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Systematic Review

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Endoscopic-Assisted Chronic Subdural Hematoma Evacuation as an Adjunct to Middle Meningeal Artery Embolization: A Case Series and Systematic Review

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ABSTRACT

AIM: Chronic subdural hematoma (cSDH) is a common neurosurgical condition in elderly patients, frequently associated with trauma, anticoagulant use, and chronic comorbidities. While surgical evacuation and now middle meningeal artery embolization remain the predominant treatment options, endoscopic-assisted techniques have been increasingly used as a surgical adjunct. We evaluated the safety, clinical outcomes, and recent advancements in endoscopic-assisted evacuation of cSDH through both a retrospective case series and an updated review of the current literature.

MATERIAL and METHODS: A retrospective analysis of 39 patients undergoing 44 endoscopic-assisted evacuations of subdural hematomas between October 2021 and May 2025 was performed. Patient demographics, imaging, operative details, complications, and recurrence were analyzed. A systematic review of 15 studies published between 2022 and 2025 was added to a prior review performed by our group to assess outcomes associated with endoscopic approaches to cSDH.

RESULTS: Of the 39 patients (67% male, ages 20 to 73), four experienced recurrence, three prior to middle meningeal artery (MMA) embolization and one after. All patients received postoperative subdural drains, and no intraoperative complications related to the endoscope occurred. The literature review included an additional 16 recent studies (n=1060 patients) in addition to 13 studies from a previous systematic review, reporting recurrence rates of 0% to 16.7%. Endoscopic evacuation was associated with reduced recurrence, shorter hospital stays, and improved hematoma clearance compared to traditional techniques.

CONCLUSION: Endoscopic-assisted evacuation of cSDH appears to be a safe and effective adjunct to conventional surgical methods through improved visualization, potential coagulation of distal meningeal artery territories, and reduced recurrence. While results are promising, larger prospective studies are needed to confirm long-term benefits and refine patient selection.

KEYWORDS: Chronic subdural hematoma, Endoscope, Middle meningeal artery, Case series, Systematic review

ABBREVIATIONS: **cSDH:** Chronic subdural hematoma, **MMA:** Middle meningeal artery, **EBHC:** Endoscopic-assisted burr hole craniostomy, **TBHC:** Traditional two-burr hole craniostomy

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INTRODUCTION

Chronic subdural hematoma (cSDH), or non-acute subdural hematoma (NASH), is one of the most common neurosurgical conditions, particularly among the elderly (10,27). The exact pathophysiological mechanism of cSDH remains unclear and is attributed to an ischemic-hypoxic mechanism governed by inflammatory signaling cascade at the level of the dura-membrane interface (3,17,22). Multiple factors play a role, including advanced age, use of anticoagulant or antithrombotic agents, a history of falling or head trauma, and chronic comorbidities such as hypertension (3,17,22).

CSDH management is based on severity of clinical symptoms, hematoma size, and associated mass effect. Surgical intervention remains the standard treatment in symptomatic patients (14,16,21). Twist drill evacuation, burr hole aspiration, mini-craniotomy, and craniotomy are among the surgical methods used to remove cSDH (4,5,12,33). Recurrence of cSDH remains a clinical challenge, despite advancements in surgical techniques and perioperative care. Several recent studies have sought to identify and validate predictive risk factors for patient stratification and treatment optimization. Recent popularity of middle meningeal artery embolization has especially emerged in the west with completion of the EMBOLISE trial (7). In recent years, the endoscope-assisted approach, a minimally invasive technique, has held attention for providing a clear visualization, reducing invasiveness, and better hematoma evacuation (1,12,13,25,26,29,33). However, comprehensive data assessing the efficacy and safety of endoscope-assisted techniques in cSDH management remain limited.

In this study, we evaluated the feasibility, safety, efficacy, and clinical outcomes of surgical evacuation of cSDH using endoscope assistance through a single-center consecutive case series and systematic literature review.

MATERIAL and METHODS

Case Series

We conducted a retrospective, single-surgeon (MK), multi-institutional consecutive case series of patients undergoing endoscopic-assisted cSDH evacuation between October 2021 and May 2025. Institutional review board approval was obtained for all retrospective patients (University of Utah #001530; Global Neuroscience Institute #20200568; University of Michigan HUM00266268) with informed consent for all case presentations. A subset of patients in this series (n=9) were previously published (6).

