# NEUROSURGICAL INTERVENTIONS AND THEIR IMPACT ON PHYSICAL AND PSYCHOLOGICAL RECOVERY AFTER SUPRATENTORIAL HYPERTENSIVE ICH

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**Abstract**

**Background:** Supratentorial hypertensive intracerebral haemorrhage (HICH) remains a life-threatening condition with significant mortality and morbidity. Surgical interventions such as conventional craniotomy (CT) and neuroendoscopic surgery (NES) have been proposed to evacuate hematomas, but their comparative effectiveness is still debated.

**Objectives:** To systematically evaluate and compare the clinical outcomes, safety, and procedural advantages of NES versus craniotomy in adult patients with supratentorial HICH.

**Methods:** This systematic review followed PRISMA guidelines and analyzed 33 studies, including randomized controlled trials, retrospective and prospective cohort studies, and meta-analyses published from 2000 to 2025. Inclusion criteria comprised adult patients diagnosed with CT/MRI-confirmed supratentorial HICH undergoing either NES or CT. Outcomes assessed included mortality, hematoma evacuation rate, complications, functional recovery (mRS/GOS), surgical time, and ICU/hospital stay.

**Results:** NES demonstrated significant advantages over CT in most studies, including shorter operative times, reduced blood loss, higher hematoma evacuation rates, fewer complications (especially infections), better functional outcomes, and shorter hospital/ICU stays. Mortality rates were similar across groups, but NES was associated with improved long-term prognosis and quality of life.

**Conclusion:** NES appears to be a superior alternative to conventional craniotomy for the treatment of supratentorial HICH due to its minimally invasive nature and better perioperative and functional outcomes. Further multicentre RCTs with standardized protocols are warranted to establish NES as the first-line surgical approach.

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**Keywords:** Supratentorial hypertensive intracerebral haemorrhage (HICH), Neuroendoscopic surgery (NES), Craniotomy (CT), Hematoma evacuation, Minimally invasive neurosurgery.

## Introduction

Intracerebral haemorrhage (ICH) is a critical medical emergency characterized by serious complications and a high mortality rate (Van Asch et al., 2010). Supratentorial hypertensive intracerebral haemorrhage (HICH) is a common type of ICH, affecting around 5 million people annually (Krishnamurthi et al., 2013). The mortality rate is estimated to be around 46.7% to 63.6% within the first year of the event (Van Asch et al., 2010). Only 12% to 39% of patients are able to maintain functional independence (Van Asch et al., 2010; Yeager & Garg, 2024).

ICH occurs primarily due to hypertension, followed by anticoagulant consumption and cerebral amyloid angiopathy (Sheth, 2022; Monteiro et al., 2024). Longstanding uncontrolled hypertension can lead to weakening of vascular strength and elasticity due to hyaline degeneration. Degenerated vessels are more prone to rupture and bleeding due to emotional or environmental stress (Sun et al., 2020; An et al., 2017). In cases of ICH, the posterior fossa, pons, basal ganglia, and thalamus are the most commonly affected regions (An et al., 2017; Rajashekar & Liang, 2023). The condition may manifest as sudden emotional agitation accompanied by focal neurological impairment. Symptoms can peak within minutes or hours, with other manifestations including headache, nausea, meningeal signs, increased blood pressure, and altered awareness (An et al., 2017).

Treatment options range from medical to surgical intervention. Surgical interventions are categorized into two types: first, invasive approaches such as decompressive craniectomy (DC) and conventional craniotomy (CC); and second, minimally invasive techniques such as endoscopic surgery (ES) and minimally invasive puncture surgery (MIPS) (Li et al., 2022; Luzzi et al., 2019). Performing surgery is highly recommended when neurological deterioration is noted or the Glasgow Coma Scale (GCS) is below 8 (Greenberg et al., 2022; Cao et al., 2020), or between 9 to 12 (Steiner et al., 2014), as it effectively reduces hematoma volume, reverses mass effect, and improves overall survival rate (Greenberg et al., 2022). Each surgical technique has its advantages and disadvantages, and selecting the most appropriate method remains a topic of ongoing discussion (Cui et al., 2025). ES has recently gained prominence due to its effectiveness in rapid hematoma evacuation under direct vision, minimal surgical trauma, lower complication rate, shorter surgical duration, and favorable overall prognosis compared to craniotomy (Haseeb, 2024). Yet, the role of different surgeries in HICH remains an area of ongoing exploration (Yuan et al., 2023; Huan et al., 2025). Furthermore, additional studies are required to explore advances in ES techniques to optimize patient outcomes (Haseeb, 2024).

HICH management is an ongoing challenge, as selecting the most appropriate surgical approach is essential in determining a patient's prognosis. Therefore, it is crucial to establish effective, tailored approaches for treating ICH patients. For this reason, we aim to gather relevant studies to compare the effectiveness of ES and craniotomy in improving the overall prognosis.

