Meta-analysis

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Single versus double burr hole in subdural hematoma: A Bayesian pairwise meta-analysis of hospital stay

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Abstract

Subdural hematoma (SDH) is a common neurosurgical emergency typically treated with burr hole craniostomy. However, whether single burr hole (SBH) or double burr hole (DBH) techniques influence hospital stay remains unclear. The aim of this study was to compare SBH and DBH in terms of hospital length of stay using a Bayesian pairwise meta-analysis. A systematic search of PubMed, Scopus, Scilit, and Web of Science was conducted for records indexed up to May 29, 2025. Studies reporting hospital length of stay as the mean ± standard deviation (SD) for patients undergoing SBH or DBH were eligible for inclusion. Effect sizes were calculated as standardized mean differences using Hedges' g and pooled using a Bayesian random-effects model with broad, plausible prior distributions that limited extreme estimates without overriding the observed data. Posterior summaries were presented as pooled effect estimates with 95% credible intervals (CrI), between-study heterogeneity (τ), posterior probability of direction, and sensitivity analyses with leave-one-out refitting. Data from eight studies comprising 465 patients were pooled in the meta-analysis. The pooled standardized mean difference in hospital stays between SBH and DBH was -0.02 (95%CrI: -0.47 to 0.39), indicating no meaningful difference. Between-study heterogeneity was moderate (τ=0.37, 95%CrI: 0.02 to 0.96). The posterior probability that SBH led to longer hospitalization than DBH was 46%, and the Bayes factor (BF_{01}=2.26) favored the null hypothesis of no difference. In conclusion, the Bayesian analysis revealed no statistically significant difference in hospital length of stay between SBH and DBH.

Keywords: Bayesian meta-analysis, double burr hole, length of hospital stay, single burr hole, subdural hematoma

Introduction

Subdural hematoma (SDH) is one of the most frequent neurosurgical emergencies, with a particularly high incidence among older adults, individuals with a history of head trauma, and patients receiving anticoagulant or antiplatelet therapy [1]. Age-related brain atrophy leads to stretching of the bridging veins, making them more prone to rupture even after minor trauma [2]. Coagulopathy, whether due to medications or systemic disease, further increases bleeding risk and contributes to hematoma expansion [3]. In addition, comorbidities such as hypertension, alcohol misuse, and cerebral small vessel disease may increase susceptibility to SDH and the risk of its recurrence [4]. Mechanistically, SDH often develops as venous blood accumulates in the

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subdural space, with fibrinolytic activity and inflammatory responses contributing to membrane formation and repeated microhemorrhages [5]. These processes sustain hematoma growth, impair reabsorption, and predispose to re-accumulation. Surgical evacuation is generally required when the hematoma causes neurological symptoms or radiological mass effect [6]. Compared with craniostomy, burr hole craniostomy has become the preferred approach for most chronic and subacute SDH cases because it achieves effective decompression while being less invasive, associated with shorter operative time, and applicable across a wide spectrum of patients [7]. Despite its widespread adoption, important questions remain about optimizing surgical technique and tailoring it to the risk profiles of patients prone to recurrence or delayed recovery [8].

Two common variations of burr hole craniostomy are single burr hole (SBH) and double burr hole (DBH) techniques. SBH involves a single cortical opening and is technically faster, requires less drilling, and is often favored in urgent cases, in elderly or fragile patients, or in settings with limited surgical resources [9]. Its simplicity can reduce operative time and may be associated with less intraoperative blood loss [10]. However, some surgeons raise concerns that the narrower access may lead to incomplete evacuation of the hematoma or insufficient irrigation of the subdural space. DBH, on the other hand, provides wider exposure and enables more thorough evacuation, irrigation, and inspection of the hematoma cavity. This theoretically reduces the likelihood of residual clot, re-accumulation, and recurrence [11]. Yet, DBH requires longer operative time, additional drilling, and potentially greater cortical manipulation [12]. Although some neurosurgeons consider DBH more effective in reducing recurrence, others contend that any clinical benefit is limited and may not justify the additional invasiveness [13]. Both SBH and DBH are widely practiced across centers, but their use is often determined more by surgeon preference, institutional habit, and patient condition than by strong comparative evidence. Consequently, clinical practice varies considerably, with some institutions predominantly using SBH and others favoring DBH. Despite decades of use, the relative benefits of SBH versus DBH remain unclear, particularly in terms of patient-centered outcomes such as recovery speed and hospitalization length.

