification of criteria for operations is heavily warranted.

The most significant limitation of the study is an aforementioned lack of standardization which prevents us from giving a more complete picture since we have limited data. Similarly, the fact that different studies and centers have different thresholds and criteria for each surgical procedure lend to the problem. Also, our dataset only contains one trial, which limits the confidence of our conclusions. Furthermore, our findings, although generalizable to a broad segment of the population, cannot be said to apply to specific subgroups of patients based on age, comorbidity, or certain other factors. We have not explored, for lack of data, the effects of different socioeconomic aspects, operative techniques and periprocedural characteristics on endpoints which need to be factored in any future analysis.

Furthermore, it is very relevant clinically to sub stratify mortality and morbidity meta-analysis outcomes with cause of ASDH to make either procedure more indication-specific, however due to paucity of data in that regard within the studies analysed, that could not be achieved. Further studies should be conducted showing how patients with low pre-operative GCS scores fared post-operatively.

Even with our efforts to limit confounding bias, it cannot be said to have been eliminated. Visual inspection of forest plots also reveals publication bias. Grey literature unaccounted for on major databases is also not included.

Conclusion

As it stands, our conclusions concur with previous meta-analyses. While DC does have therapeutic value in relieving ICP, and in some cases improving outcomes for high-severity head trauma patients, it appears that refraining from pre-emptively employing this technique is clinically safe. Our subgroup analysis further favors CO as a gold standard of ASDH treatment. Our conclusions do not completely discount DC as a treatment method, however its use is contingent upon careful preprocedural patient selection. Further investigation via randomized clinical trials should be conducted.

Author Contributions

Syed Hasham Ali: Conceptualization, Project Administration, Writing-Review and Editing
Zoaib Habib Tharwani: Formal Analysis, Resources
Asad Ali Siddiqui: Formal Analysis
Fizza Iqbal: Data Curation
Mahnoor Sadiq: Writing- Original Draft
Ali Abdullah: Data curation
Abdullah Khalid: Data Curation
Huzaifa Ul Haq Ansari: Data curation
Muhammad Usman: Data Curation
Shurjeel Uddin Qazi: Methodology, Investigation
Uzair Munaf: Resources
Ibtehaj Ul Haque: Resources
Shayan Marsia: Supervision

ORCID iD

Syed Hasham Ali https://orcid.org/0000-0001-8452-4052

Data Availability Statement

Data can be supplied on request.

