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# Comparing surgical outcomes: Craniotomy versus decompressive craniectomy in acute subdural hematoma - A systematic review and meta-analysis

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ABSTRACT

*Introduction:* Acute subdural hematomas (SDH) pose a significant health risk, often resulting from traumatic head injuries. The choice between surgical interventions, craniotomy, and decompressive craniectomy, remains a subject of debate. This meta-analysis aims to compare outcomes and guide clinical decision-making.

*Methods:* Following PRISMA guidelines, a comprehensive literature search was conducted in databases such as Ovid Medline, PubMed, and Cochrane, up to December 2023. Selection criteria included studies comparing craniotomy and decompressive craniectomy for acute SDH. Data extraction utilized the Newcastle–Ottawa Quality Assessment Tool, and statistical analysis employed the random-effects model.

*Results:* The meta-analysis included 17 studies and 6848 patients. Craniotomy demonstrated a significant reduction in mortality rates (RR 0.80, 95% CI 0.73–0.89, $P < 0.0001$). GCS scores favored craniotomy for severe cases. GOS outcomes showed a trend favoring craniotomy, particularly in good recovery (RR 1.34, 95% CI 1.04–1.74, $P = 0.03$). Additional factors explored included co-existing sub-epidural hematoma, mydriasis, extracranial injuries, residual SDH, revision rates, and intracranial pressure.

*Conclusion:* The meta-analysis suggests that craniotomy may be a favorable surgical strategy for acute SDH, displaying a significant decrease in mortality rates and a lower risk of raised intracranial pressure. However, the nuanced nature of outcomes emphasizes the need for a tailored approach, considering broader clinical contexts. Future research should address limitations and provide a basis for well-informed clinical decision-making.

## 1. Introduction

Acute subdural hematomas (SDH) are blood clots that form between the dura mater, the brain's hard outer covering, and the surface of the brain. These clots are typically caused by surface veins straining and rupturing. When the brain is abruptly shocked or shaken by a head injury, these veins burst.[1] Many symptoms, such as headaches, nausea, vomiting, dizziness, weakness, seizures, and behavioral abnormalities, can affect patients with subdural hematomas. Sometimes, no symptoms are visible immediately following the injury and only become noticeable days after the accident as the hematoma expands.[2] Among all brain traumas, traumatic acute SDHs are among the deadliest. They are frequently accompanied by cerebral contusions and are linked to more serious, widespread brain damage. SDHs can occur in up to 30% of fatal injuries and are observed in 10–20% of cases of traumatic brain injury. The best method for diagnosing SDHs is a computed tomography (CT) scan.[1]

In accordance with the recommendations for surgical therapy of traumatic brain injury, regardless of the Glasgow Coma Scale (GCS) score, surgical evacuation of an acute SDH is suggested if the thickness reaches 10 mm or the midline shifts 5 mm. Even with milder acute SDHs, evacuation may be necessary in patients with a GCS of less than 9. Acute

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SDH has been linked to a high death rate of 40–60% and a functional recovery rate of 19–45%, even with prompt imaging and transportation, intensive care treatment, and ICP monitoring. There are two different kinds of techniques used to evacuate acute SDH patients.[3]

There are two preferred treatments for acute subdural hematoma, namely craniotomy and decompressive craniectomy. A craniotomy is a surgical operation in which the blood clot is removed by opening the skull. To reach the problematic area, a scalp incision is done initially, and a bone flap—a section of missing bone—is then removed. After the blood clot is removed, the scalp incision is sutured, and the skull hole is sealed by restoring and reattaching the bone flap. Bleeding and infection are risks associated with surgery of any kind. Following surgery, there is a chance that the brain will enlarge or that fluid will build up, which might cause brain damage and other dangerous side effects. In addition to causing damage to healthy brain tissue, surgery may also impair a patient's capacity to think, see, or talk.[3]

Decompressive craniectomy is an alternate surgical technique that involves raising a bone flap, removing a hematoma, and storing the bone flap afterward. This allows space for the growth of oedematous cerebral tissue and helps with ICP control. Nevertheless, a follow-up cranioplasty treatment is necessary for this procedure.[4]

There is an ongoing debate on the best surgical therapy for acute subdural hematoma—decompressive craniectomy or craniotomy. Decompressive craniectomy proponents contend that it offers superior control of intracranial pressure and edema following surgery. This justification, however, is not always valid since not all patients experience postoperative cerebral edema, and some studies provide contradictory findings about ICP management. Moreover, Decompressive craniectomy comes with a unique set of drawbacks, most notably those related to cranioplasty. Even while decompressive craniectomy may not be directly associated with a higher survival rate, many neurosurgeons tend to tilt towards it when treating high-energy trauma patients with GCS8 upon admission. In the end, the treating surgeon typically has the final say on whether to use Decompressive craniectomy or Craniotomy. There isn't any agreement or set rules that specify the best course of action.[5]

Sometimes it's easy to decide which is better, as in the case of an elderly patient whose brain has relaxed following hematoma evacuation, or a young patient whose brain is so enlarged that replacing the bone back is not an option. More data is needed to standardize care since the situations that fall in between the two extremes are those in which surgeons retain discretion over the procedure they choose.[6] Therefore a systematic review and meta-analysis was performed to address the relative outcomes and complications of craniotomy when compared to decompressive craniectomy for acute SDH.

## 2. Methods

This meta-analysis was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines.[7]

### 2.1. Literature search strategy

We conducted electronic searches using Ovid Medline, PubMed, Cochrane Central Register of Controlled Trials (CCTR), and Google Scholar from inception to December 2023. To maximize sensitivity, we used the terms "subdural hematoma," "subdural hemorrhage," "craniotomy," "craniectomy," or "decompressive craniectomy" as keywords or MeSH terms. Reference lists of retrieved articles were also examined for additional relevant studies.

### 2.2. Selection criteria

Included studies compared outcomes of craniotomy and decompressive craniectomy for acute subdural hematoma. Single-arm studies focusing solely on craniotomy or decompressive craniectomy were excluded. In cases of duplicate publications from institutions with accumulating patients or extended follow-up periods, only the most comprehensive reports were considered for quantitative assessment. Studies were restricted to those involving human subjects and available in English. Exclusions comprised abstracts, case reports, conference presentations, editorials, expert opinions, and review articles due to potential bias and result duplication.

### 2.3. Data extraction and critical appraisal

Data were extracted from article texts, tables, and figures. Two investigators independently reviewed each article, with discrepancies resolved through discussion and consensus with a third reviewer. For the quality assessment of the included studies, the Newcastle–Ottawa Quality Assessment Tool was used.[8]

### 2.4. Statistical analysis

The odds ratio (OR) served as the summary statistic, and both fixed- and random-effect models were assessed. The fixed-effects model assumed uniform treatment effects across studies, while the random-effects model considered variations. Heterogeneity was examined using $\chi 2$ tests, with I2 statistic indicating the proportion of total variation attributed to heterogeneity. I2 values exceeding 50% indicated substantial heterogeneity. If present, a qualitative exploration of clinical and methodological reasons was conducted. The meta-analysis employed the random-effects model to account for potential clinical and methodological diversity. Due to the unavailability of raw data, specific analyses considering confounding factors were not feasible. All analyses were 2-sided and conducted using Review Manager Version 5.3.2 (Cochrane Collaboration, Software Update, Oxford, United Kingdom).