Hospital stay is a practical and clinically relevant outcome for comparing these approaches. It reflects the patient's recovery trajectory, the efficiency of hematoma evacuation, and the occurrence of complications [14]. Longer hospitalization often indicates postoperative morbidity, recurrence, or delayed recovery, making it an overall parameter of surgical success [15]. In addition, length of stay has direct implications for healthcare systems: it influences bed occupancy, costs, and the risk of hospital-acquired complications [16]. This is particularly relevant in constrained settings, where minimally invasive alternatives such as endoscopic evacuation or twist-drill craniostomy are often unavailable.

Given the conflicting evidence regarding the comparative effectiveness of SBH and DBH [17,18], this study conducted a Bayesian pairwise meta-analysis to compare hospital length of stay between the two techniques in patients with SDH. The Bayesian framework enables direct probabilistic interpretation of treatment effects, incorporates between-study heterogeneity, and quantifies uncertainty using credible intervals and Bayes factors [19]. This approach may provide a more informative assessment of the available evidence and support surgical decision-making across diverse clinical settings.

Methods

Study design

A systematic review with Bayesian pairwise meta-analysis was performed to compare SBH versus DBH craniostomy in patients with SDH. The review and analysis were performed in accordance with the PRISMA 2020 guidelines and the Cochrane Handbook for Systematic Reviews of Interventions [20]. The protocol was registered in PROSPERO with number CRD420251139427.

Eligibility criteria

Study selection followed the population, intervention, control, outcome, and study design (PICOS) framework. Eligible studies included randomized controlled trials (RCTs) and observational studies involving patient of any age diagnosed with chronic or subacute SDH undergoing burr hole craniostomy. The intervention was SBH compared with DBH in the control group. The outcome in this study was duration of hospital stay, reported as mean ± standard deviation (SD).

Search strategy and study selection process

A comprehensive search of PubMed, Scopus, Scilit, and Web of Science was conducted from database inception to May 29, 2025. The search strategy combined terms related to "subdural hematoma," "burr hole," "single," and "double," together with relevant Medical Subject Headings (MeSH), where the search details are presented in **Table 1**. No language restrictions were applied, and non-English reports were translated using Google Translate when necessary. The reference lists of included studies and relevant reviews were also screened to identify additional eligible articles.

All retrieved records were imported into Rayyan.ai, where duplicates were removed. Two reviewers (FPSW and AMTS) independently and blindly screened the titles and abstracts and subsequently assessed the full texts of potentially eligible articles against the predefined inclusion and exclusion criteria. Disagreements at either stage were resolved through consultation with a third reviewer (SA).

Table 1. Keywords combination for literature searching

Database	Keywords combination	Hits
PubMed	("Chronic Subdural Hematoma" OR "Chronic Subdural Hemorrhage" OR "CSDH" OR "Chronic SDH") AND ("Single Burr Hole Drainage" OR "SBH" OR "Single Burr Hole") AND ("Double Burr Hole Drainage" OR "Double Burr Hole" OR "DBH")	282
Scopus	("Chronic Subdural Hematoma" OR "Chronic Subdural Hemorrhage" OR "CSDH" OR "Chronic SDH") AND ("Single Burr Hole Drainage" OR "SBH" OR "Single Burr Hole") AND ("Double Burr Hole Drainage" OR "Double Burr Hole" OR "DBH")	241
Scilit	("Chronic Subdural Hematoma" OR "Chronic Subdural Hemorrhage" OR "CSDH" OR "Chronic SDH") AND ("Single Burr Hole Drainage" OR "SBH" OR "Single Burr Hole") AND ("Double Burr Hole Drainage" OR "Double Burr Hole" OR "DBH")	318
Web of Science	("Chronic Subdural Hematoma" OR "Chronic Subdural Hemorrhage" OR "CSDH" OR "Chronic SDH") AND ("Single Burr Hole Drainage" OR "SBH" OR "Single Burr Hole") AND ("Double Burr Hole Drainage" OR "Double Burr Hole" OR "DBH")	346

Data extraction

Two reviewers (FPSW and AMTS) independently extracted data on study characteristics (first author, year, country, study design), sample sizes, and mean±SD of hospital stay for both SBH and DBH groups. For studies reporting hospital length of stay as the median with an interquartile range (IQR) or range, the values were converted to the mean and SD using established and validated methods [21]. Discrepancies in the extracted data were resolved by discussion or consultation with a third reviewer (AFM).

