Research Paper

Endoscope-Assisted Versus Burr-Hole Craniotomy for Chronic Subdural Hematoma: A Scoping Review of Clinical Evidence and Knowledge Gaps

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ABSTRACT

Objectives

Chronic subdural hematoma (CSDH) is a common neurosurgical condition, especially in older people, with a rising incidence. This study aimed to assess and map the existing evidence comparing endoscope-assisted surgery with burr-hole craniotomy for CSDH and to identify knowledge gaps to inform future research priorities.

Methods

In accordance with the PRISMA Extension for Scoping Reviews (PRISMA-ScR) guidelines, we performed extensive search of literature across PubMed, Scopus, WOS, Cochrane CENTRAL, EMBASE, CNKI, and LILACS databases from January 1, 2020, to December 31, 2025. Eligible studies included those comparing endoscope-assisted surgery with BHC in adult patients with CSDH, regardless of study design.

Results

From 1,847 records screened, 7 comparative studies involving 910 patients (325 endoscope-assisted, 585 BHC) were mapped. Studies published between 2020 and 2025 originated mainly in China (4 studies), with one study from India, Japan, and Taiwan. Six were retrospective, and one was prospective. Sample sizes ranged from 35 to 270, with follow-up of 6-12 months. Evidence indicates that endoscope-assisted surgery results in lower recurrence rates (0–12.5% compared to 0–23.0%), fewer complications (0–4.4% versus 5.0–30.0%), shorter drainage durations (18.7–55.9 hours versus 55.9–72.0 hours), and reduced hospital stays (4.5–6.0 days compared to 7.0–8.2 days). However, it involves longer operative times (95.2–128.5 minutes versus 50.8–71.4 minutes). The advantages appear most pronounced in complex CSDH cases with septations or mixed-density types.

Conclusions

This review suggests that endoscope-assisted surgery may be more effective than traditional BHC for CSDH, especially in complicated cases. While the data indicate lower recurrence and complication rates, significant gaps exist in patient selection, standardized protocols, long-term outcomes, and cost-effectiveness. This review highlights current evidence and key priorities: multicenter RCTs, uniform surgical procedures, economic studies, and inclusion of diverse populations to enhance minimally invasive CSDH treatment management.

Keywords: Chronic subdural hematoma; Neuroendoscopy; Burr-hole craniotomy; Scoping review; Surgical outcomes.

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Introduction

Chronic subdural hematoma (CSDH) is defined as an encapsulated collection of blood and blood degradation products between the dura mater and arachnoid membrane, typically manifesting three or more weeks after initial cranial trauma. The condition represents one of the most common neurosurgical pathologies, with an incidence ranging from 8.2 to 17.6 per 100,000 persons per year in the general population, increasing substantially to 46.9–129.5 per 100,000 in individuals aged ≥80 years [1, 2]. Global demographic shifts toward aging populations and increasing use of antithrombotic agents are projected to escalate the clinical burden of CSDH in the coming decades [1, 3], following trauma that tears bridging veins, neomembranes form, containing fragile vessels prone to microhemorrhages. Hyperfibrinolysis within the hematoma leads to fluid accumulation and expansion. In some cases, fibrous septations create separate compartments, complicating surgical evacuation [4, 5].

Current Treatment Landscape

Surgical evacuation is the definitive treatment for symptomatic CSDH. Burr-hole craniotomy (BHC) with closed-system drainage is widely used due to its simplicity, shorter operative time, and suitability for local anesthesia use [6, 7]. However, BHC lacks direct intracavitary visualization, risking incomplete drainage, poor drain placement, and inadequate hemostasis, which may contribute to recurrence rates of 5–33%. While craniotomy offers better visualization, it is associated with greater surgical trauma, longer operative duration, and increased complications, which limit its use in elderly or comorbid patients, highlighting the need for minimally invasive techniques that incorporate direct endoscopic visualization [6-8].

Emergence of Endoscopic Techniques

Neuroendoscopic techniques have advanced considerably over the last twenty years, driven by improvements in optics, illumination, and instrument miniaturization, allowing their use in CSDH surgery [9, 10]. Endoscope-assisted surgery for CSDH involves performing a standard burr hole or small craniotomy, then introducing a rigid or flexible endoscope into the hematoma cavity to permit direct visualization of the entire space, identification and lysis of fibrous septations, evacuation of organized clots, electrocoagulation of bleeding vessels, and guided placement of drainage catheters [10–12]. Previous research indicates that endoscope-assisted methods may decrease recurrence rates and enhance outcomes, particularly in complicated CSDHs. Nonetheless, this approach demands specialized equipment, longer surgery times, and higher levels of surgical skill compared to standard BHC [12, 13]. Important questions remain about overall efficacy, safety, cost-effectiveness, and optimal patient selection.