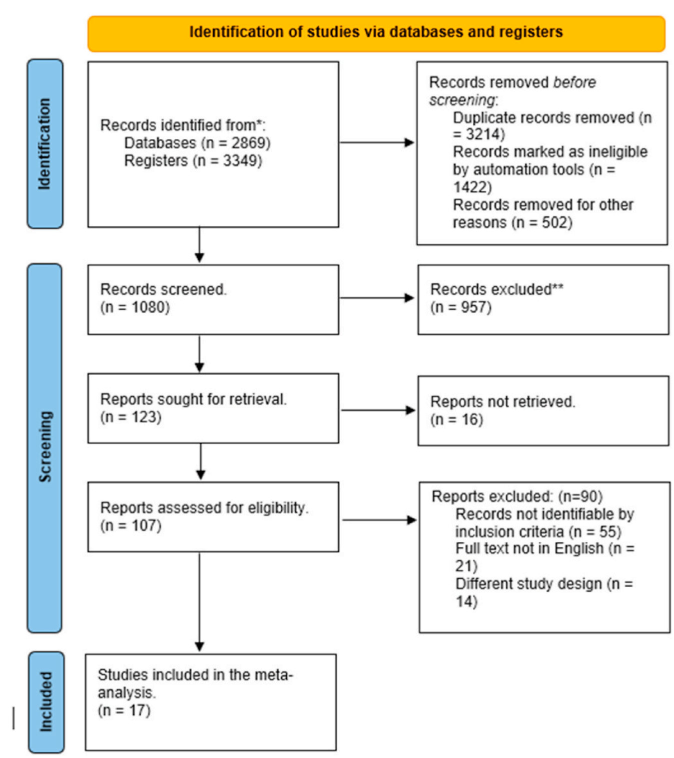


**Fig. 1.** PRISMA flow chart showing study selection procedure ($n = 17$).

**Table 1**
Baseline Characteristics of included studies.

| | | | | | | Craniotomy | | | | | Craniectomy | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| First author | Country | Study type | Total number of participants | No of craniotomies | No of craniectomies | No of pts | Average follow up | Mean Age | Male/ Female | Any antithrombotic medication — no./total no. | No of pts | Average followup | Mean Age | Male/ Female | Any antithrombin medication no./total no. |
| Chris Woertgen | Germany | Retrospective | 180 | 111 | 69 | 111 | 5.1 years | 57.2 years | male 70/ 111, female 41/111 | – | 69 | 5.1 years | 52 years | male 43/ 69, female 26/69 | – |
| Lucia M.Li | England | Retrospective review of prospectively colllected data | 91 | 40 | 51 | 36 (42%) | 6 months | 59 years | male 18/ 36, female 18/36 | – | 49 (58%) | 6 months | 45 years | male 33/ 49, female 16/49 | – |
| Shih-Han Chen | Taiwan | Observational retrospective cohort study | 102 | 42 | 60 | 42 | 1 year | 47.4 years | male 21/ 42, female 21/42 | – | 60 | 1 year | 41.2 years | male 41/ 60, female 19/60 | – |
| P.J. Hutchinson | United Kingdom | Experimental randomized control trial | 450 | 228 | 222 | 228 | 12 months | 48.3 years | male 178/ 228, female 50/228 | 30/209 (14.4) | 222 | 12 months | 48.8 years | male 179/ 222, 43 female | 31/202 (15.3) |
| Young Sub Kwon | South Korea | retrospective analysis | 46 | 20 | 26 | 20 | 6 months | 63.4 years | males 12/ 20, females 8/20 | 5 | 26 | 6 months | 65.5 years | males 16/ 26, females 10/26 | 12 |
| Barret RUSH | United States | retrospective cohort analysis | 60,435 | 1763 | 177 | 1763 | 6 month | 68.9 years | male 1150/ 1763, females 613/1763 | none mentioned | 177 | 6 months | 49.5 years | male 127/ 177, females 50/ 177 | none mentioned |
| Georgios Tsermoulas | United Kingdom | observational cohort study | 99 | 30 | 69 | 30 | 6 months | 48 years | male 22/ 30, female 8/30 | none mentioned | 69 | 6 months | 44 years | male 57/ 69, female 12/69 | none mentioned |
| Thomas A. van Essen | Europe and Israel | observational cohort study | 336 | 245 | 91 | 245 | 6 months | 59 years | male 169/ 245, females 76/ 245 | 28 | 91 | 6 months | 49 years | male 73/ 91, females 18/91 | 5 |
| Saad Bin Anis | Pakistan | retrospective analysis | 165 | 87 | 78 | 87 | 24.6 months | 42.4 years | male 73/ 87, female 14/87 | – | 78 | 23 months | 34.4 years | male 72/ 78, female 6/78 | – |
| Heba Mohamed Azouz | Egypt | prospective comparative randomized study | 30 | 15 | 15 | 15 | 1 month | 40 years | male 11/ 15, female 4/15 | not mentioned | 15 | 1 month | 40 years | male 11/ 15, female 4/15 | not mentioned |
| Joseph Synèse Bemora | Madagascar | retrospective analysis | 73 | 19 | 54 | 19 | not mentioned | 44.16 years | 6 | not mentioned | 54 | not mentioned | 35.63 years | 63/73 (total males) | not mentioned |
| Ni Luh Putu Julita Yanti | Bali, Indonesia | Historical cohort study | 80 | 40 | 40 | 40 | 3 months and 2nd follow-up at 6 months | 46.2 years | male 26/ 40, females 14/40 | none mentioned | 40 | 3 months and 2nd follow-up at 6 months | 44.5 years | males 25/ 40, females 16/40 | none mentioned |
| Andrea G Ruggeri | Rome | retrospective analysis | 94 | 50 | 44 | 50 | 12 months | not mentioned | not mentioned | none mentioned | 44 | 12 months | not mentioned | not mentioned | none mentioned |
| Nasim Ahmed | USA | retrospective design | 2370 | 1852 | 518 | 1852 | – | 49 years | male 1299/ 1852, female 553/ 1852 | – | 518 | – | 38 years | male 387/ 518, female 131/518 | – |
| Kathleen R. Ran | Unites states of America | retrospective study | 138 | 76 | 62 | 76 | 12 months | 68.9 years | male 46/ 76, females 30/76 | 11/76 (14.5) | 62 | 12 months | 47.5 years | males 50/ 62, females 12/62 | 7/62 (11.3) |

(*continued on next page*)

**Table 1** (*continued*)

| First author | Country | Study type | Total number of participants | No of craniotomies | No of craniectomies | Craniotomy | | | | | Craniectomy | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | No of pts | Average follow up | Mean Age | Male/ Female | Any antithrombotic medication — no./total no. | No of pts | Average followup | Mean Age | Male/ Female | Any antithrombin medication no./total no. |
| Imran Altaf | Sialkot, Pakistan | retrospective observational study | 17 | 5 | 12 | 5 | 4 months | 36 years | 16/17 males | none | 12 | 4 months | 42.2 years | 16/17 males | none |
| Rimantas Vilcinis | Kaunas, Lithuania | prospective review | 643 | 394 | 249 | 394 | short follow-up period | 60.34 | 202 males 192 females | not mentioned | 249 | short follow-up period | 54.52 | 201 males 48 females | not mentioned |

**Table 2**
Summary of Outcomes reported in included studies.

| Outcomes Reported | No. of included studies | Craniotomy (n) % | Craniectomy (n) % |
|---|---|---|---|
| Overall Mortality | 17 | 402/1303 (30.85%) | 518/1131 (45.80%) |
| GCS 3-8 | 6 | 314/544 (57.7%) | 338/501 (67.4%) |
| GCS 9-13 | 5 | 76/316 (24.0%) | 51/279 (18.2%) |
| GCS 14-15 | 4 | 74/296 (25.0%) | 36/253 (14.2%) |
| GOS 1/death | 4 | 112/394 (28%) | 132/380 (34.7%) |
| GOS 2/vegetative state | 4 | 22/394 (5.6%) | 17/380 (4.5%) |
| GOS 3/severe disability | 4 | 98/394 (24.8) | 90/380 (23.6%) |
| GOS 4/moderate disability | 4 | 54/394 (13.7%) | 65/380 (17.1%) |
| GOS 5/good recovery | 4 | 108/394 (27.4%) | 76/380 (20%) |
| Co-existing sub-epidural hematoma | 4 | 17/474 (2.9%) | 16/282 (5.6%) |
| Unilateral Mydriasis | 4 | 55/462 (11.9%) | 48/291 (16.4%) |
| Bilateral Mydriasis | 4 | 108/462 (23.3%) | 95/291 (32.6%) |
| Hygroma | 1 | 4/11 (3.6%) | 6/69 (8.7%) |
| Extracranial injuries | 3 | 96/321 (29.9%) | 79/180 (43.8%) |
| Residual SDH | 1 | 1/111 (1%) | 3/69 (4.3%) |
| Revision rates | 5 | 65/312 (20.8%) | 38/232 (16.37%) |
| Raised ICP(>20) | 3 | 130/300 (43.3%) | 109/183 (59.5%) |
| Outcome at follow-up: | | | |
| favorable | 1 | 40/99 (40.4%) | 18/59 (30.5%) |
| unfavorable | 1 | 59/99 (59.3%) | 41/59 (69.4%) |