Risk of bias assessment

The risk of bias in randomized controlled trials was assessed using the Cochrane Risk of Bias 2 (RoB 2) tool across five domains: the randomization process, deviations from intended interventions, missing outcome data, outcome measurement, and selection of the reported result. Each domain and the overall study were judged as having a low risk of bias, some concerns, or a high risk of bias. The RoB 2 assessments were visualized as traffic-light plots using the robvis tool.

Observational studies were appraised using the Newcastle–Ottawa Scale (NOS), which evaluates study selection, comparability of groups, and ascertainment of exposure or outcome. NOS results were presented in tabular form, with stars (★) indicating the score awarded for each item. Two reviewers (DDCHR and FPSW) independently conducted all assessments, and disagreements were resolved through discussion with a third reviewer (AMTS).

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Statistical analysis

Statistical analysis was performed using RStudio with the "bayesmeta" and "brms" packages. Standardized mean differences, expressed as Hedges' *g*, were calculated for hospital length of stay, with positive values indicating longer stays following SBH than DBH. A Bayesian random-effects meta-analysis model was fitted with the following priors: Normal (0, 0.45) for the pooled effect and Student-t (1, 0, 1) for between-study heterogeneity (τ). Posterior estimates were summarized as means with 95% credible intervals (CrI). Model convergence was assessed using R-hat statistics and visual inspection of trace plots. Robustness of findings was evaluated through leave-one-out (LOO) analyses to examine the influence of individual studies, and Bayes factors were calculated using the Savage–Dickey density ratio to quantify evidence for the null hypothesis (H_0: $\mu=0$).

Results

Study selection

The database search yielded 1,187 records from PubMed, Scopus, Scilit, and Web of Science. After removing 563 duplicates, 624 records remained for title and abstract screening, of which 586 were excluded for not meeting inclusion criteria. Two articles could not be retrieved. A total of 36 full-text articles were assessed for eligibility, of which 28 were excluded because of irrelevant outcomes, inappropriate study design, or ineligible study populations. Ultimately, eight studies met the eligibility criteria and were included in the meta-analysis. The PRISMA flow diagram of study selection is presented in **Figure 1**.