Rationale for the Present Scoping Review:

Recent systematic reviews and meta-analyses have synthesized quantitative evidence on endoscope-assisted CSDH surgery [12, 13]. Liu et al.'s 2024 meta-analysis of 20 studies found endoscopic approaches significantly reduced recurrence (OR 0.27, 95% CI 0.18–0.38) and complications (OR 0.48, 95% CI 0.30–0.78). However, these reviews mainly focused on pooled effect estimates without exploring the broader scope of the evidence, identifying gaps, or delineating future research directions.

The main goal of our scoping review was to systematically map and analyze the body of evidence comparing endoscope-assisted surgery with burr-hole craniotomy for chronic subdural hematoma in adults. Specific objectives included identifying and describing recent comparative studies published in the last 5 years; charting their features, such as design, sample size, geographic origin, and detailing intervention, e.g., endoscopic methods, equipment, and procedural variations. Additionally, we aimed to compile outcomes such as recurrence, complications, operative metrics, and functional results, and to highlight research gaps and underserved areas to establish evidence-based priorities to guide future clinical research in this area.

Materials and Methods

Scoping Review Framework

This scoping review was conducted according to the framework proposed by Arksey and O'Malley [14] and adhered to the PRISMA Extension for Scoping Reviews (PRISMA-ScR) checklist [15]. The review followed five stages: defining the question, identifying and selecting studies, charting data, and reporting results. No protocol was pre-registered, which is typical for scoping reviews. Since it focused on evidence mapping over quality assessment, no critical appraisal of the included studies was conducted.

Research Question

This review focused on the extent and nature of evidence comparing endoscope-assisted surgery to BHC for CSDH in adults. It also examined study designs, locations, patient groups, techniques, outcomes, and identified gaps in evidence.

Eligibility Criteria

Adult patients ≥18 years with radiologically confirmed CSDH requiring surgery were included, regardless of hematoma side, density, or presence of septations. Studies comparing endoscope-assisted surgery—using rigid or flexible neuroendoscopy—

with standard BHC performed without endoscopy were eligible, from any setting, region, or healthcare system. All primary comparative study designs were accepted.

We excluded single-arm case series, case reports, systematic reviews, meta-analyses, narrative reviews, editorials, and conference abstracts without full-text access. The search was restricted to studies published from January 1, 2020, to December 31, 2025, with no language restrictions applied; non-English publications were considered for translation as feasible.

Information Sources and Search Strategy

A comprehensive literature search was performed across PubMed/MEDLINE, Scopus, Web of Science Core Collection, Cochrane Central Register of Controlled Trials (CENTRAL), EMBASE, China National Knowledge Infrastructure (CNKI), and Literatura Latino-Americana e do Caribe em Ciências da Saúde (LILACS).

The search strategy was developed collaboratively by the research team and a medical librarian, combining controlled vocabulary (MeSH terms, Emtree, DeCS) with free-text keywords. The core structure employed was: (chronic subdural hematoma OR CSDH OR subdural haematoma OR subdural effusion) AND (endoscop OR neuroendoscop OR endoscope-assisted OR endoscopic) AND (burr hole OR burr-hole OR trepanation OR craniotomy OR drainage). To enhance search sensitivity, we supplemented the database search by manually reviewing reference lists from all included articles, tracking forward citations via Google Scholar, and contacting corresponding authors for clarification or additional unpublished data when required.

Selection Process

All citations were imported into EndNote 20 for management and duplicate removal. Titles and abstracts were independently screened by two authors against eligibility criteria. Potentially relevant articles were then assessed for full text independently by the same reviewers. Discrepancies were resolved through discussion and, if needed, by a third reviewer. Inter-reviewer agreement was quantified using Cohen's kappa statistic. Reasons for exclusion at the full-text stage were documented systematically and reported in the PRISMA-ScR flow diagram (Figure 1).

Data Charting Process

Data extraction was performed independently by two reviewers using standardized electronic forms developed specifically for this review and piloted on a subset of 7 studies. Discrepancies were resolved through discussion.

Charted Variables:

The charted variables included study characteristics such as first author, publication year, country, study design, total sample size, group-specific sample size, study period, duration of follow-up, funding source, and declarations of conflict of interest. Patient data included age, sex, hematoma characteristics, neurological status, comorbidities, and medication use. Intervention variables covered endoscope type, angle, diameter, anesthesia, burr-hole size and number, septum lysis, irrigation, drainage setup, and duration. Comparators involved burr hole count, irrigation, and drainage type. Outcomes measured were recurrence, complications, operative time, drainage duration, hospital stay, hematoma evacuation success, brain re-expansion, mortality, and functional status via Glasgow Outcome Scale, Modified Rankin Scale, and Glasgow Coma Scale follow-up.