Surgical Technique

Endoscopic-assisted surgery utilized a 30-degree endoscope and flexible 8F suction coblator via a widened burr hole or mini-craniotomy. The technique evolved to two burr holes, with the posterior enlarged for combined endoscope/coblator use (Figure 1). Removal of the inner table with saucerization of the outer table aided the angles required for endoscope use. Bridging vessels and membranes were coagulated when feasible. Dura along the inner table within the location of the middle meningeal artery was coagulated. Two 10F JP drains tunneled anteriorly/posteriorly and placed on suction for 24-48 hours. A postoperative CT head was obtained at 24 hours.

Patient Selection for Combined Therapy

Patients selected for combined endoscopic evacuation and MMA embolization were those with recurrent or refractory cSDH after initial drainage, complex or septated hematoma morphology, extensive membranes, or at high risk of recurrence (ongoing anticoagulant use, advanced age, or significant comorbidities). This approach aimed to maximize hematoma clearance and minimize recurrence risk. The treatment algorithm outlining the decision-making process for managing cSDH, including traditional burr-hole surgery and endoscopic evacuation are noted in Figure 2.

Data Collection

Patients were excluded if presenting with an acute subdural hematoma requiring urgent evacuation. Patient demographics, pathology, surgical approach, complications, pre- and postoperative imaging, and recurrence were collected. Recurrence was defined as a postoperative increase in subdural fluid volume that required repeat operative intervention. The study was conducted in accordance with the PROCESS (Preferred Reporting of Case Series in Surgery) guidelines for surgical case series.

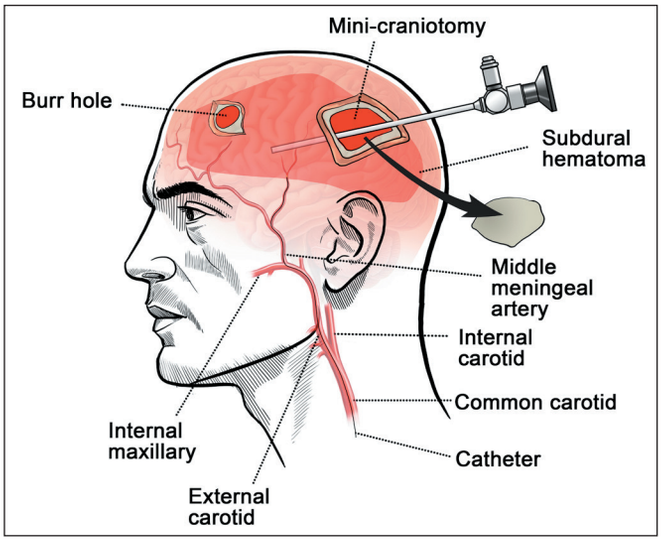

Figure 1: Schema of endoscopic-assisted chronic subdural hematoma (cSDH) evacuation in conjunction with middle meningeal artery (MMA) embolization. Inline burr holes with a posterior burr hole enlargement or minicraniectomy can aid in the use of a 30 degree endoscope for hematoma visualization and evacuation, hemostasis, coagulation of bridging veins, and coagulation of membranes along the path of the distal MMA. Endovascular MMA embolization remains a key method for proximal and distal coagulation as a method to interrupt the hypoxic-ischemic mechanism of cSDH formation.

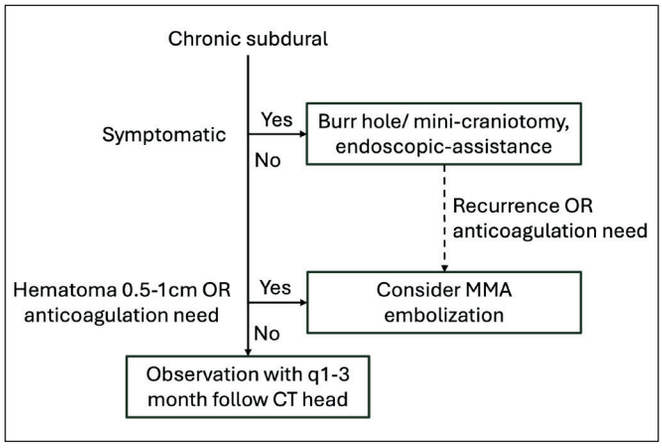

Figure 2: cSDH treatment algorithm. Schema illustrating cSDH patient decision making to proceed with traditional burr-hole surgery, direct endoscopic evacuation, or combined treatment.

Systematic Literature Review

To evaluate recent advancements in the management of cSDH, we conducted an updated systematic review that expands upon the previous systematic analysis by Cutler et al. (2022) of 13 total studies and used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines (6).