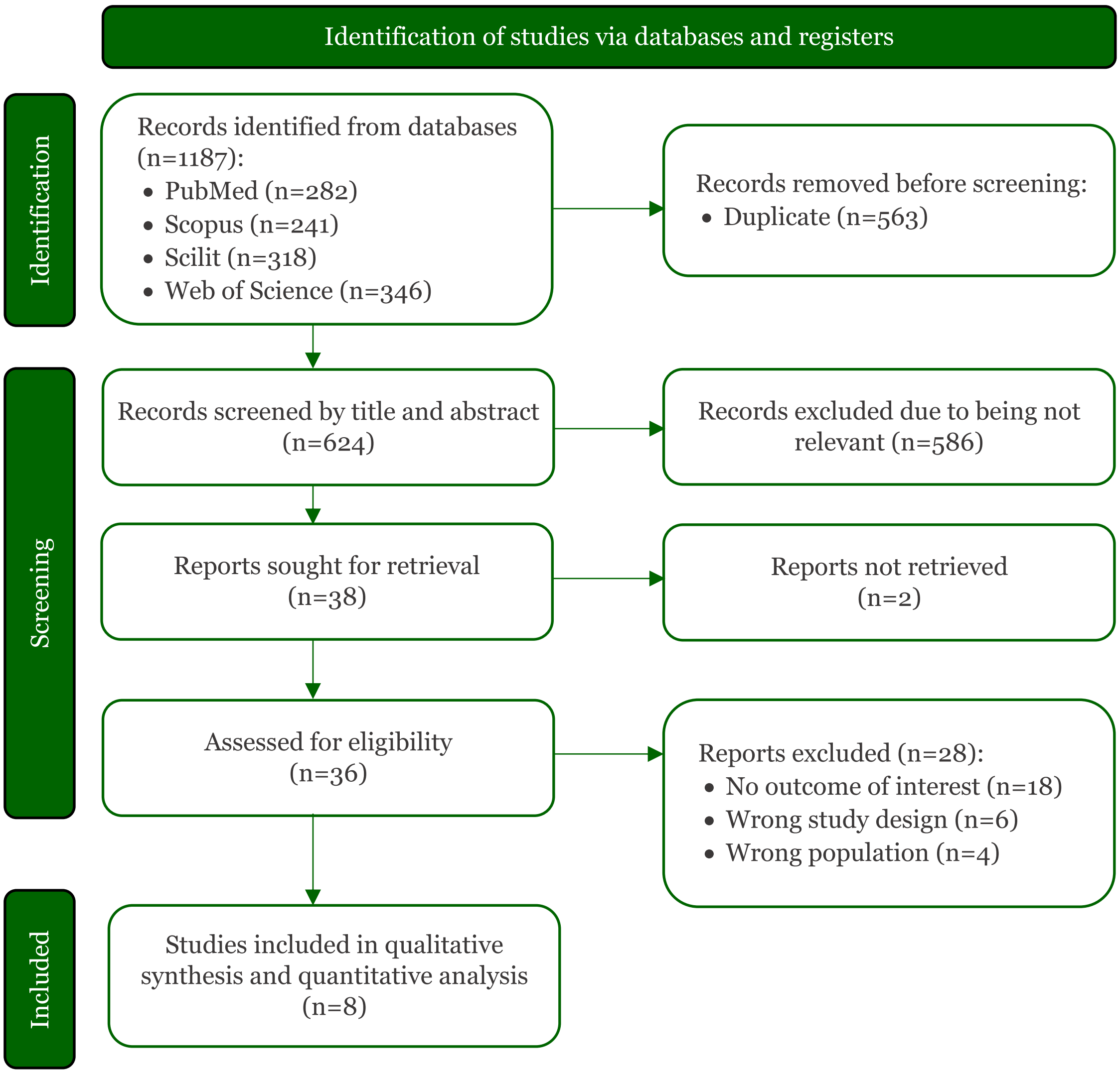

Figure 1. PRISMA flowchart of selection process.

Study characteristics

Eight studies published between 2008 and 2024 were included, encompassing a total of 465 patients. The included studies comprised RCTs as well as prospective and retrospective observational cohorts. Sample sizes ranged from 21 to 97. All studies enrolled patients with SDH, with the minimum age of 54 years. Mean hospital stay was reported separately for SBH and DBH groups in all studies. Key study characteristics are summarized in **Table 2**.

Quality assessment

The result of the quality assessment using RoB 2.0 is presented in **Figure 2**, indicating a low risk of bias. The assessment of observational studies with the NOS is summarized in **Table 3**. The overall risk of bias in most studies were of good methodological quality. However, some methodological concerns were noted. Three studies did not apply multivariate adjustment for relevant covariates. Moreover, one study employed only short-term follow-up, which may have introduced bias in outcome measurement.

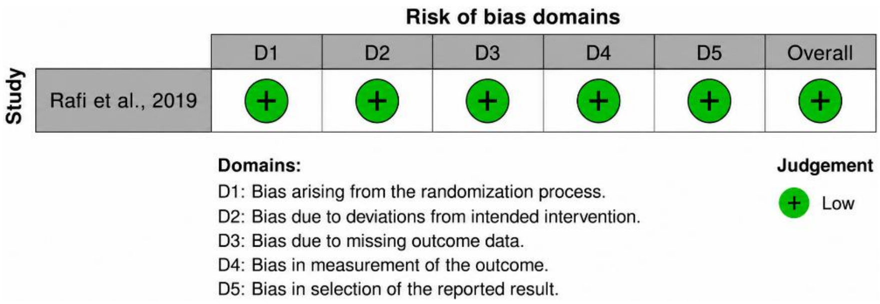

Figure 2. Quality assessment of included RCT study using RoB 2.0.