## 3. Results

### 3.1. Literature search

The preliminary literature search yielded 133 results, of which were screened for title and abstract. Consequently, they were assessed for eligibility and full-text screening, which led to the inclusion of 17 studies.[9–25] The searching and screening process is shown in the flowchart (Fig. 1). A total of 6848 patients were included in 17 studies (i.e., 5013 patients in the craniotomy group and 1835 patients in the craniectomy group respectively). The basic characteristics and outcomes of the included studies are shown in Tables 1 and 2 respectively.

1 Assessment of study quality and risk of bias

The Newcastle OTAWA Scale was utilized to evaluate studies, taking into consideration factors like insufficient outcome data, participant blinding, random sequence generation, outcome assessment, and other potential validity concerns. Each variable in the studies was categorized as low risk, uncertain risk, or high risk. The quality assessment of included studies is included in Table 3.

2 Basic preoperative characteristics of the population

The mean age of the patients included in the craniectomy, and craniotomy group ranged from 34.4 to 65.5 years and 36–68.9 years, respectively. The male proportion was reported in 16 of the 17 included studies, revealing a significantly lower proportion of males in the craniotomy group compared to the craniectomy group (67.7% vs. 76.8%, RR 0.90, 95% CI 0.85–0.95, I2 55%, $P = 0.004$), with moderate heterogeneity. A sensitivity analysis identified Rimantas' study as the source of increased heterogeneity (I2 55%, $P = 0.004$) (Fig. 2).

3 Overall Mortality

This outcome was evaluated using the number of deaths reported in

**Table 3**
Risk of Bias Assessment of included Studies.

| | Selection | | | | Comparability | Outcomes | | | Total (max 9✩) |
|---|---|---|---|---|---|---|---|---|---|
| First author | Representativeness of exposed cohort | Selection of non-exposed cohort | Ascertainment of exposure | Demonstration That Outcome of Interest Was Not Present at the Start of Study | | Assessment of outcomes | Long Enough Follow-up for Outcomes to Occur | Adequacy of Follow Up of Cohorts | |
| Chris Woertgen | | | ✱ | ✱ | ✱ | ✱ | ✱ | | (5/9) |
| Lucia M.Li | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | ✱ | (7/9) |
| Shih-Han Chen | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (7/9) |
| P.J. Hutchinson | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | ✱ | (8/9) |
| Young Sub Kwon | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (6/9) |
| Barret RUSH | ✱ | | ✱ | ✱ | ✱ | ✱ | | | (6/9) |
| Georgios Tsermoulas | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | ✱ | (8/9) |
| Thomas A. van Essen | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (6/9) |
| Saad Bin Anis | ✱ | | ✱ | ✱ | | ✱ | ✱ | ✱ | (6/9) |
| Heba Mohamed Azouz | ✱ | | ✱ | | ✱ | ✱ | ✱ | | (6/9) |
| Joseph Synèse Bemora | ✱ | | ✱ | | ✱ | ✱ | | | (5/9) |
| Ni Luh Putu Julita Yanti | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (7/9) |
| Andrea G Ruggeri | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (6/9) |
| Nasim Ahmed | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (5/9) |
| Kathleen R. Ran | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (6/9) |
| Imran Altaf | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (6/9) |
| Rimantas Vilcinis | ✱ | | ✱ | ✱ | ✱ | ✱ | ✱ | | (6/9) |

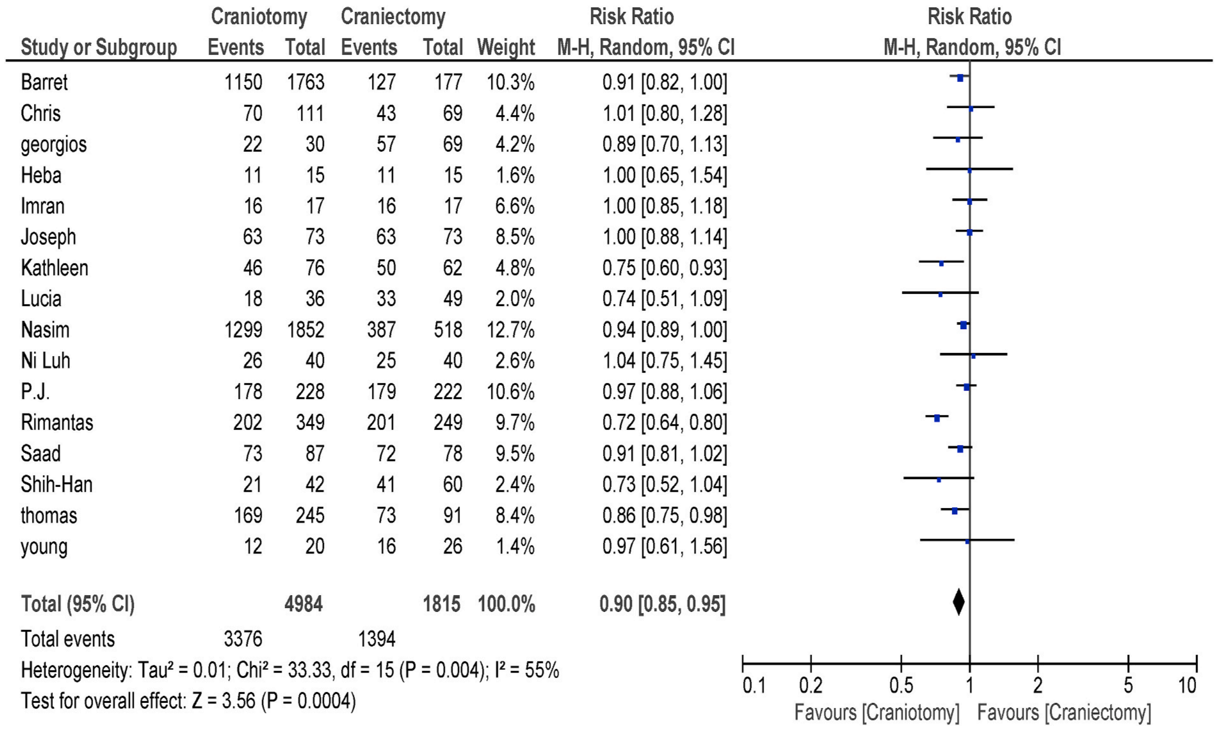


**Fig. 2.** Male proportion: According to the forest plot above, the male proportion of the craniotomy group was found to be significantly lower (67.7%) than in the craniectomy group whose male proportion was 76.8%. Moderate heterogeneity was sought by performing sensitivity analysis which revealed Rimantas to be the source of all of the heterogeneity.