A systematic literature review was conducted using PubMed, Web of Science, and Embase, identifying studies published between 2022 and 2025. Targeted keywords included "chronic subdural hematoma" or "cSDH"; "neuroendoscopy," "endoscopic evacuation," or "endoscope-assisted"; "middle meningeal artery embolization"; "membranectomy"; and "minimally invasive neurosurgery". Studies were eligible for inclusion if they discussed endoscopic surgical approaches to non-acute subdural hematomas and were published in English. Articles were excluded if they were review papers, single-patient case reports, not written in English, or published before 2022.

After eliminating duplicate records, two independent reviewers screened the remaining studies for eligibility using titles, abstracts, and relevant keywords as the basis for selection. Eligible studies included those reporting on endoscopic evacuation and any other strategy for cSDH evacuation including surgical treatment or MMA embolization. Data on recurrence rates, antiplatelet/anticoagulation therapy use preoperatively, continuation of postoperative drain, and overall patient outcomes were extracted and qualitatively synthesized. This review was registered on PROSPERO.

RESULTS

Case Series

A total of 39 patients (age range: 20–73 years; 67% male) underwent 44 endoscopic-assisted procedures for the treatment of subdural hematoma (SDH): 10 on the left side, 22 on the right, and 12 bilateral. Recurrence occurred in 4 patients - 3 prior to middle meningeal artery embolization and 1 following the procedure. Postoperative subdural drains were placed in all cases. No intraoperative or postoperative complications related to the use of endoscopic use or endoscopic assisted coagulation were observed.

The decision to combine MMA embolization with endoscopic evacuation was made in patients with one or more of the following: recurrent cSDH after burr-hole evacuation, evidence of thick or vascularized membranes on imaging or intraoperative inspection, high risk for recurrence (such as with anticoagulant use or bilateral hematomas), or when intraoperative findings suggested incomplete hemostasis of distal MMA branches (7,12).

Illustrative Case 1

A 73-year-old male presented with altered mental status and left-sided weakness (Figure 3). His medical history was notable for atrial fibrillation managed with warfarin (admission INR: 2.0) and multiple recent falls (Figure 3A, B). He underwent right-sided burr hole evacuation and craniotomy (Figure 3C, D), followed by endoscopic-assisted hematoma evacuation (Figure 3E), membrane coagulation (Figure 3F, G), and subdural drain placement (Figure 3H). His postoperative course was uneventful, and he was discharged on postoperative day 4.

Illustrative Case 2

Another 73-year-old male presented with altered mental status, lethargy, and asymmetric weakness (left greater than right) following a ground-level fall two weeks prior (Figure 4A). Initial bilateral burr hole drainage resulted in near-complete resolution of the right-sided hematoma and clinical improvement; however, the left-sided SDH persisted with new acute components (Figure 4B). Bilateral MMA embolization was performed 4 days later (Figure 4C, D). Despite this, follow-up imaging at 7 days demonstrated ongoing left-sided mass effect (Figure 4E). The patient underwent a left-sided reoperation with enlargement of the posterior burr hole via craniotomy, endoscopic-assisted hematoma evacuation, membrane coagulation, and drain placement. At 1-month follow-up, imaging revealed significant improvement of the hematoma (Figure 4F).

Systematic Review

A total of 15 studies met the inclusion criteria for this literature review, each examining the use of endoscopy in the management of subdural hematomas (Figure 5, Table I). Collectively, these studies encompassed 1060 patients with a mean age of 66.4 years. Reported recurrence rates following endoscopic treatment for cSDH ranged from 0% to 16.7% with an overall average of 12.44%. Middle meningeal artery embolization was addressed in only two studies, while preoperative alcohol use was reported in two papers, with prevalence ranging from 19.6% to 47.9%. The use of a novel brain retractor was discussed in two papers. Membranectomy was discussed in 8 of the 15 studies. Preoperative use of antiplatelet or anticoagulant medications varied widely, ranging from 3.2% to 83.3%. All but one study reported the use of a postoperative drain, with most utilizing subdural drains and two specifying subgaleal drain placement.