Data Synthesis and Presentation

Following scoping review methodology, no formal critical appraisal or risk of bias assessment was performed. Results were summarized descriptively through numerical data: categorical variables shown as frequencies and percentages, and continuous variables as ranges. Data were also organized into tables to highlight study features, patient groups, interventions, controls, and outcomes in a structured way. The visual presentation included a PRISMA-ScR flow diagram to show the study selection process, along with graphical representations of the evidence's temporal and geographic distribution. In addition, a narrative synthesis was undertaken to describe the principal findings, identify recurring patterns, and highlight important gaps in the literature. No meta-analysis or statistical pooling was performed, and where outcomes were reported across multiple studies, ranges of reported effect estimates were presented to reflect the breadth and heterogeneity of the available evidence.

Results

Study Selection

The database search retrieved 1,847 records; after removing 558 duplicates, 1,289 unique records were screened. Of these, 1,214 were deemed irrelevant based on title and abstract, leaving 75 for full-text review. 68 were excluded: 32 were single-arm studies or systematic reviews, 26 involved different interventions, and 10 focused on pediatric or acute subdural hematoma cases. Ultimately, 7 studies (see Table 1) met all criteria and were included in this scoping review. Inter-rater agreement at title/abstract screening was $\kappa = 0.82$, and at full-text screening was $\kappa = 0.89$, indicating excellent agreement. The complete study selection process is illustrated in Figure 1 (PRISMA-ScR flow diagram).

Study Characteristics

The seven included studies were published between 2020 and 2025, with all appearing after 2020. Geographically, studies were mainly conducted in

China (n=4, 57.1%), with single contributions from India (n=1, 14.3%), Japan (n=1, 14.3%), and Taiwan (n=1, 14.3%).

Study Designs:

Six studies (85.7%) used retrospective cohort designs [10, 16-19, 21], and one study (14.3%) was prospective [20]. No randomized controlled trials or quasi-experimental studies were identified.

Sample Sizes:

The total sample across all studies comprised 910 patients: 325 in the endoscope-assisted groups and 585 in the BHC groups. Individual study sample sizes ranged from 35 to 270 patients. The median sample size was 124 patients (IQR: 83–225).

Follow-up Duration:

All studies reported follow-up ranging from 6 to 12 months postoperatively. No studies reported outcomes beyond 12 months.

Patients' Characteristics

Age and Sex Distribution:

Mean patient age ranged from 60.3 to 77.1 years, consistent with an elderly population diagnosed with CSDH. Most patients were male (60-78%), aligning with the known epidemiology of CSDH.

Hematoma Characteristics

Unilateral hematomas were the most common presentation, with bilateral cases accounting for 12% to 28% of patients. Regarding CT density, mixed-density hematomas were specifically examined in three studies [17, 20, 21], while the others involved heterogeneous densities. Septations were reported in five studies (71.4%) [10, 16, 17, 19, 21]. In terms of comorbidities and medications, anticoagulant or antiplatelet use was documented in 18% to 45% of patients. Hypertension was the most frequent comorbidity, affecting 40% to 68% of the cohort, followed by diabetes and cardiovascular disease, each present in 15% to 28% of cases.

Intervention Characteristics

Rigid endoscopes were used in five studies (71.4%) [10, 16, 17, 18, 21], with diameters from 2.7 to 4.0 mm and angles of 0°, 30°, or 45°. Flexible endoscopes were used exclusively or in combination in the remaining two studies (28.6%) [19, 21]. Technical variations included meticulous membranectomy using arachnoid knives, as described by Hong et al. [18], S-shaped curved aspirators employed by Wang et al. [20], and flask-shaped bone windows used by Deng et al. [19] to facilitate endoscope angulation. General anesthesia was administered in all reported endoscopy cases, whereas local anesthesia was occasionally used for BHC in control groups. Burr-hole diameters for endoscopy ranged from 2.0 to 4.5 cm, while control groups used single or double burr holes. All studies used closed subdural drainage systems postoperatively, with drainage duration systematically reported in five studies.

Outcomes Reported

Primary Outcome: Recurrence Rate

All seven studies reported recurrence rates as a primary or secondary outcome, with definitions generally including symptomatic re-accumulation requiring reoperation within the follow-up period. For endoscope-assisted surgery, recurrence rates ranged from 0% to 12.5%. Hong et al. [18] and Deng et al. [19] both reported 0% recurrence, while Wang et al. [20] and Zhang et al. [17] reported rates of 1.6% and 2.4%, respectively. Amano et al. [16] observed a 6.5% rate in complicated CSDH, and An et al. [21] reported 12.5%. In comparison, recurrence rates for BHC ranged from 0% to 23.0%. Deng et al. [19] reported 0%, while Hong et al. [18], Wang et al. [20], and An et al. [21] reported 6.5%, 8.2%, and 10.3%, respectively. Higher rates were found by Zhang et al. [17] at 16.9% and Amano et al. [16] at 23.0% in complicated CSDH. Subgroup analysis by Amano et al. [16] showed significant benefits in complicated CSDH, with recurrence rates dropping from 23.0% to 6.5% ($p=0.010$), though no difference was seen in simple CSDH. Zhang et al. [17] specifically evaluated mixed-density hematomas, reporting 2.4% recurrence with endoscopy versus 16.9% with BHC ($p=0.026$).