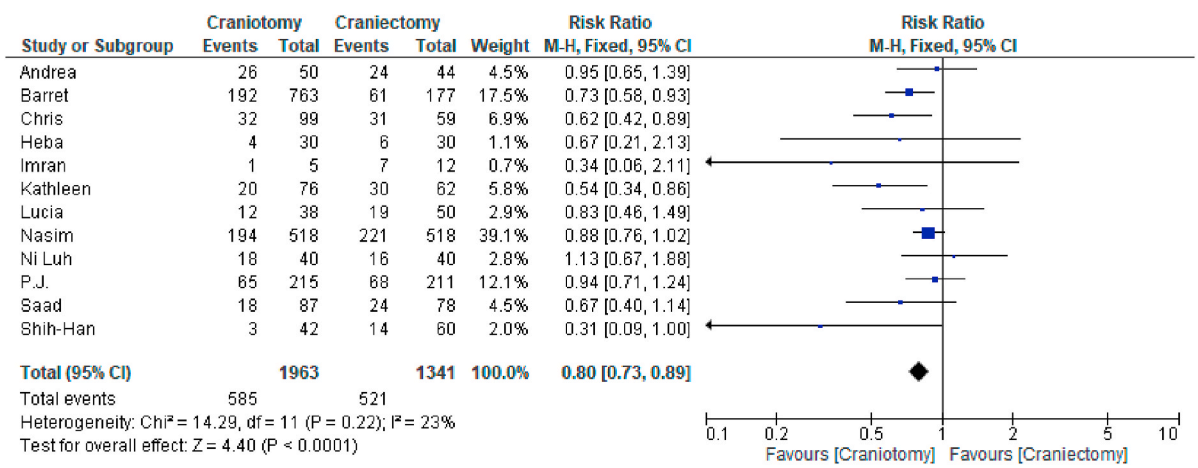


**Fig. 3.** Mortality: This forest plot demonstrates a significant association of mortality with craniotomy than with the craniectomy group with mild heterogeneity.

12 out of 17 included studies. There was a reduction in the incidence of mortality in the craniotomy group (29.8%, 585 out of 1963) compared to the group undergoing craniectomy (38.9%, 521 out of 1341). The result was statistically significant (RR 0.80, 95% CI 0.73–0.89, $P < 0.0001$) with mild heterogeneity was detected (I2 23%, $P = 0.22$) (Fig. 3).

## 4 GCS scale

The Glasgow Coma Scale was utilized to gauge the severity of the initial traumatic injury. Among patients with the most severe GCS scores (ranging from 3 to 8), there was a significantly lower proportion of such patients in the craniotomy group compared to craniectomy (57.7% vs 67.4%, RR 0.78, 95% CI 0.63–0.97, $P = 0.02$, I2 = 73%) Fig. 4). No significant difference was observed for patients with GCS scores of 9–13 (24.0% vs 18.2%, RR 1.44, 95% CI 0.98–2.13, $P = 0.06$, I2 = 36%) (Fig. 5). For patients with GCS scores of 14–15, there was a significantly higher proportion in the craniotomy group compared to the craniectomy group (25.0% vs 14.2%, RR 1.69, 95% CI 1.18–2.42, $P = 0.004$, I2 0%) (Fig. 6).

## 5 Follow-up using the Glasgow Outcome Scale

Follow-up using the Glasgow Outcome Scale (GOS) was available for a total of 774 patients reported in 4 included studies only. The distribution of GOS outcomes revealed statistically non-significant differences for GOS1/death (28% vs 34.7%, RR 0.74, 95% CI 0.53–1.03, $p = 0.07$, I2 47%) (Fig. 7). Similarly, the GOS 2/vegetative state showed no significance, with 5.6% of patients in the craniotomy group and 4.5% of patients in the craniectomy group (RR 1.13, 95% CI 0.61–2.13, $p = 0.69$,

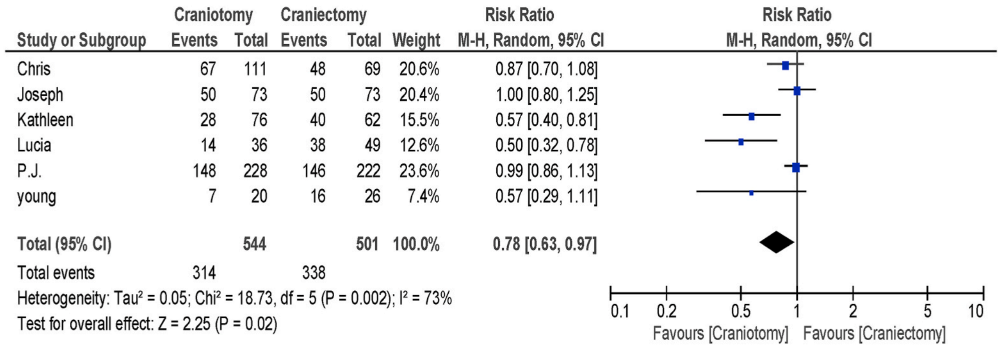


**Fig. 4.** GCS3-8: According to the forest plot above, 57.7% of patients in the craniotomy group have a GCS score of 3–8, and 67.4% of patients in the craniectomy group have a GCS score of 3–8.

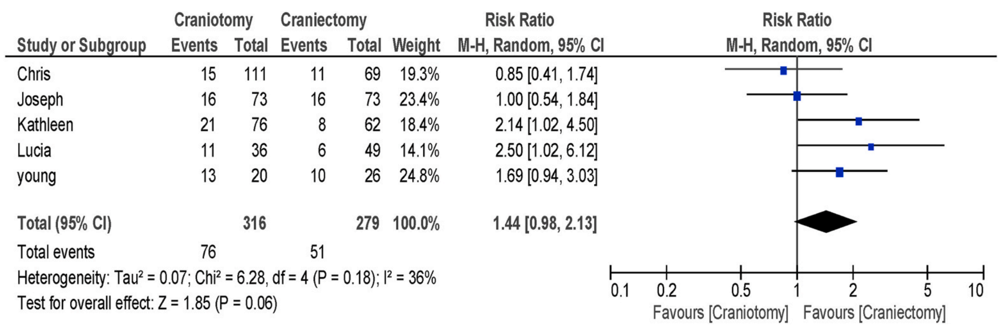


**Fig. 5.** GCS9-13: This forest plot exhibits that 24.0% of patients in the craniotomy group have a GCS score of 9–13 and 18.2% of patients in the craniectomy group have a GCS score of 9–13.

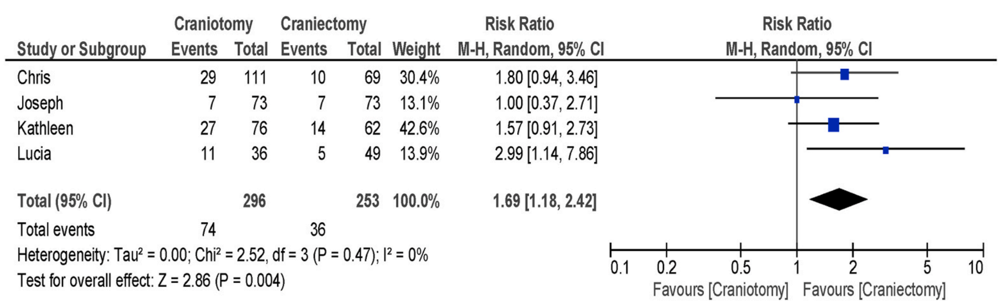


**Fig. 6.** GCS14-15: This forest plot illustrates that 25.0% of patients in the craniotomy group have a GCS score of 14 15and 14.2% of patients in the craniectomy group have a GCS score of 14–15.

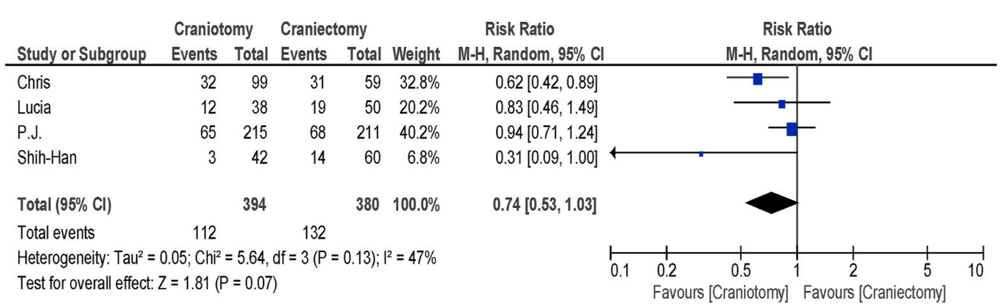


**Fig. 7.** GOS1/Death: This forest plot shows that 28% of patients in the craniotomy groups had a GOS score of 1 whereas 34.7% of patients had a GOS score of 1 in the craniectomy group.