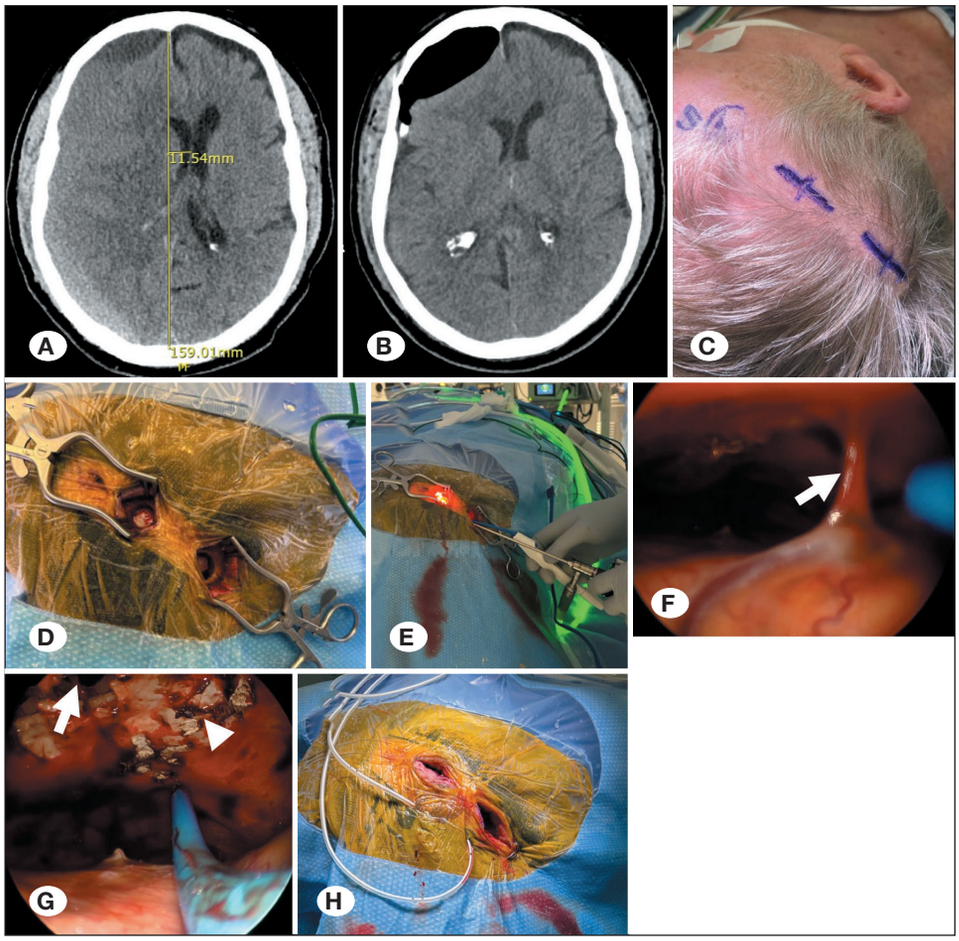

Figure 3: Illustrative Case 1. **A)** A 73 year old male presenting with right sided cSDH underwent evacuation. **B)** Postoperative images are shown. **C)** Supine positioning with the head in a horseshoe headrest demonstrates placement of burr holes along the superior temporal line. **D)** Burr hole generation is shown with enlargement and saucerization of the posterior burr hole. **E)** A 30 degree endoscope with 8F suction coblator is used for hematoma evacuation and coagulation. **F)** Coagulation of bridging veins (arrow) at risk for rehemorrhage can be coagulated. **G)** Coagulation of distal dural membranes (arrowhead) along the distribution of the middle meningeal artery can be used to disrupt the mechanism of cSDH formation. The anterior burr hole is seen (arrow). **H)** Anterior and posterior directed 10F JP drains can be used for evacuation of hematoma and air from the surgical cavity.