Secondary Outcome: Complications

Six studies provided detailed complication data, covering intracranial rebleeding, infection, pneumocephalus, seizures, and residual hematoma. Complication rates for endoscope-assisted surgery ranged from 0% to 4.4%. Multiple studies reported 0% for specific complications, such as intracranial hematoma in Wang et al. [20], while Deng et al. [19] reported an overall complication rate of 4.35%. Conversely, Burr-Hole Craniotomy complication rates ranged from 5.0% to 30.0%. Wang et al. [20] noted 5% intracranial hematomas in the BHC group compared to 0% in the endoscopy group, and Deng et al. [19] reported a complication rate of 15.0% in the craniotomy group.

Secondary Outcome: Operative Time

Four studies reported operative time [17, 18, 20, 21]. Mean operative times for endoscope-assisted surgery ranged from 95.2 to 128.5 minutes. Zhang et al. [17] recorded 95.2 ± 24.1 minutes, An et al. [21] recorded 103.6 ± 20.9 minutes, and Hong et al. [18] recorded the longest time at 128.5 ± 49.6 minutes, attributed to meticulous membranectomy. Conventional BHC was consistently faster, with mean times ranging from 50.8 to 71.4 minutes. An et al. [21] reported 50.8 ± 12.4 minutes for a two-burr-hole technique, Hong et al. [18] reported 65.2 ± 32.9 minutes, and Zhang et al. [17] reported 71.4 ± 18.9 minutes. All studies reporting this

outcome found statistically significant differences favoring shorter times with conventional BHC.

Secondary Outcome: Drainage Duration

Postoperative drainage duration was reported in four studies [17, 19, 20, 21]. For endoscope-assisted surgery, durations ranged from 18.7 to 55.9 hours, with An et al. [21] reporting the shortest duration at 18.7 ± 5.9 hours. BHC durations ranged from 55.9 to 72.0 hours, with An et al. [21] reporting 55.9 ± 23.0 hours. Studies consistently reported significantly shorter drainage durations with endoscopic approaches (all $p<0.001$ where tested).

Secondary Outcome: Hospital Length of Stay

Five studies reported hospital length of stay [16, 17, 19-21]. For endoscope-assisted surgery, stays ranged from 4.5 to 6.0 days in most studies. Deng et al. [19] reported 5.3 ± 1.9 days, Zhang et al. [17] reported 5.7 ± 2.0 days, and An et al. [21] reported 6.0 ± 1.7 days, noting the longer stay was due to case complexity. BHC stays ranged from 4.7 to 8.2 days. An et al. [21] reported 4.7 ± 1.8 days for their two-burr-hole control group, while Zhang et al. [17] and Deng et al. [19] reported 7.3 ± 2.2 days and 8.2 ± 1.0 days, respectively.

Secondary Outcome: Hematoma Evacuation and Brain Re-expansion

Two studies provided quantitative data on evacuation efficiency. Zhang et al. [17] reported 3D volumetric evacuation rates of 87.3 ± 8.6% for endoscopy versus 76.8 ± 12.4% for BHC ($p=0.009$). Wang et al. [20] found 61% complete brain re-expansion at 3 days postoperatively for endoscopy compared to 36% for BHC ($p<0.05$).

Secondary Outcome: Mortality

Four studies (57.1%) reported mortality data [18-21]. Individual study mortality rates ranged from 0% to 4.35% across both groups. No study found statistically significant differences in mortality between endoscope-assisted and BHC groups.

Secondary Outcome: Functional Outcomes

Two studies (28.6%) reported long-term functional outcomes using the Modified Rankin Scale (mRS) at 6-month follow-up [16, 19]. Deng et al. [19] found 100% of patients achieved mRS 0–2 (functionally independent) in both groups. No significant differences were observed between techniques in studies reporting this outcome.

Additional Findings

Patient Selection Considerations: Five studies (71.4%) identified specific patient subgroups that could benefit most from endoscopy, including septated hematomas, mixed-density collections, organized clots, and recurrent cases following previous BHC [17-21]. Yadav et al. [10] observed that 51% of their endoscopy patients had solid clots, septations, or bridging vessels that posed challenges for management with conventional BHC.