REFERENCES

1. van Essen TA, Lingsma HF, Pisică D, et al. Surgery versus conservative treatment for traumatic acute subdural haematoma: a prospective, multicentre, observational, comparative effectiveness study. *Lancet Neurol*. 2022;21(7):620-631.
2. Kwon YS, Yang KH, Lee YH. Craniotomy or decompressive craniectomy for acute subdural hematomas: surgical selection and clinical outcome. *Korean J Neurotrauma*. 2016;12(1):22-27.
3. Anis SB, Khan SA, Mitha R, Shamim MS. Craniotomy or craniectomy for acute subdural hematoma? Difference in patient characteristics and outcomes at a tertiary care hospital. *Asian J Neurosurg*. 2022;17(04):563-567.
4. Gopalakrishnan MS, Shanbhag NC, Shukla DP, Konar SK, Bhat DI, Devi BI. Complications of decompressive craniectomy. *Front Neurol* [Internet]. 2018. Available from: https://www.frontiersin.org/articles/10.3389/fneur.2018.00977
5. Page MJ, McKenzie JE, Bossuyt PM, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *BMJ*. 2021;372:n71.
6. Van Essen TA, Van Erp IAM, Lingsma HF, et al. Comparative effectiveness of decompressive craniectomy versus craniotomy for traumatic acute subdural hematoma (CENTER-TBI): an observational cohort study. *eClinicalMedicine*. 2023;63:102161.
7. Hutchinson PJ, Adams H, Mohan M, et al. Decompressive craniectomy versus craniotomy for acute subdural hematoma. *N Engl J Med*. 2023;388(24):2219-2229.
8. Rush B, Rousseau J, Sekhon MS, Griesdale DE. Craniotomy versus craniectomy for acute traumatic subdural hematoma in the United States: a national retrospective cohort analysis. *World Neurosurg*. 2016;88:25-31.
9. Ahmed N, Greenberg P, Shin S. Mortality outcome of emergency decompressive craniectomy and craniotomy in the management of acute subdural hematoma: a national data analysis. *Am Surg*. 2021;87(3):347-353.
10. Shibahashi K, Sugiyama K, Tomio J, Hoda H, Morita A. In-hospital mortality and length of hospital stay with craniotomy versus craniectomy for acute subdural hemorrhage: a multicenter, propensity score–matched analysis. *J Neurosurg*. 2020;133(2):504-513.
11. Vilcinis R, Bunevicius A, Tamasauskas A. The association of surgical method with outcomes of acute subdural hematoma patients: experience with 643 consecutive patients. *World Neurosurg*. 2017;101:335-342.
12. Cochrane. *Handbook for Systematic Reviews of Interventions* [Internet]. Available from: https://training.cochrane.org/handbook
13. Azouz HM, Soffar HMH, Abbass WA, Ahmed AE, El-far MT. Comparative study between the outcome of decompressive craniotomy versus craniectomy in the management of acute subdural hematoma. *Egypt J Neurosurg*. 2023;38(1):30.
14. Wan X, Wang W, Liu J, Tong T. Estimating the sample mean and standard deviation from the sample size, median, range and/or interquartile range. *BMC Med Res Methodol*. 2014;14(1):135.
15. Altaf I, Shams S, Vohra AH. Role of surgical modality and timing of surgery as clinical outcome predictors following acute subdural hematoma evacuation: clinical outcome predictors following acute subdural hematoma evacuation. *Pak J Med Sci [Internet]*. 2020;36(3):412-415. Available from: https://www.pjms.org.pk/index.php/pjms/article/view/1771
16. Li LM, Kolias AG, Guilfoyle MR, et al. Outcome following evacuation of acute subdural haematomas: a comparison of craniotomy with decompressive craniectomy. *Acta Neurochir (Wien)*. 2012;154(9):1555-1561.
17. Chen SH, Chen Y, Fang WK, Huang DW, Huang KC, Tseng SH. Comparison of craniotomy and decompressive craniectomy in severely head-injured patients with acute subdural hematoma. *J Trauma*. 2011;71(6):1632-1636.
18. Castaño-Leon AM, Gómez PA, Paredes I, et al. Surgery for acute subdural hematoma: the value of pre-emptive decompressive craniectomy by propensity score analysis. *J Neurosurg Sci*. 2023;67(1):83-92. Available from: https://www.minervamedica.it/index2.php?show=R38Y2023N01A0083
19. Ruggeri AG, Cappelletti M, Tempestilli M, Fazzolari B, Delfini R. Surgical management of acute subdural hematoma: a comparison between decompressive craniectomy and craniotomy on patients treated from 2010 to the present in a single center. *J Neurosurg Sci*. 2022;66(1):22-27. Available from: https://www.minervamedica.it/index2.php?show=R38Y2022N01A0022
20. Tsermoulas G, Shah O, Wijesinghe HE, Silva AHD, Ramalingam SK, Belli A. Surgery for acute subdural hematoma: replace or remove the bone flap? *World Neurosurg*. 2016;88:569-575.
21. Woertgen C, Rothoerl RD, Schebesch KM, Albert R. Comparison of craniotomy and craniectomy in patients with acute subdural haematoma. *J Clin Neurosci*. 2006;13(7):718-721.
22. Surgical management of acute subdural haematomas: current practice patterns in the United Kingdom and the Republic of Ireland - PubMed [Internet]. Available from: https://pubmed.ncbi.nlm.nih.gov/23530712/
23. Phan K, Moore JM, Griessenauer C, et al. Craniotomy versus decompressive craniectomy for acute subdural hematoma: systematic review and meta-analysis. *World Neurosurg*. 2017;101:677-685.
24. Abouhashem S, Albakry A, El-Atawy S, Fawzy F, Elgammal S, Khattab O. Prediction of early mortality after primary decompressive craniectomy in patients with severe traumatic brain injury. *Egypt J Neurosurg*. 2021;36(1):1.
25. Cooper PR, Hagler H, Clark WK, Barnett P. Enhancement of experimental cerebral edema after decompressive craniectomy: implications for the management of severe head injuries. *Neurosurgery*. 1979;4(4):296-300.
26. Bor-Seng-Shu E, Figueiredo EG, Amorim RLO, et al. Decompressive craniectomy: a meta-analysis of influences on intracranial pressure and cerebral perfusion pressure in the treatment of traumatic brain injury. *J Neurosurg*. 2012;117(3):589-596.
27. Bor-Seng-Shu E, Figueiredo EG, Fonoff ET, Fujimoto Y, Panerai RB, Teixeira MJ. Decompressive craniectomy and head injury: brain morphometry, ICP, cerebral hemodynamics, cerebral microvascular reactivity, and neurochemistry. *Neurosurg Rev*. 2013;36(3):361-370.
28. Kurland DB, Khaladj-Ghom A, Stokum JA, et al. Complications associated with decompressive craniectomy: a systematic review. *Neurocrit Care*. 2015;23(2):292-304.
29. Stiver SI. Complications of decompressive craniectomy for traumatic brain injury. *Neurosurg Focus*. 2009;26(6):E7.
30. Su TM, Lee TH, Chen WF, Lee TC, Cheng CH. Contralateral acute epidural hematoma after decompressive surgery of acute subdural hematoma: clinical features and outcome. *J Trauma*. 2008;65(6):1298-1302.
31. Yang XF, Wen L, Shen F, et al. Surgical complications secondary to decompressive craniectomy in patients with a head injury: a series of 108 consecutive cases. *Acta Neurochir (Wien)*. 2008;150(12):1241-1247.
32. Fattahian R, Bagheri SR, Sadeghi M. Development of posttraumatic hydrocephalus requiring ventriculoperitoneal shunt after decompressive craniectomy for traumatic brain injury: a systematic review and meta-analysis of retrospective studies. *Med Arch*. 2018;72(3):214-219.
33. Kolias AG, Kirkpatrick PJ, Hutchinson PJ. Decompressive craniectomy: past, present and future. *Nat Rev Neurol*. 2013;9(7):405-415.
34. Jost JN. Primary decompressive craniectomy after traumatic brain injury: a literature review. *Cureus*. 2022;14(10):e29894.
35. Grant GA, Jolley M, Ellenbogen RG, Roberts TS, Gruss JR, Loeser JD. Failure of autologous bone—assisted cranioplasty following decompressive craniectomy in children and adolescents. *J Neurosurg*. 2004;100(2):163-168.
36. Zanaty M, Chalouhi N, Starke RM, et al. Complications following cranioplasty: incidence and predictors in 348 cases. *J Neurosurg*. 2015;123(1):182-188.
37. Lee L, Ker J, Quah BL, Chou N, Choy D, Yeo TT. A retrospective analysis and review of an institution's experience with the complications of cranioplasty. *Br J Neurosurg*. 2013;27(5):629-635.
38. Waziri A, Fusco D, Mayer SA, McKhann GM, Connolly ES. Postoperative hydrocephalus in patients undergoing decompressive hemicraniectomy for ischemic or hemorrhagic stroke. *Neurosurgery*. 2007;61(3):489-493.
39. Rish BL, Dillon JD, Meirowsky AM, et al. Cranioplasty: a review of 1030 cases of penetrating head injury. *Neurosurgery*. 1979;4(5):381-385.
40. Kawaguchi T, Hosoda K, Shibata Y, Koyama J. Expanded polytetrafluoroethylene membrane for prevention of adhesions in patients undergoing external