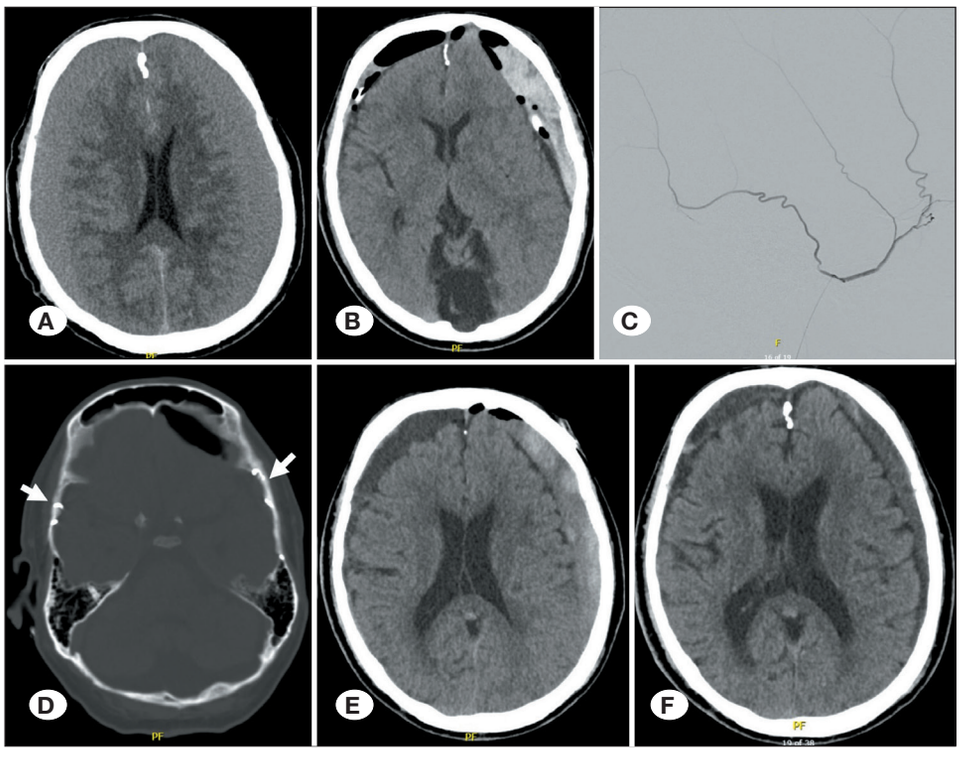

Figure 4: Illustrative Case 2. **A)** A 73 year old male presenting with bilateral cSDH underwent burr hole evacuation. **B)** Postoperative images demonstrated adequate right side evacuation but early recurrence of acute SDH component. **C, D)** An MMA embolization was successfully performed bilaterally with embolisate identified postoperatively (arrows). **E)** Delayed recurrence and persistence of left side cSDH hematome underwent a repeat drainage with endoscopic-assisted evacuation. **F)** 1 month followup scan demonstrated bilateral improvement of cSDH components.