Technical Innovations: Studies described various technical refinements, including specialized bone window configurations, curved aspirators for accessing difficult areas, and systematic approaches to septum lysis and membrane removal [10, 16, 18].

Learning Curve Considerations: Two studies (28.6%) discussed the learning curve for endoscopic techniques, noting that operative times may decrease with experience and that standardized training is essential [17, 18].

Knowledge Gaps Identified

This scoping review emphasizes a limited evidence base, characterized by the lack of randomized trials, dependence on observational studies, and concentration of data originating from Asian populations, which limits generalizability. Important gaps also include short follow-up durations, lack of cost-effectiveness analyses, inconsistent surgical techniques, and the absence of validated criteria to guide patient selection for endoscopic treatment. In addition, key groups such as pediatric or very old patients, those with major comorbidities or anticoagulant use, and patients with simpler hematoma patterns remain underrepresented. At the same time, quality-of-life outcomes, training requirements, implementation issues, and standardized safety reporting have been insufficiently addressed.

Discussion:

This scoping review included 7 comparative studies with 910 patients, comparing endoscope-assisted surgery to BHC for CSDH. Published between 2020 and 2025, all studies were from Asian countries (100%) and mostly used retrospective cohort designs (85.7%). The evidence mapping showed consistent results favoring endoscope-assisted methods, especially for complex CSDH presentations.

Across the reviewed studies, endoscope-assisted surgery was linked to lower recurrence rates (ranges 0–12.5% compared to 0–23.0% for BHC), fewer complications (0–4.4% versus 5.0–30.0%), and shorter postoperative drainage durations. (18.7–55.9 hours vs. 55.9–72.0 hours), and generally shorter hospital stays (4.5–6.0 days vs. 4.7–8.2 days). However, these benefits came at the cost of longer operative times (95.2–128.5 minutes vs. 50.8–71.4 minutes). No differences in mortality or long-term functional outcomes were apparent, though reporting of these outcomes was limited.

Relationship with Prior Syntheses

Our scoping review expands on prior systematic reviews by mapping evidence rather than focusing solely on quantitative synthesis [12, 13]. Liu et al.'s [12] meta-analysis of 20 studies (898 endoscope-assisted vs. 1,448 BHC patients) showed significant

reductions in recurrence (OR 0.27, 95% CI 0.18–0.38), complications (OR 0.48, 95% CI 0.30–0.78), and hospital stay. Guo et al.'s [13] analysis of 441 patients found similar benefits. Of our 7 articles, 5 overlapped with Liu et al., covering about 70% of patients, but our review includes 2 post-2023 studies [20, 21], offering recent data and advances [17]. Unlike Liu et al., who pooled diverse populations without detailed subtype analysis, our review mapped evidence, identified geographic trends, and highlighted gaps, including the lack of RCTs and focus on Asian populations.

This scoping review complements rather than replicates prior meta-analyses. While Liu et al. answered, "Does endoscopy reduce recurrence?" (conclusion: yes), we focus on "What is the full scope of evidence, where does it come from, what gaps exist, and what research is needed?", a different and equally valuable contribution.

Mechanistic Insights

The consistent reduction in recurrence across studies may be attributed to the endoscopic visualization advantages. It enables direct inspection to identify and remove fibrous septations that could otherwise block complete drainage in BHC, preventing residual hematoma [16, 18]. It also allows thorough removal of clots and trabeculae, eliminating inflammatory components that could cause further hematoma growth. Thirdly, active bleeding sites can be cauterized under direct sight prior to drain placement. Lastly, drainage catheters can be accurately positioned under visual guidance, preventing parenchymal penetration.

The shorter drainage duration and hospital stay probably indicate more thorough initial hematoma removal, which decreases the need for extended postoperative drainage. Conversely, longer operative times represent the trade-off for meticulous inspection, septum lysis, and hemostasis. This time investment seems justified by a significant decrease in recurrence rates, which reduces the need for reoperation. Reoperation involves additional operative time, anesthetic risks, and patient burden.

Clinical Implications and Patient Selection

Evidence suggests endoscope-assisted surgery benefits specific CSDH types, such as septated, mixed-density, organized, recurrent, bilateral, and potentially younger patients, especially when recurrence risk is high. Traditional BHC still suits homogeneous, hypodense hematomas in elderly or resource-limited settings. A major gap is the absence of validated patient selection algorithms considering imaging features like septation, density, volume, and location.

A major limitation is that all evidence originates from Asia (100%), with China accounting for 57.1% of studies. This raises questions about applicability to other healthcare systems with different reimbursement, resources, and infrastructure, and about potential variations in ethnic groups, anatomy, treatment response, and clinical practices. The lack of randomized controlled trials is problematic, as all seven studies are observational, risking selection bias and unmeasured confounding. Although one used propensity score matching, RCTs remain the gold standard. Most studies are retrospective (85.7%), limiting confidence due to issues like incomplete reporting and residual confounding.