Pooled analysis

Across all included studies, the Bayesian random-effects model yielded a pooled standardized mean difference (SMD) of −0.02 (95%CrI: −0.47 to 0.39) for SBH compared with DBH, indicating no clinically meaningful difference in hospital stay between the two techniques (**Figure 3**). Between-study heterogeneity was moderate (τ=0.37; 95%CrI: 0.02 to 0.96). The posterior probability that SBH results in longer hospital stay compared with DBH was 0.458, suggesting near-equipoise between the two strategies. Convergence diagnostics demonstrated stable chains with good mixing across all parameters (**Supplementary Figure 1**), supporting the robustness of the Bayesian model.

Across all included studies, the pooled posterior mean was centered near zero, with the posterior density sharply peaked and symmetric, indicating high probability mass around the null effect (**Supplementary Figure 2**). The 95%CrI ranged from −0.47 to 0.39, further supporting the absence of a clinically meaningful difference in hospital stay. The shrinkage plot demonstrates how study-specific posterior means were moderated toward the pooled effect, particularly for smaller or more imprecise studies, reflecting the partial pooling property of the Bayesian hierarchical model (**Figure 4**). Ridgeline density plots of the posterior study-specific effects further illustrated substantial overlap across studies, with most credible intervals spanning zero, reinforcing the lack of consistent difference between SBH and DBH (**Supplementary Figure 3**).

Sensitivity analyses

LOO analyses showed that the pooled estimate and heterogeneity were stable, with posterior mean effects (μ) ranging from −0.09 to 0.07 across omitted studies (**Table 4, Supplementary Figure 4**). This consistency indicates that no single study exerted undue influence on the overall findings, supporting the robustness of the pooled estimate. For instance, omitting *Taussky et al.,* 2008 shifted the pooled mean slightly toward favoring DBH (μ=−0.095), whereas excluding *Atar et al.,* 2023 moved the estimate in the opposite direction toward favoring SBH (μ=0.068). However, in both cases the credible intervals still overlapped zero, underscoring the absence of clinically meaningful differences. The stability of τ across omitted studies further suggests that heterogeneity is not being driven disproportionately by any one dataset, but rather reflects modest variability across the evidence base.

Table 2. Characteristics of included studies

Author, year	Study design	Country	Intervention	Sample size	Female/male	Age	Hospital stay (days)	Type of SDH
Atar *et al.*, 2023 [22]	Retrospective cohort	Turkey	SBH	14	3/11	69.15±12.26	5.28±1.38	Unilateral (14)
			DBH	7	2/5	76.14±9.08	8.57±3.99	Unilateral (7)
Jang *et al.*, 2015 [23]	Retrospective cohort	Korea	SBH	31	13/18	70.00±10.39	13±8.89	NA
			DBH	32	9/23	72.17±7.05	11.5±7.41	
			DBH + irrigation	30	9/21	66.17±15.21	11±3.33	
Lee *et al.*, 2009 [24]	Retrospective cohort	South Korea	SBH + CSD	25	9/16	65.28±14.30	44.88±42.19	NA
			DBH + CSD	32	7/25	65.31±12.12	29.59±33.61	
Nalin *et al.*, 2021 [25]	Prospective cohort	India	SBH + drainage	30	6/24	58.77±14.29	5.67±2.15	Right side
			DBH	30	10/20	57.07±15.02	6.6±2.97	Right side
Omerhodzic *et al.*, 2024 [26]	Retrospective cohort	Turkey	SBH	49	11/38	76.67±10.18	5.85±2.28	NA
			DBH	53	10/43	71.21±12.25	7.64±3.91	NA
Rafi *et al.*, 2018 [27]	Randomized controlled trial	Iran	SBH	35	16/19	54.12±42.2	4.1±98.1	Bilateral (4), Right-side (17), Left-side (14)
			DBH	35	18/17	56.40±13.80	3.2±1.1	Bilateral (3), Right-side (17), Left-side (15)
Taussky *et al.*, 2008 [28]	Retrospective cohort	Switzerland	SBH	34	72/25	70.00±12.60	12±6	Bilateral
			DBH	63		69.00±11.60	9±4	

Data were presented in mean±SD. CSD: Closed Drainage System; DBH: Double Burr Hole; NA: Not Applicable; SBH: Single Burr Hole.