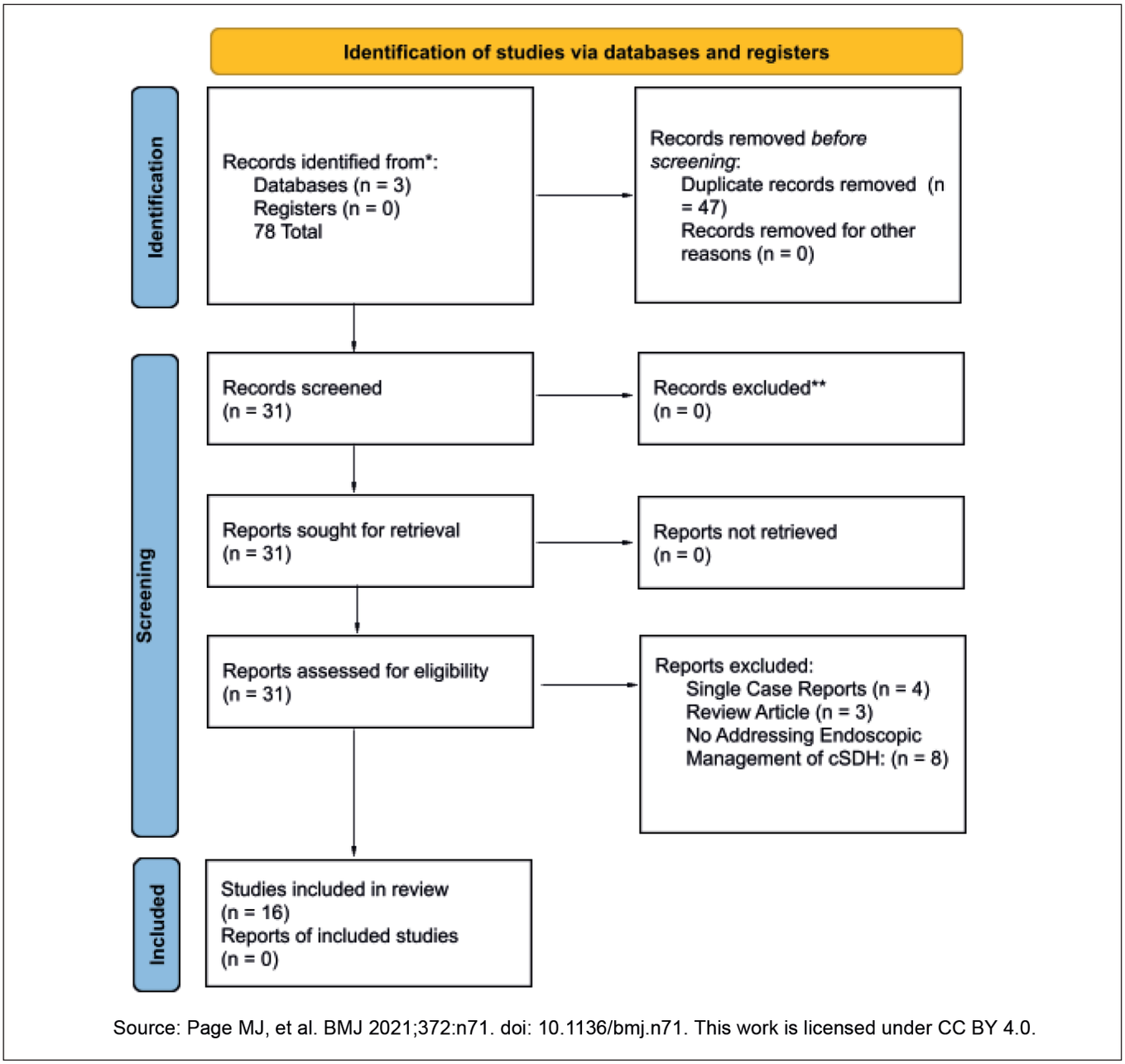

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Figure 5: Preferred reporting items for systematic reviews and meta-analyses (PRISMA) flow diagram depicting study selection for a literature review on endoscopic treatment of nonacute subdural hematomas.

DISCUSSION

Our findings support the safety and feasibility of endoscope-assisted evacuation for patients with non-acute subdural hematoma. Among the 39 patients treated, 4 (10%) experienced recurrence including "1" patient despite MMA embolization. No complications related to endoscope use were seen. One case of ours underwent both combined MMA embolization and endoscopic-assisted evacuation with dural coagulation with post-treatment recurrence. Both surgical procedures were technically successful. Risk factors for this specific patient included recurrent falls and alcoholism. These results suggest that recurrence despite aggressive treatment may still occur but in low numbers of patients as evident by our results and the literature. The systematic review demonstrated recurrence rates for cSDH ranging from 0-16.7% with an overall average of 12.44%. Modern series have increasingly discussed the use of endoscopic-assisted treatment with middle meningeal artery embolization (Table I).

Endoscopic-assisted treatment was effective in visualization of hematoma evacuation cavities, inspection of the brain, identification of active hemorrhage sites, and coagulation of membranes or distal MMA vessels. Endoscopic-assisted

Table I: Comparative Summary of Included Studies on Endoscopic-Assisted and Combined Approaches to cSDH

Reference	No. of Patients	Mean Age (years)	Recurrence Rate (%)	MMA Embolization Rate (%)	Alcohol Use (%)	Operative Duration (min)	Complication Rate (%)	Surgical Technique	Membranectomy Performed	Antiplatelet/ Anticoagulant Use Pre-op (%)	Drain Type	Notes / Key Outcomes
An et al., 2025 (2)	48	73.75	12.5	–	47.9	103.6 (EBHC) vs 50.8 (TBHC)	–	30° endoscope	Outer 25%	–	Subdural	EBHC: shorter drainage (18.7h), longer operation time
Egemen et al., 2024 (8)	21	65.63	NR	–	–	–	Minimal	0° rigid endoscope	–	23.8	Subdural	Safe/effective in septated hematomas
Fang et al., 2024 (9)	41	64.3	2.4	–	19.6	–	–	Rigid endoscope	–	Patients excluded	Subdural	Higher clearance, shorter stay vs BHC, lower recurrence
Guo et al., 2023 (11)	20	62.25	0	100	–	–	No adverse postop complications	Rigid short endoscope	–	35	Subdural	Combined MMA + endoscopy reduced recurrence
Hong et al., 2022 (15)	13	71.1	0	–	–	128.5 (Endo) vs 65.2 (Non)	No surgical complications in either group	0° & 30° (2.7mm) post-BHC	Yes	15.4	None	No recurrence in Endo group
Li et al., 2023 (18)	45	67.89	2.2	–	–	67 (NHE) vs 55 (BHC)	Recurrence: 2.2% (NHE) vs 18.8% (BHC)	0° endoscope	Outer	–	Subdural	Faster recovery, lower drainage, improved clearance vs BHC
Ma et al., 2022 (19)	48	64.12	2.0	–	–	104.9 (Endo) vs 65.2 (BHC)	0 (Endo) vs 12.5 (BHC)	Neuroendoscope	–	–	Subdural	Shorter stay: 8.46d (Endo) vs 10.22d (BHC)
Nomura et al., 2022 (20)	4	74.75	NR	75	–	–	–	Variable	–	–	Subdural	Embolization enhances the healing process
Park et al., 2023 (23)	6	71	16.67	–	–	–	No surgery related complications	0° or 30° endoscope	–	83.3	Subdural	Effective in cSDH + hygroma
Priyadharshan et al., 2023 (24)	19	60.4	0	–	–	43.3 for endoscopic membranectomy	No post op seizures, wound healing issues, or infections	Rigid 0° / 30° endoscope	Inner	15.8	Subdural	Lower recurrence and faster recovery
Sharma et al., 2024 (25)	248	69	2.0	–	–	56 for novel brain retractor	Lower complications with endoscopy vs TBH	0°/30° endoscope	Yes	3.2	Subgaleal	Improved visualization and hematoma removal with brain retractor
Singh et al., 2022 (26)	68	68.8	2.0	–	–	157.5 with endoscope	No infections with endoscope	0° rigid endoscope	Yes	39.7	Subdural	Reduced recurrence and complications
Wang et al., 2022 (30)	61	57.26	2.0	–	–	Longer for endoscopy	None reported for neuroendoscopy group	Rigid Storz	Yes	–	Subdural	Clear visualization, lower recurrence
Wang et al., 2023 (31)	42	55.3	NR	–	–	60	–	Rigid Storz (0°)	–	–	Subdural	CT-based positioning to optimize access
Yadav et al., 2023 (32)	341	67	0.06	–	–	60	None	0°/30° endoscope	–	3.2	Subgaleal	Retractor improved access, low recurrence