Recurrence was reported in all studies, but definitions varied; some considered reoperation necessary, others included radiographic progression without intervention. Follow-up periods ranged from 6 to 12 months, with inconsistent complication classifications. This diversity hinders quantitative analysis and highlights the need for standardized core outcome sets in CSDH research to improve evidence synthesis. Notably, no studies conducted cost-effectiveness analyses despite longer operative times with endoscopic approaches, a gap given the importance of economic evaluations in healthcare decision-making. Patient-centered outcomes like quality of life were rarely reported, with only two of seven studies addressing this, limiting understanding of recovery and functional outcomes from the patient's perspective.

Technical variation among studies includes different endoscopes, dissection methods, and setups, complicating outcome assessment. Consensus guidelines are needed for standardization to improve reproducibility, training, and comparison of results across future research.

This scoping review used a rigorous methodology aligned with established frameworks [14, 15], including a comprehensive search across seven databases, regional sources, and no language restrictions to capture global evidence. It covers literature up to December 2025, follows PRISMA-ScR guidelines, involves duplicate screening with high agreement, uses broad eligibility criteria, extracts data across multiple domains, and identifies knowledge gaps for future research. Unlike systematic reviews, it did not conduct formal quality assessments, focusing instead on mapping the evidence landscape—characterizing scope, distribution, and gaps rather than estimating pooled effect sizes.

Limitations

This scoping review has certain limitations that must be acknowledged. It did not include a formal quality appraisal or risk-of-bias assessment, consistent with scoping methodology, which means the findings

should be interpreted with caution due to the observational nature of the studies included. There is also a potential publication bias, as studies with negative or neutral results from centers with less favorable endoscopy experiences might be underreported. Additionally, non-English studies might have been missed despite no formal language restrictions. The review excluded gray literature like conference abstracts and unpublished data, and it did not statistically quantify heterogeneity. The concentration of publications from 2020–2025 limits assessment of long-term trends. There may be interpretation bias from single-reviewer data synthesis despite independent dual-reviewer charting. Also, secondary analyses were excluded, which could limit contextual understanding.

Based on these gaps, future research should focus on immediate priorities within 1–3 years, such as multicenter randomized controlled trials comparing endoscope-assisted surgery with BHC in patients with septated or mixed-density CSDH, including 12-month follow-up and blinded outcome assessments. Developing international consensus on technical standards through Delphi processes and establishing prospective registries for long-term outcomes are also critical. Medium-term goals (3–5 years) include creating validated patient selection algorithms using clinical and imaging features, conducting comprehensive cost-effectiveness analyses across different healthcare systems, studying non-Asian populations to evaluate generalizability, and developing structured training curricula with clear competency milestones. Long-term objectives (5–10 years) involve comparative effectiveness research in underrepresented populations, exploring predictive biomarkers, and evaluating new technologies like 3D endoscopes and augmented reality navigation.

Despite these knowledge gaps, current evidence offers initial guidance for stakeholders: clinicians should consider endoscope-assisted surgery for complex CSDH with septations or mixed densities, balancing benefits with longer operative times and equipment needs, while conventional BHC remains suitable for simple hematomas in elderly patients. Researchers need to focus on high-quality RCTs, standardized outcomes, long-term follow-up, and diverse populations. Institutions should implement structured training programs, invest in necessary equipment, monitor outcomes, and adopt new techniques gradually with mentorship to address learning curves. Policymakers should support the use of endoscopy in suitable settings for complicated CSDH, develop reimbursement policies that account for longer procedures when outcomes justify it, and fund research on RCTs, registries, and cost-effectiveness studies to improve evidence-based minimally invasive treatment management.

Conclusions

This review suggests that endoscope-assisted surgery may be a preferable alternative to traditional BHC for CSDH, especially in complex cases. It shows lower recurrence and complication rates with endoscopic techniques, but highlights gaps like patient selection, standard protocols, long-term outcomes, and cost-effectiveness. Current evidence includes seven studies with 910 patients (2020-2025), showing fewer recurrences, complications, shorter drainage, and hospital stays, though operative times are longer. Major gaps include no randomized trials, limited populations, lack of long-term and cost data, and technical variability. These limit recommendations and set research priorities: multicenter trials, standardization, long-term registries, selection algorithms, and economic analyses, to define endoscope-assisted surgery's role in CSDH. As neuroendoscopy advances, these approaches could shift from blind drainage to precise, visualization-guided interventions, but addressing evidence gaps through rigorous global research is essential.

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Data Availability Statement: All data charted during this scoping review are presented within the manuscript and tables. Additional details are available from the corresponding author upon reasonable request.