Table 3. Quality assessment of included observational studies using NOS

Author, year	Study design	Selection	Comparability	Outcome	Total	Remark
Atar *et al.*, 2023	Retrospective	★★★★	★	★★★	8	Good
Jang *et al.*, 2015	Retrospective	★★★★	★★	★★★	9	Good
Lee *et al.*, 2009	Retrospective	★★★★	★	★★★	8	Good
Nalin *et al.*, 2021	Prospective	★★★★	★	★★	7	Good
Omerhodzic *et al.*, 2024	Retrospective	★★★★	★★	★★★	9	Good
Taussky *et al.*, 2008	Retrospective	★★★★	★★	★★★	9	Good

Table 4. Leave-one-out sensitivity analysis results

Omitted study	μ (SMD)	τ
Atar *et al.*, 2023	0.068	0.316
Jang *et al.*, 2015	−0.044	0.412
Jang *et al.*, 2015a	−0.060	0.408
Lee *et al.*, 2009	−0.069	0.395
Nalin *et al.*, 2021	0.017	0.398
Omerhodzic *et al.*, 2024	0.051	0.362
Rafi *et al.*, 2018	−0.031	0.416
Taussky *et al.*, 2008	−0.095	0.35

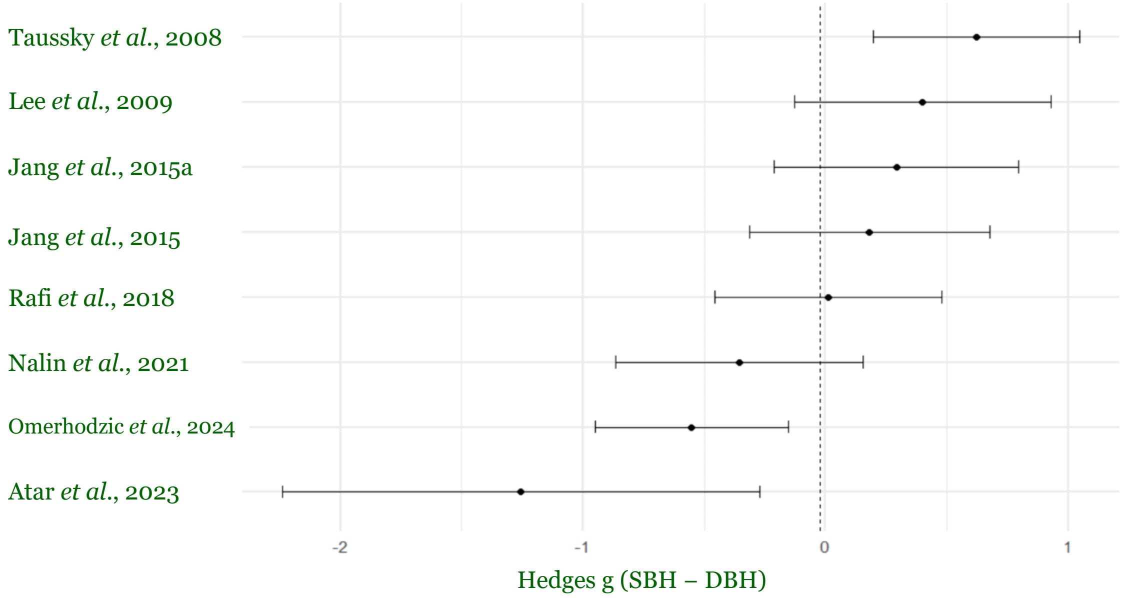

Figure 3. Forest plot of standardized mean differences (Hedges g) in hospital stay between single burr hole (SBH) and double burr hole (DBH) craniostomy for subdural hematoma. Points represent individual study estimates with 95% confidence intervals, while the dashed vertical line indicates the pooled posterior mean from the Bayesian random-effects model. Negative values favor shorter stay with SBH, positive values favor DBH. The pooled posterior mean was −0.02 (95%CrI: −0.47 to 0.39), with between-study heterogeneity τ=0.37. The posterior probability that SBH results in longer hospital stay (Pr(μ >0)) was 0.46.