I2 0%) (Fig. 8). GOS 3/severe disability (24.8% vs 23.6%, RR 1.07, 95% CI 0.82–1.41, $p = 0.62$, I2 5%) (Fig. 9) and GOS 4/moderate disability (13.7% vs 17.1%, RR 0.90, 95% CI 0.65–1.25, $p = 0.52$, I2 0%) (Fig. 10) were observed in small numbers without statistically significance. Notably, GOS 5/good recovery was observed in 108 out of 394 patients (27.4%) in the craniotomy group and 76 out of 380 patients (20%) craniectomy group. This result favored craniotomy more than the craniectomy (RR 1.34, 95% CI 1.04–1.74, $p = 0.03$). No heterogeneity was reported (I2 0%, $p = 0.90$) (Fig. 11)

In the craniotomy group, there were 204 (51.7 %) unfavorable

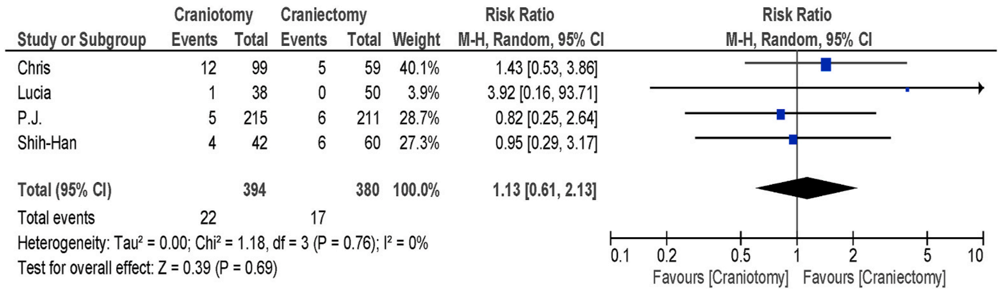


**Fig. 8.** GOS2/Vegetative state: This forest plot signifies that 22 out of 394 patients (5.6%) have a GOS score of 2 in the craniotomy group, whereas 17 out of 380 patients (4.5%) have a GOS score of 2 in the craniectomy group.

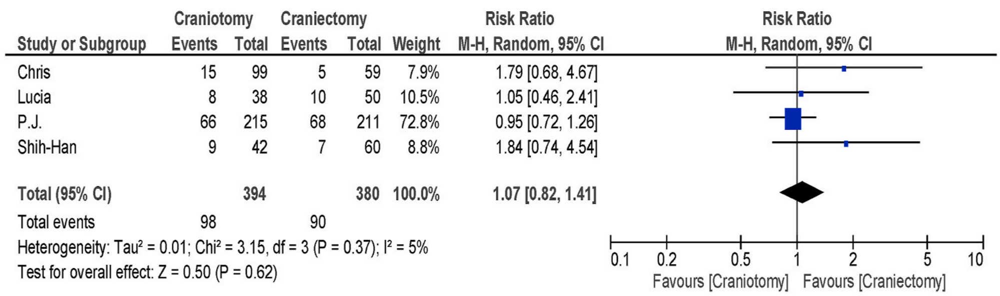


**Fig. 9.** GOS3/Severe disability: This forest plot demonstrates that 98 out of 394 patients (24.8%) have a GOS score of 3 in the craniotomy group, whereas 90 out of 380 patients (23.6%) have a GOS score of 3 in the craniectomy group.

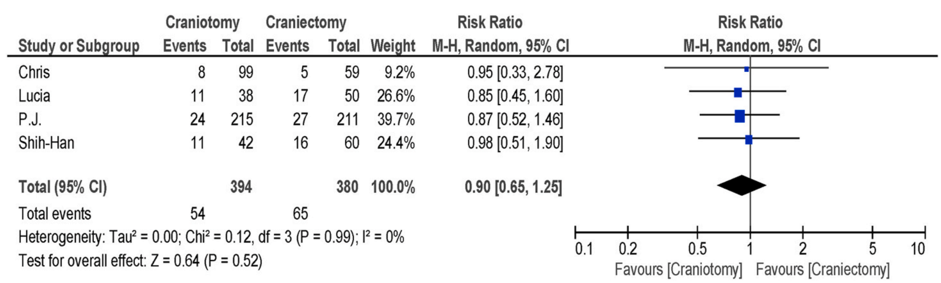


**Fig. 10.** GOS4/Moderate disability: This forest plot shows that 54 out of 394 (13.7%) had a GOS score of 4 in the craniotomy group and 65 out of 380 patients (17.1%) had a GOS score of 3 in the craniectomy group.

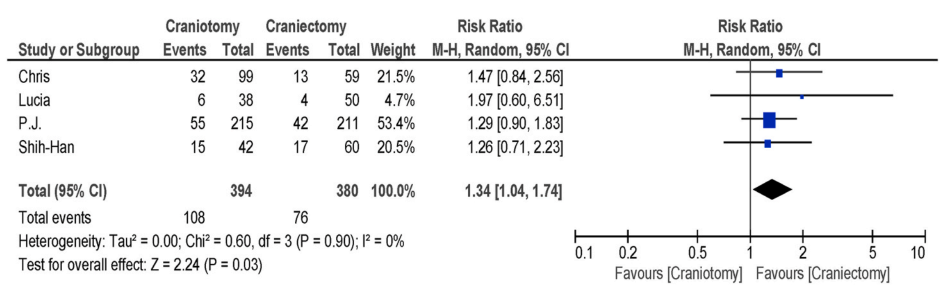


**Fig. 11.** GOS5/Good recovery: Forest plot demonstrating 108 out of 394 (27.4%) had a GOS score of 5 in the craniotomy group and 76 out of 380 patients (20%) had a GOS score of 5 in the craniectomy group.

outcomes and 95 (47.7%) favorable outcomes. Whereas in the craniectomy group, there were 212 (55.7%) unfavorable outcomes and 78 (40%) favorable outcomes. In terms of the percentages alone, there is a difference in distribution between the craniotomy and craniectomy group but without statistical significance from the forest plot analysis, we should interpret these percentages with caution and consider the broader clinical context (Figs. 12 and 13)

6 Co-existing sub-epidural Hematoma

No statistically significant difference was found between the groups in terms of the proportion of patients with co-existing epidural hematoma (2.9% vs 5.6%, RR 0.73, 95% CI 0.37–1.44, I 2 = 0%, $P = 0.36$) (Fig. 14). However, this variable was reported in only four of the included studies. The lack of statistical significance may stem from

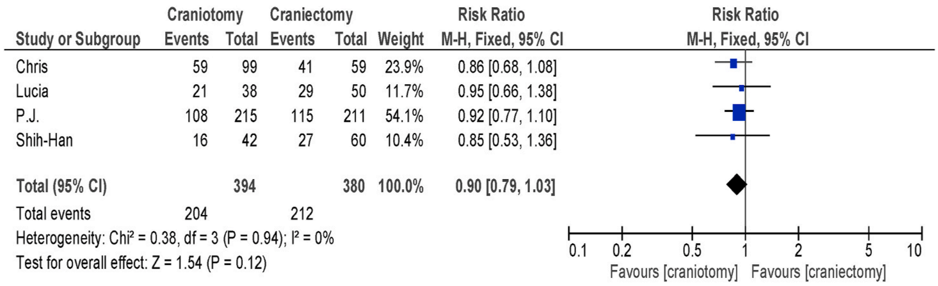


**Fig. 12.** Unfavorable outcomes: This forest plot shows no significant association of unfavorable outcomes with craniotomy and craniectomy with 51.7% of patients in craniotomy and 55.7 patients in the craniectomy group having unfavorable outcomes.