Author Contributions

UME, AKA, IHA, SSNA, OMB, MDA, and KS conceptualized and designed the scoping review. SHA and SSA conducted the literature search, screening, and data charting. SKA, LSA, and RAA contributed to data interpretation and evidence mapping. AKA, IHA, SSNA, OMB, MDA, and KS participated in manuscript drafting and critical revision. KS and UME supervised the project and provided methodological expertise. All authors reviewed and approved the final manuscript and agreed to be accountable for all aspects of the work.

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Figure (1): PRISMA-ScR Flow Diagram of Study Selection

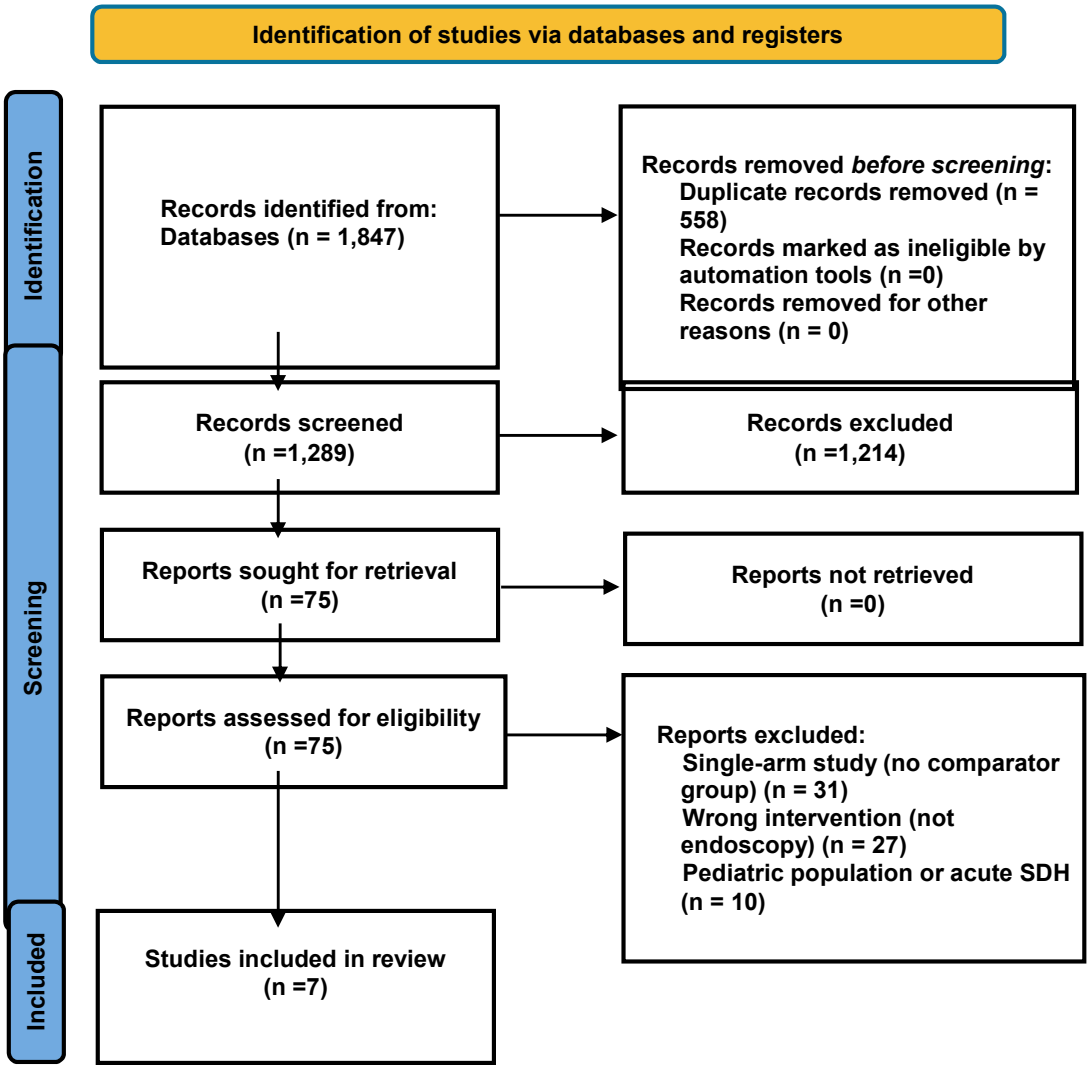

Table (1): Baseline Demographic and Clinical Characteristics of Included Studies

Study	*Country*	*Design & Sample*	*Intervention/ Exposure*	*Main Outcome Findings*	*Key Conclusion*
Yadav et al. 2020 [10]	India	Retrospective case series with comparative analysis; N=35 (endoscopy cohort); Inclusion: CSDH with solid clots, septations, bridging vessels	Endoscopic management using brain retractor and flexible/rigid scope vs historical BHC controls	Complete hematoma removal: 51% required endoscope; Organized clots: 17 cases; Septations: 2 cases; Bridging vessels: 2 cases; Visualization superior to conventional approach	Endoscopes are very effective for CSDH with solid clots, septations, and bridging vessels; they avoid the need for a brain retractor in 27% of cases.
Amano et al. 2021 [16]	Japan	Retrospective cohort with propensity score matching; N=270 total (135 matched pairs); Inclusion: complicated CSDH	Endoscopic treatment (various techniques) vs standard BHC	Recurrence in complicated CSDH: 6.5% (9/139) vs 23.0% (31/131); p=0.010; Reoperation: 0% vs 9.7%; p=0.027; No difference in simple CSDH; PSM analysis-controlled confounding	Endoscopic treatment significantly reduced rebleeding and reoperation in patients with complicated CSDH; a propensity score analysis strengthened the evidence.
Zhang et al. 2022 [17]	China	Retrospective cohort; N=124 (41 endoscopy, 83 BHC); Inclusion: mixed-density CSDH on CT	Rigid neuroendoscopy-assisted resection vs traditional BHC	Recurrence: 2.4% (1/41) vs 16.9% (14/83); p=0.026; Operation time: 95.20 ± 24.13 min vs 71.36 ± 18.92 min; p<0.001; Evacuation rate: 87.3% vs 76.8	Rigid neuroendoscopy reduced recurrence, improved evacuation, and shortened hospitalisation for mixed-density CSDH