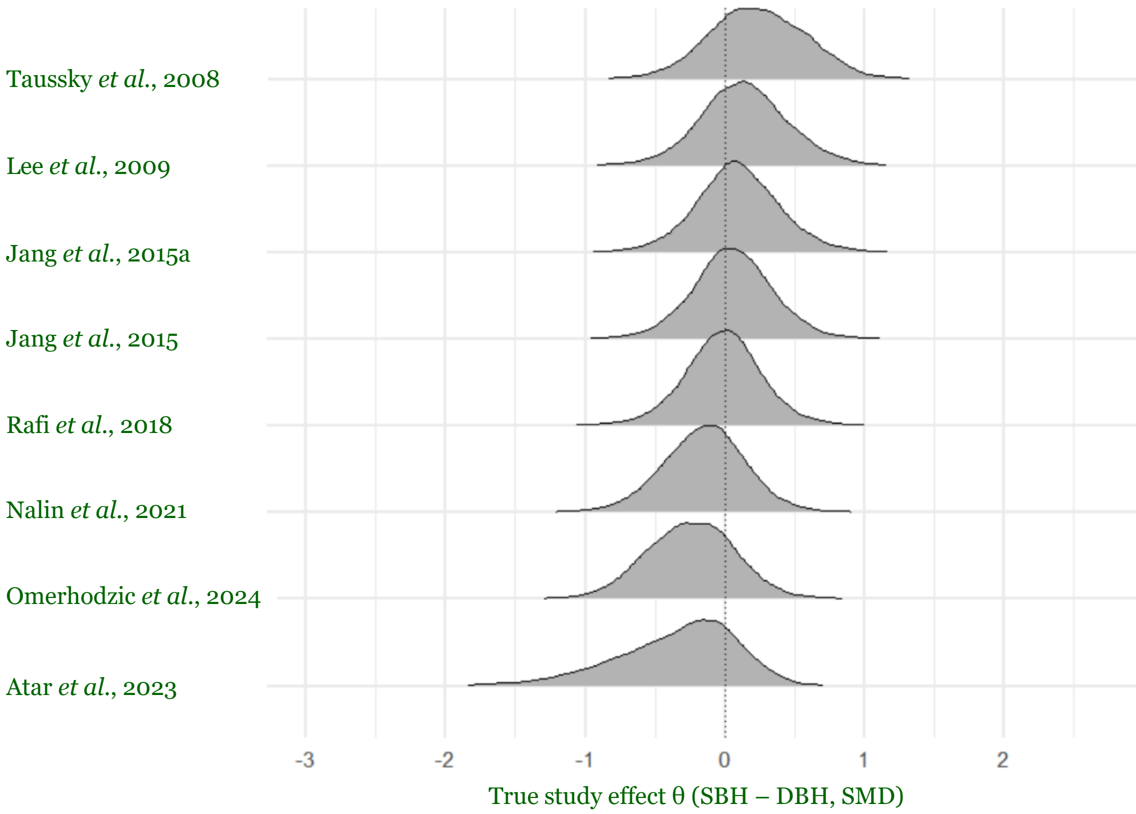

Figure 4. Shrinkage plot comparing observed study estimates (open circles, with 95% CI bars) and posterior study-specific means (solid circles). Smaller or less precise studies are pulled closer to the overall pooled estimate (vertical dotted line at zero), illustrating the effect of hierarchical Bayesian modelling.

Bayes factor analysis using the Savage–Dickey method indicated BF10=0.44 and BF01=2.26, providing weak-to-moderate evidence in favor of the null hypothesis (no difference between SBH and DBH). Taken together, the LOO and Bayes factor findings reinforce the main result that hospital stay does not meaningfully differ between SBH and DBH.

Discussion

This Bayesian pairwise meta-analysis suggests that there is no clinically meaningful difference in hospital stay between SBH and DBH craniostomy for SDH. The pooled standardized mean difference was essentially null (SMD: -0.02; 95%CrI: -0.47 to 0.39), with modest between-study heterogeneity (τ=0.37; 95%CrI: 0.02 to 0.96) and a posterior probability of only 0.46 that SBH results in longer hospitalization. Sensitivity analyses reinforced the stability of this conclusion, where the LOO analysis demonstrated that no individual study materially altered the pooled effect. Similarly, Bayes factor analysis provided weak-to-moderate evidence in favor of the null hypothesis, suggesting the length of hospital stay was not meaningfully influenced by the choice of SBH or DBH. Posterior shrinkage and density plots further highlighted consistency across studies, with most study-specific estimates clustering around the pooled mean. Collectively, these findings suggest that length of hospitalization is unlikely to be a decisive factor when choosing between SBH and DBH.