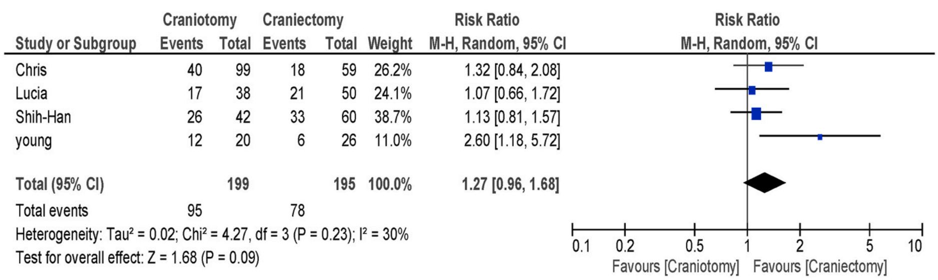


**Fig. 13.** Favorable outcomes: This depicts no significant association of favorable outcomes with craniotomy vs craniectomy group with 47.7% of patients in craniotomy and 40% of patients in craniectomy having favorable outcomes.

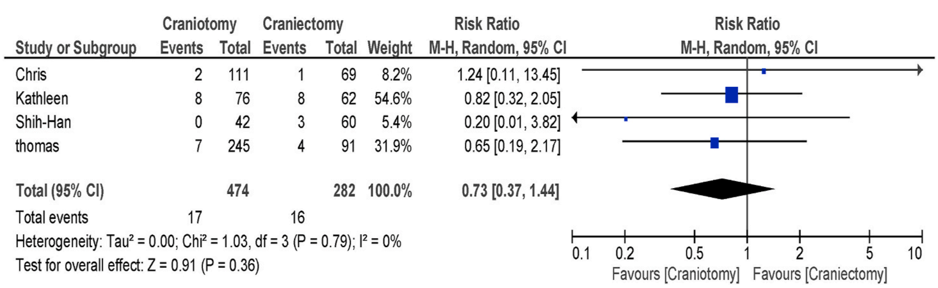


**Fig. 14.** Coexisting epidural hematoma: The forest plot above signifies that 2.9% of patients in the craniotomy group have co-existing epidural hematoma whereas 5.6% of patients in the craniectomy group have co-existing epidural hematoma.

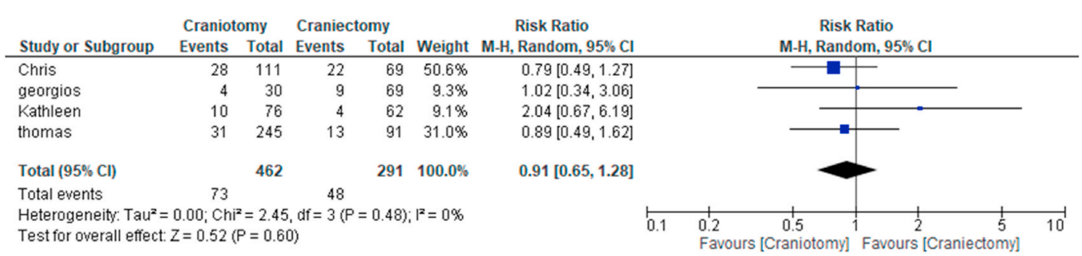


**Fig. 15.** Unilateral mydriasis: This forest plot shows that 15.8% patients in craniotomy group had unilateral mydriasis whereas 16.4% patients in craniectomy group had unilateral mydriasis.

inadequate patient sample sizes. Consequently, no definitive conclusion can be drawn regarding operative management of acute subdural hematoma with co-existing epidural hematomas.

## 7 Mydriasis

Regarding unilateral mydriasis, no difference was found between craniotomy and craniectomy groups (15.8% vs 16.4%, RR 0.91, 95% CI 0.65–1.28, I 2 = 0%, $P = 0.60$) (Fig. 15). In terms of bilateral mydriasis, fewer cases were found in the craniotomy group compared to the craniectomy group (23.3% vs 32.6%, RR 0.66, 95% CI 0.35–1.23, I2 = 82%, $P = 0.19$) (Fig. 16).

## 8 Extracranial injuries

A significant difference was found between the craniotomy and craniectomy groups concerning extra-cranial injuries (29.9% vs 43.8%, RR 0.42, 95% CI 0.17–1.02, I2 = 70%, $P = 0.05$) (Fig. 17).

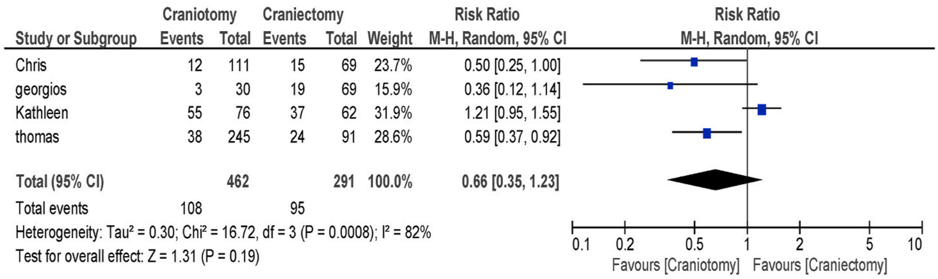


**Fig. 16.** Bilateral mydriasis: This forest plot demonstrates that 23.3% of patients in the craniotomy group have bilateral mydriasis whereas 32.6% of patients in the craniectomy group have bilateral mydriasis.

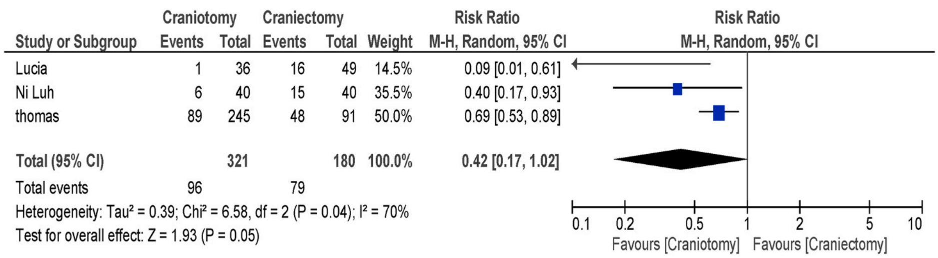


**Fig. 17.** Extracranial injuries: The forest plot above displays that 29.9% of patients in the craniotomy group have extracranial injuries whereas 43.8% of patients in the craniectomy group have extracranial injuries.

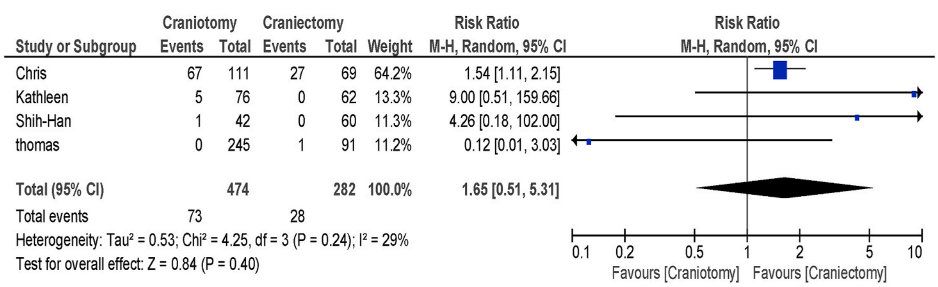


**Fig. 18.** Residual SDH: This forest plot shows that 15.4% of patients in the craniotomy group have Residual SDH whereas 9.9% of patients in the craniectomy group have Residual SDH.