				%; p=0.009; Hospital stay: 5.71 ± 2.04 d vs 7.33 ± 2.18 d; p<0.001	
Deng et al. 2022 [19]	China	Retrospective cohort; N=43 (23 endoscopy, 20 craniotomy); Inclusion: septated CSDH confirmed on imaging	Neuroendoscopic treatment via C-shaped frontal incision vs standard large bone flap craniotomy	Recurrence: 0% (0/23) vs 0% (0/20); p=1.000; Total hospital stay: 5.26 ± 1.89 d vs 8.15 ± 1.04 d; p<0.001; Postoperative stay: 4.47 ± 1.95 d vs 7.96 ± 0.97 d; p<0.001; Complications: 4.35 % vs 15.0 %; p>0.05	Neuroendoscopic treatment is safe and effective for septated CSDH; minimally invasive with a shorter stay than craniotomy.
Hong et al. 2022 [18]	Taiwan	Retrospective cohort; N=229 (13 endoscopy, 216 non-endoscopy); Inclusion: CSDH with organized clots/compartmentation	Endoscope-assisted membranectomy (0° and 30°, 2.7 mm endoscope) vs standard BHC-D	Recurrence: 0% (0/13) vs 6.5% (14/216); p<0.05; Operation time: 128.53 ± 49.56 min vs 65.18 ± 32.89 min; p<0.001; No difference in age, sex, BMI, comorbidities, anticoagulation	Endoscope-assisted membranectomy eliminated recurrence despite longer operative time; effective for complicated CSDH.
Wang et al. 2022 [20]	China	Prospective cohort; N=122 (61 endoscopy, 61 BHC); Inclusion: CSDH requiring surgery, age 30–85 years	Neuroendoscopy via 2cm × 3cm bone window vs traditional burr-hole drainage	Recurrence: 1.6% (1/61) vs 8.2% (5/61); p<0.05; Brain re-expansion (complete) at 3d: 61% vs	Neuroendoscopy promoted early brain re-expansion, reduced recurrence and complications; safe and

				36%; p<0.05; Intracranial hematoma: 0% vs 5%; p<0.05; Operation time: longer in endoscopy (NR)	effective
An et al. 2025 [21]	China	Retrospective cohort; N=87 (48 endoscopy, 39 two-burr-hole); Inclusion: septated CSDH	Endoscopic-assisted BHC (EBHC) vs two-burr-hole craniotomy (TBHC)	Recurrence: 12.5% (6/48) vs 10.3% (4/39); p=0.742; Operation time: 103.56 ± 20.93 min vs 50.77 ± 12.40 min; p<0.001; Drainage time: 18.66 ± 5.89 h vs 55.87 ± 23.03 h; p<0.001; Hospital stay: 6.02 ± 1.68 d vs 4.66 ± 1.79 d; p<0.001	TBHC is effective for septated CSDH with shorter operative time and comparable recurrence to EBHC; EBHC has advantages in drainage time

CSDH = chronic subdural hematoma; BHC = burr-hole craniotomy; BHC-D = burr-hole craniotomy with drainage; PSM = propensity score matching; NR = not reported.