Findings of the present study are broadly consistent with previous evidence suggesting that the number of burr holes may have limited influence on postoperative hospitalization. A multicenter cohort study from Bosnia and Herzegovina reported a longer hospital stay with DBH than with SBH despite similar recurrence rates [26], whereas an RCT found no significant difference in recurrence between the two techniques, although SBH required less operative time [29]. A 2023 network meta-analysis also suggested that DBH may reduce recurrence relative to some alternative techniques, but did not demonstrate an improvement in hospital stay [11]. In contrast, perioperative factors such as enhanced recovery after surgery protocols, early mobilization, anticoagulant resumption, and drain management may have a greater effect on hospitalization. Likewise, a large randomized trial found that 24-hour drainage shortened neurosurgical-ward stay compared with 48-hour drainage without increasing recurrence [30]. A 2024 ERAS cohort further reported comparable safety and length of stay under a standardized perioperative pathway [31]. Collectively, these findings suggest that hospital stay may be influenced more by perioperative care and drainage strategies than by the use of a single or double burr hole.

Although the present study findings do not indicate a significant difference in hospital length of stay between SBH and DBH, this does not imply that the two techniques are interchangeable in all clinical circumstances. DBH may retain value in selected patients at higher risk of incomplete evacuation or recurrence, including those receiving anticoagulant or antiplatelet therapy and those with septated, mixed-density, or multiloculated hematomas [32,33]. In such cases, the wider operative access provided by DBH may permit more extensive irrigation and removal of residual clots or membranes that may be difficult to address through a single burr hole [23]. Thus, although hospital stay appears comparable between SBH and DBH, DBH may remain advantageous when hematoma morphology or intraoperative findings suggest that more extensive evacuation is required. Surgical decision-making should therefore be guided by patient-specific risk factors, hematoma characteristics, and intraoperative judgment rather than by anticipated hospitalization alone. In practice, SBH may be preferred when technical simplicity and shorter operative time are priorities, whereas DBH remains a reasonable option when wider access and more complete evacuation are considered necessary.

This analysis has several strengths, including the application of a Bayesian framework that provides probabilistic interpretation of the results, incorporation of hierarchical random-effects modeling with partial pooling of smaller studies, and sensitivity analyses confirming stability of the findings. Importantly, the Bayesian approach is particularly advantageous in the context of limited and heterogeneous evidence, as it allows uncertainty to be fully quantified, priors to regularize estimates, and smaller studies to borrow strength from the overall distribution rather than being interpreted in isolation. However, several limitations should be acknowledged. The number of eligible studies was relatively small, with most evidence derived from observational designs, and there was notable heterogeneity in patient characteristics, perioperative management, and discharge practices across centers. Additionally, hospital stay may not be an optimal or clinically decisive endpoint for comparing single versus double burr hole techniques, as it is strongly influenced by non-surgical factors such as institutional discharge policies and postoperative care pathways. Therefore, the lack of a meaningful difference in hospital stay should be interpreted with caution.

Conclusion

The present Bayesian meta-analysis revealed that there was no clinically meaningful difference in the length of hospital stay between patients undergoing SBH and DBH craniostomy for SDH. In contexts where minimally invasive alternatives are limited, both techniques remain appropriate, and SBH can be considered a practical default given its technical simplicity. Surgical decision-making should instead focus on recurrence prevention, patient characteristics, and surgeon expertise.

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Competing interests

All the authors declare that there are no conflicts of interest.

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Underlying data

All data supporting the findings of this study are included in this article. All supplementary data are available at https://doi.org/10.6084/m9.figshare.31858054.

Declaration of artificial intelligence use

This study used the artificial intelligence (AI) tool ChatGPT for technical writing assistance, including suggestions for grammatical correction and accurate expression. We confirm that all AI-assisted content was critically reviewed by the authors to ensure the integrity and reliability of the manuscript. The final decisions and interpretations presented in this article were made solely by the authors.

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