coagulation was especially useful in cases when MMA embolization could not be performed due to tortuous vessels or if patients recurred in spite of embolization. Challenges remain in the treatment of patients with narrow subdural spaces and limited use of rigid endoscopes or current suction coblators.

Literature Review

Along with our case series findings, recent studies also support the safety of endoscopic evacuation for cSDH (19,24,25,29). This technique has been associated with lower rates of hematoma reaccumulation, infection, or mortality compared to conventional surgical methods (8,24). This is especially beneficial for recurrent hematomas or in elderly or anticoagulated patients, for whom minimally invasive approaches reduce perioperative risk (10,27,28). These findings were supported by the literature reviewed. A previous systematic review from our group identified 13 studies evaluating the use of endoscope-assisted cSDH evacuation (6), and our current analysis adds another 15 studies between 2022 to 2025.

Priyadharshan et al. reported excellent clinical outcomes: 100% of patients were neurologically intact at follow-ups, and 89.5% showed no recurrence on 6-month CT scans (24). Singh et al. found similar benefits, with endoscopic evacuation offering superior visualization and clearance of cSDH, potentially reducing recurrence compared to common interventions (26). An et al. provided direct comparison between endoscopic-assisted burr hole craniostomy (EBHC) and traditional two-burr hole craniostomy (TBHC), highlighting that EBHC offers benefits such as shorter drainage times and hospitalization (2).

Our results support that endoscopic intervention, through improved intraoperative visualization, enables safer, more complete hematoma evacuation and drain placement similar to other studies (18,32). Furthermore, these studies highlight the minimally invasive nature of the endoscope-assisted techniques. Endoscopic approaches, whether performed via a burr-hole or mini-craniotomy, allow for smaller incisions and reduced brain manipulation. Minimization of surgical incisions via burr holes or mini-craniotomies may improve postoperative recovery but requires further study to support for cSDH treatment (9,18,32). Regardless of technique chosen, endoscopic visualization could be used as an adjunct for surgical treatment.

Combining MMA Embolization and the Endoscope

Additionally, combining endoscopic evacuation with MMA embolization may help further reduce recurrence in cSDH. Current multicenter level 1 evidence from the EMBOLISE trial suggests MMA embolization results in a recurrence rate of 4.1% vs. 11.3% (relative risk, 0.36; 95% confidence interval [CI], 0.11 to 0.80; p=0.008) (7). Embolization may interrupt vascular supply to the outer membrane, reducing inflammation and regrowth; endoscopy enables direct visualization to confirm embolization effectiveness and guide treatment (20). This approach may be beneficial in recurrent or refractory cases (11,30). Endoscopic treatment may offer additional disruption to potential cSDH membranes or be used in cases where embolization cannot be safely performed due to vessel tortuosity or unsafe reflux into vessels supplying critical neurological structures (e.g., ophthalmic artery).