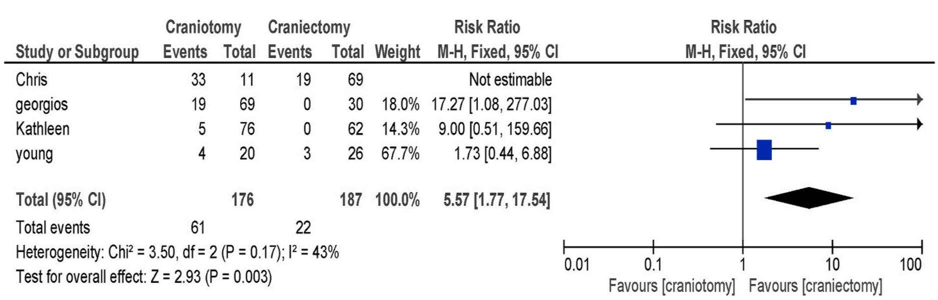


**Fig. 19.** Revision rates: This forest plot shows statistically significant revision rates in the craniectomy group with moderate heterogeneity. Sensitivity analysis revealed Young to be the source of all the heterogeneity.

## 9 Residual SDH and revision rates

Although results for residual SDH were not statistically significant, a greater percentage of patients in the craniotomy group had residual SDH when compared to the craniectomy group (15.4% vs 9.9%, RR 1.65, 95% CI 0.51–5.31, I2 29%, $p = 0.40$) (Fig. 18). Revision rates, reported in four included studies, were significant between the craniotomy and craniectomy groups (35% vs 11.8%, RR 5.57, 95% CI 1.77–17.54, I2 = 43%, $P = 0.003$) (Fig. 19).

## 10 Raised Intracranial pressure (ICP>20)

Results from three studies that reported raised intracranial pressure were statistically significant. The risk of having raised ICP was lower in the craniotomy group compared to the craniectomy group (39.39% vs 59.5%, RR 0.74, 95% CI 0.57–0.97, $p = 0.03$, I2 52%) (Fig. 20).

### *3.2. Publication bias*

The funnel plot analysis for the 2 outcomes (i.e. male proportionality

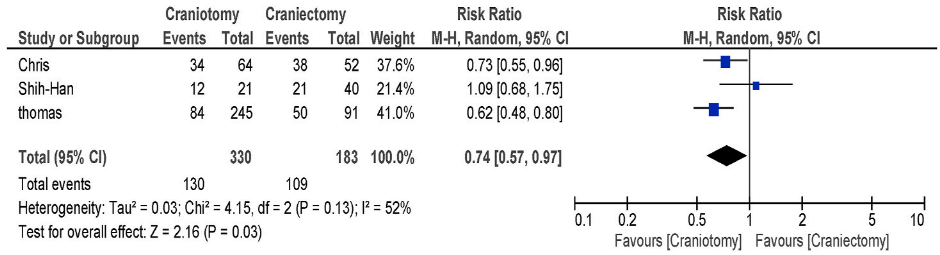


**Fig. 20.** This forest plot demonstrates that 39.39% of patients in the craniotomy group had 59.5% of patients in the craniectomy group had ICP>20.

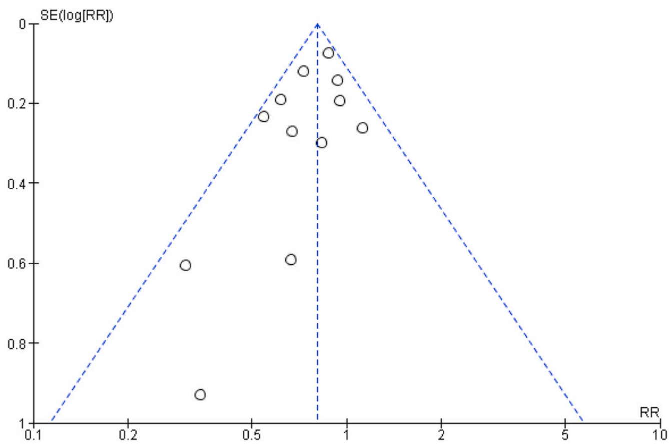


**Fig. 21.** Funnel plot for mortality outcome shows considerable asymmetry indicating a high likelihood of publication bias.

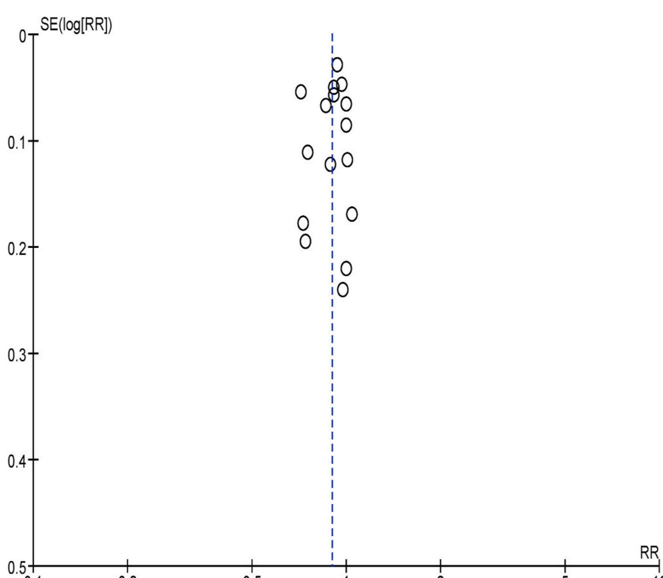


**Fig. 22.** The funnel plot for male proportionality showed symmetry and proximity to the midline, indicating low heterogeneity and absence of publication bias.

and mortality) is included in supplementary figures, each involving more than 10 studies. The funnel plot for male proportionality showed symmetry and proximity to the midline, indicating low heterogeneity and the absence of publication bias. In contrast, the funnel plot for mortality displayed a more asymmetrical pattern which raises concerns for potential publication bias (Figs. 21 and 22).

### 3.3. Sub-analysis

The forest plot of the larger set (including randomized studies and observational studies) depicts a significant association of mortality with the craniotomy group; however, pooled results of only randomized studies demonstrate no significant association of either group with mortality raising a potential suspicion of confounding bias in the larger set contributed by observational studies. However, it must be noted that heterogeneity in the larger set is higher ($I^2 = 23\%$) than in the randomized study group ($I^2 = 0$), the likely explanation of this being the inclusion of different study designs in the larger set (Fig. 23).

If the "male proportion" is set into the discussion, although, the pooled result of randomized studies endorses the results of the larger set, that is, the male proportion being greater in the craniectomy group than in the craniotomy group, the larger set depicts statistically significant results as compared to the pooled result for the randomized studies. Furthermore, the heterogeneity displayed by the larger set is greater (55%) as compared to the pooled result of the randomized studies for which the heterogeneity is just 7% (Fig. 24). However, no conclusion can be drawn from the randomized studies group given its small sample size and minimum number of studies for both outcomes that have been reported.

## 4. Discussion

Surgical management is frequently the treatment option of choice among patients suffering from acute SDH, with the goal of reducing the occurrence and impact of secondary brain injury.[26] The morbidity and mortality rate for this type of disease are highly significant even with treatments. Two frequently used surgical procedures include craniotomy and decompressive craniectomy. Currently, the choice between the two options is primarily at the discretion of the surgeons. Based on a survey conducted in 2011[27] by members of the British Neurosurgical Trainees' Association, the NeuroCritical Care Network, the European Association of Neurosurgical Societies, and the Society of British Neurological Surgeons, 44% of neurosurgeons in continental Europe employed decompressive craniectomy in more than half of their cases[28] of acute SDH, whereas only 21% of neurosurgeons in Britain and Ireland did the same. On the other hand, a review of the National Surgical Quality Improvement Program,[29] a significant prospective U.S. database, discovered that among these patients, craniotomy was done ten times more frequently than decompressive craniectomy. The lack of high-quality evidence and precise standards for this condition is reflected in the enormous variations in practice between continents, countries, and even within departments. The literature shows mixed results when it comes to craniotomy and decompressive craniectomy for acute SDH. While some research points to a higher risk of complications following decompressive craniectomy, other studies find no significant difference.