decompression and subsequent cranioplasty. *Neurol Med Chir (Tokyo)*. 2003;43(6):320-323.
41. Abecassis IJ, Young CC, Caldwell DJ, et al. The Kempe incision for decompressive craniectomy, craniotomy, and cranioplasty in traumatic brain injury and stroke. *J Neurosurg*. 2021;135(6):1807-1816.
42. Hsu YC, Po-Hao Huang A, Xiao FR, Kuo LT, Tsai JC, Lai DM. Decompressive cranioplasty (osteoplastic hinged craniectomy): a novel technique for increased intracranial pressure-initial experience and outcome. *World Neurosurg*. 2019;124:e431-e435.
43. Kim YH, Lee CH, Kim CH, et al. Clinical efficacy and safety of silicone elastomer sheet during decompressive craniectomy: anti-adhesive role in cranioplasty. *Brain Sci*. 2021;11(1):124.
44. Thimukonda Jegadeesan J, Baldia M, Basu B. Next-generation personalized cranioplasty treatment. *Acta Biomater*. 2022;154:63-82.
45. Yao S, Zhang Q, Mai Y, et al. Outcome and risk factors of complications after cranioplasty with polyetheretherketone and titanium mesh: a single-center retrospective study. *Front Neurol*. 2022;13:926436.
46. Thien A, King NKK, Ang BT, Wang E, Ng I. Comparison of polyetheretherketone and titanium cranioplasty after decompressive craniectomy. *World Neurosurg*. 2015;83(2):176-180.
47. Henry J, Amoo M, Taylor J, O'Brien DP. Complications of cranioplasty in relation to material: systematic review, network meta-analysis and meta-regression. *Neurosurgery*. 2021;89(3):383-394.

Appendix

Abbreviations

ASDH	acute subdural hematoma
CO	craniotomy
DC	decompressive craniectomy
GOS	glasgow outcome scale
GOS-E	glasgow outcome scale-extended
MR	multivariate regression
OR	odds ratio
CI	confidence interval
MD	mean difference
GCS	glasgow coma scale
ICP	intracranial pressure
SSI	surgical site infection
mm	millimeter