Future studies could benefit from a morphology-based stratification model to guide treatment selection. For example, patients with non-septated, homogenous hematomas might be adequately treated with burr-hole drainage with or without MMA embolization, whereas those with septated or multiloculated collections, thick vascular membranes, or recurrent hematomas could be prioritized for endoscopic-assisted evacuation with or without MMA embolization (9,15,18). Such models could be based on preoperative imaging (CT/MRI) scoring systems and refined by intraoperative findings.

Limitations of the Endoscope

While endoscope-assisted evacuation of cSDH has shown promising outcomes, several studies also note potential challenges with this technique. Wang et al. emphasized the requirement for general anesthesia and a relatively larger craniotomy compared to traditional burr hole procedures, which may limit its use in certain patient populations (30). An et al. reported that EBHC resulted in a significantly longer operative time compared to TBHC (103.6 vs. 50.8 minutes, $p<0.001$) (2). However, this was offset by benefits such as shorter drainage duration (18.7 vs. 55.9 hours, $p<0.001$) and reduced hospital stay (4.66 vs. 6.02 days, $p<0.001$) (2). Similarly, Hong et al. reported a longer average operative time in the endoscope group (128.5 vs. 65.2 minutes, $p<0.0001$), though they noted that the approach was particularly effective for patients with compartmentalized hematomas (15).

Priyadharshan et al. further highlights the technical demands of endoscopic methods, pointing to the need for precise optimal alignment between the patient and the endoscope (24). For example, the flexible endoscope offers mobility but lacks image clarity compared to rigid scopes. The endoscope technique learning curve is high, specifically for membranectomy or complex septations (24). To mitigate this learning curve, structured training in neuroendoscopy, including simulation-based practice, stepwise integration into simpler cSDH cases, and mentorship by experienced surgeons, should be emphasized. Early in the learning curve, cases with larger subdural spaces and less septation may be preferable, reserving complex hematomas for more experienced operators (2,15,24). Despite these challenges, the overall benefits of endoscopic evacuation, such as reduced recurrence rates and improved patient outcomes, make it an advantageous alternative to conventional approaches (23,26,31).

Recent research has explored the use of adjunctive tools such as soft brain retractors to address these technical challenges of endoscopy. Sharma et al. and Yadav et al. both demonstrated that retractors improve access to complex hematoma structures, facilitating removal (25,32). Their use was associated with low recurrence, no complications, and improved outcomes, making this an important avenue for future exploration (25,32).

Study Limitations

This study design may have several limitations. In regards to the case series, patient selection was limited to a single surgeon's practice with significant heterogeneity of patient presentations, comorbidities, and cSDH configurations, which may limit external validity and generalizability to other practices and centers. Our study and the overall advantages of endoscopic techniques limited our ability to incorporate a matched control group of patients receiving alternative treatment options. Further, we did not specifically analyze operative time as a marker of the learning curve over this multi-year, multi-institutional series which could be an area of future study. Additional markers could include some component of MMA territory coagulation on postoperative imaging or degree of hematoma evacuation. However these findings would be limited unless performed in a multi-surgeon, multi-institutional manner.

In regard to the literature review, technical details such as the type of endoscope used, surgeon experience, and adjunct instrumentation (e.g., retractors, embolization materials) were variably reported, reducing reproducibility and comparability across studies. These variations highlight the need for standardized operative protocols, discussion of standardized surgical steps, and reporting guidelines. Differences in endoscope type (rigid vs. flexible), visualization angle, coblation tools, and use of adjunctive devices such as retractors may influence operative time, evacuation completeness, and complications (2,24,25,32). Likewise, surgeon experience with neuroendoscopic techniques plays a critical role in patient outcomes. Multi-center studies with clearly defined instrumentation, procedural steps, and surgeon training levels are necessary to enhance reproducibility.

CONCLUSION

Endoscopic-assisted evacuation, especially in combination with MMA embolization, offers a safe, effective, and minimally invasive option for selected patients with cSDH. Integration of endoscopy into modern cSDH management, guided by patient stratification and standardized protocols, may improve outcomes and reduce recurrence. Although current evidence supports the benefits of endoscope-assisted evacuation in cSDH, the need for larger, prospective trials to validate these findings is imperative.

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Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

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AUTHORSHIP CONTRIBUTION

Study conception and design: MK
Data collection: MK
Analysis and interpretation of results: DB, HF, CP, ED, MZ, MK
Draft manuscript preparation: DB, HF, CP, ED, MZ
Critical revision of the article: DB, HF, CP, ED, MZ, MK
All authors (DB, HF, CP, ED, MZ, MK) reviewed the results and approved the final version of the manuscript.

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