Our meta-analysis, encompassing 17 studies and 6848 patients, delves into the comparative outcomes of craniotomy and craniectomy for acute subdural hematoma (SDH). Notable findings include a significant reduction in mortality rates favoring craniotomy and a lower proportion of severe Glasgow Coma Scale (GCS) scores in the

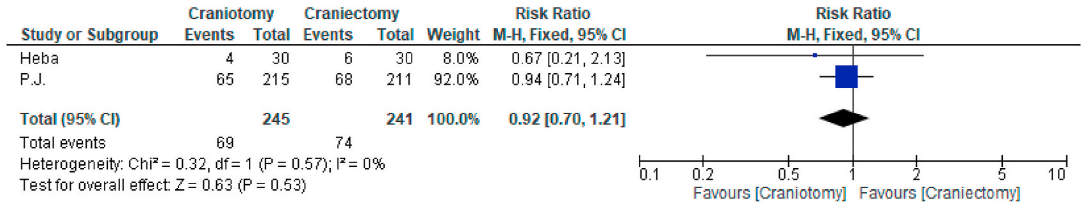


**Fig. 23.** Sub-analysis (Mortality) -This forest plot demonstrates no significant association of either group with mortality as compared to the larger set which showed a significant association of mortality with the craniotomy group.

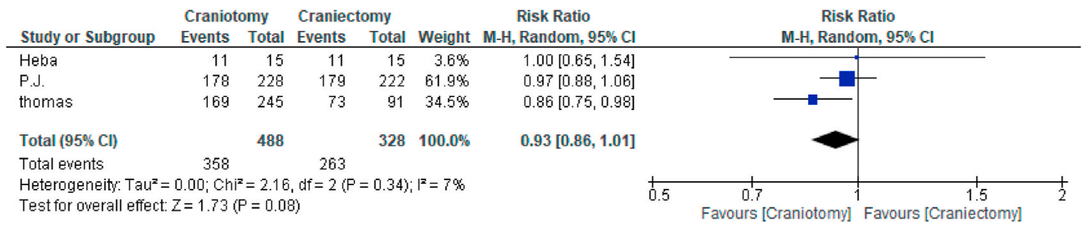


**Fig. 24.** Sub-analysis (Male proportion)- The forest plot shows that the male proportion of the craniotomy group was found to be lower (73.3%) than in the craniectomy group whose male proportion was 80.1%. However, unlike the larger set, the pooled result of randomized studies isn't statistically significant.

craniotomy group, particularly for the most critical cases. While Glasgow Outcome Scale (GOS) outcomes exhibit a statistically non-significant trend, a notable advantage for craniotomy emerges in GOS 5 (good recovery). Exploring additional factors, such as co-existing sub-epidural hematoma, mydriasis, extracranial injuries, residual subdural hematoma, revision rates, and intracranial pressure, unveils nuanced insights. No definitive conclusions emerge regarding the operative management of acute subdural hematoma with co-existing epidural hematomas. Importantly, the meta-analysis identifies a potentially lower risk of raised intracranial pressure with craniotomy.

The implications of the meta-analysis findings hold significant importance for clinical decision-making in the realm of acute subdural hematoma management. The observed reduction in mortality rates with craniotomy suggests a potential benefit for patients undergoing this surgical approach. Clinicians may consider the lower risk of raised intracranial pressure associated with craniotomy as a factor favoring its use, particularly in cases where managing intracranial pressure is critical. However, the nuanced nature of the results, especially the lack of statistical significance in certain outcomes despite apparent trends, emphasizes the need for a tailored approach. The observed differences in Glasgow Outcome Scale (GOS) outcomes, although not statistically significant, underscore the complexity of patient outcomes and highlight the importance of considering the broader clinical context.

The findings of our current meta-analysis exhibit consistency with a previous study that investigated the comparative outcomes of craniotomy and craniectomy for acute subdural hematoma (SDH).[30] Notably, the observed lower proportion of males in the craniotomy group, in contrast to the decompressive craniectomy cohort, mirrors the trends identified in the earlier meta-analysis. Additionally, our analysis concurs with the prior study in highlighting the association between lower Glasgow Coma Scale (GCS) scores and a higher likelihood of patients undergoing decompressive craniectomy, emphasizing the coherence in these critical clinical determinants. However, it's crucial to scrutinize the limitations inherent in the earlier meta-analysis. The reliance on a relatively smaller data set may have introduced potential challenges related to statistical power, potentially influencing the robustness of the reported outcomes. Furthermore, the prior study's narrower focus on specific outcomes might have constrained the comprehensive understanding of the nuanced differences between craniotomy and craniectomy in the context of acute SDH. Despite these limitations, our meta-analysis presents distinct advantages. With a larger dataset, we mitigate the impact of inadequate sample sizes, thereby enhancing the reliability and generalizability of our findings. By exploring a broader spectrum of outcomes, including co-existing epidural hematoma, mydriasis, extra-cranial injuries, residual SDH, and revision rates, our study contributes to a more detailed and nuanced comprehension of the surgical landscape in acute SDH cases.

### 4.1. Limitations

The current study is strong in its review of the literature; on the other hand, its intrinsic limitations result from the fact that the majority of the included studies were observational. A significant percentage of the trials are not randomized, which presents a possibility for bias due to unexplained confounding variables. The severity of the damage and cerebral edema frequently impact the choice to omit the bone flap in a decompressive craniectomy. This subgroup may therefore be biased against outcomes because the individuals in it usually have more severe baseline morbidity. More clear recognition and understanding of this significant factor are required when interpreting the results. Moreover, a notable limitation is the lack of consistent reporting on the extent of injuries among the included studies. Furthermore, the lack of data on bone flap size, a critical factor in surgical outcomes for acute subdural hematoma, poses a challenge to the meta-analysis. Previous prospective randomized studies comparing various thicknesses of bone flaps have suggested that larger flaps are linked to more problems but maybe a superior way to reduce cerebral edema.[31,32] Another important factor to take into account is the notable difference in surgical approaches used in the research, which includes different craniotomy techniques, changes in duroplasty, and the use of adjuncts like drains and external ventricular drains (EVDs). Because of this variation in surgical techniques, there is a degree of uncertainty, hence care must be taken when extrapolating the results to particular surgical procedures. Moreover, the study is susceptible to selection bias due to the retrospective character of the included studies. To further improve our knowledge of the best surgical treatment for acute subdural hematoma, future research endeavors should focus on addressing the limitations that have been found. These efforts should include prospective study designs, standardized reporting, and multi-center collaborations. In the end, our meta-analysis establishes the framework for future developments in the field and provides a vital basis for well-informed clinical decision-making.

## 5. Conclusion

The potential of craniotomy as a favorable surgical strategy in the management of acute SDH is shown by the significant decrease in mortality rates associated with it, as observed in our meta-analysis. This conclusion should be carefully considered by clinicians in choosing the best surgical strategy, especially since craniotomy carries a decreased risk of elevated intracranial pressure. This decreased risk might be especially significant when controlling intracranial pressure is essential for the best possible outcomes for the patient.

## Data availability statement

Not applicable.

## Ethics approval statement

Not applicable.

## Patient consent statement

Not applicable.

## Clinical trial registration

Not applicable.


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None.


## CRediT authorship contribution statement

**Abdullah Nadeem:** Writing – review & editing, Writing – original draft, Software, Methodology, Data curation, Conceptualization. **Tasmiyah Siddiqui:** Software, Formal analysis, Data curation. **Taruba Rais:** Writing – review & editing, Writing – original draft, Methodology. **Rabbia Munsab:** Writing – review & editing, Writing – original draft, Methodology. **Ashna Habib:** Writing – review & editing, Writing – original draft. **Eesha Khan Afridi:** Writing – review & editing, Writing – original draft, Software, Resources, Data curation. **Fariha Shariq:** Writing – review & editing, Formal analysis, Data curation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.


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## Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.wnsx.2024.100368.

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## Abbreviations

*PRISMA:* Preferred Reporting Items for Systematic Reviews and Meta-Analysis
*SDH:* Subdural Hematoma
*GCS:* Glasgow Coma Scale
*RR:* Risk Ratio
*CI:* Confidence Interval
*OR:* Odds Ratio
*CT:* Computed Tomography
*EVD:* External Ventricular Drain