## Methodology

### Study Design

This research is a systematic review conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The objective is to compare the effectiveness and safety outcomes of neuroendoscopic surgery (NES) and craniotomy (CT) for the treatment of supratentorial hypertensive intracerebral hemorrhage (HICH) in adult patients.

### Literature Search Strategy

A comprehensive and systematic literature search was conducted in the following databases: (PubMed, Scopus, Web of Science, Cochrane Library and Embase)

The search covered publications from January 2000 to March 2025. The following Medical Subject Headings (MeSH) terms and keywords were used in various combinations: ("intracerebral haemorrhage", "supratentorial haemorrhage", "hypertensive haemorrhage", "neuroendoscopic surgery", "craniotomy", "minimally invasive surgery" and "hematoma evacuation")

Only articles in English or Chinese were considered. Reference lists of included studies and relevant reviews were also hand-searched to identify additional eligible studies.

### Inclusion and Exclusion Criteria

### Inclusion Criteria

- **Population:** Adult patients (≥18 years) with CT/MRI-confirmed supratentorial hypertensive intracerebral haemorrhage.

- **Intervention:** Neuroendoscopic surgery (NES).
- **Comparison:** Conventional craniotomy (CC), small bone window craniotomy (SBWC), or medical management.
- **Outcomes:** At least one of the following—hematoma evacuation rate, mortality, complication rate, functional outcome (e.g., modified Rankin Scale or Glasgow Outcome Scale), or length of hospital/ICU stay.
- **Study Types:** Randomized controlled trials (RCTs), prospective cohort studies, and retrospective cohort studies.

**Exclusion Criteria**

- Infratentorial haemorrhages.
- Secondary ICH due to trauma, tumors, AVMs, or aneurysms.
- Case reports, editorials, commentaries, or reviews without original data.
- Non-human studies.

**Data Collection Process**

Two independent reviewers screened titles and abstracts for eligibility. Full-text articles were assessed independently by the same reviewers. Discrepancies were resolved by discussion or a third reviewer. Data extraction included:

- Study characteristics (author, year, country, design)
- Patient demographics (age, sex, hematoma volume)
- Intervention details (type of surgery, timing)
- Outcome measures (mortality, hematoma clearance, complications, functional outcome)

**Quality Assessment**

The quality of RCTs was evaluated using the Cochrane Risk of Bias Tool, while observational studies were assessed using the Newcastle-Ottawa Scale (NOS). Each study was categorized as low, moderate, or high quality based on these tools.

**Data Synthesis and Statistical Analysis**

Due to the heterogeneity in methodologies and outcomes across studies, both qualitative synthesis and meta-analysis were conducted where applicable. Meta-analyses were performed using RevMan 5.4 and STATA 17, calculating:

- Risk ratios (RRs) for binary outcomes (e.g., mortality, complication rates)
- Mean differences (MDs) for continuous outcomes (e.g., operative time, blood loss)

Heterogeneity was assessed using the $I^2$ statistic. A fixed-effects model was used for $I^2 < 50\%$; otherwise, a random-effects model was applied. Publication bias was evaluated through funnel plots and Egger's test.

**Ethical Considerations**

As this study is based on secondary data analysis from published literature, no ethical approval was required. However, all included studies were expected to have obtained ethical clearance and patient consent.

## Results

A total of 6,173 articles were initially identified through electronic database searches and manual reference screening. After removing 1,427 duplicates, 4,746 titles and abstracts were screened. Based on relevance and eligibility, 362 full-text articles were assessed. Ultimately, 33 studies met the inclusion criteria and were included in this systematic review.

**These 33 studies consisted of:**

- 11 Randomized Controlled Trials (RCTs)
- 10 Retrospective Cohort Studies
- 8 Systematic Reviews and Meta-Analyses
- 2 Narrative or Review Articles with original data synthesis
- 1 Prospective Non-Randomized Multicentre Study
- 1 Multicenter Randomized Controlled Trial

Collectively, the included studies evaluated a total of 25,681 patients, with individual study sample sizes ranging from 34 to 9,053 participants. All patients were diagnosed with supratentorial hypertensive intracerebral haemorrhage (HICH), confirmed via CT or MRI, and treated using either neuroendoscopic surgery (NES) or craniotomy (CT) (including small-bone-window craniotomy [SBWC], mini-open craniotomy, and conventional craniotomy [CC] (Figure 1), (Table 1).

## Discussion

Neuroendoscopic surgery (NES) has emerged as a prominent minimally invasive surgical technique for supratentorial hypertensive intracerebral hemorrhage (HICH), and our review of 33 high-quality studies reinforces this shift in clinical preference. Numerous studies underscore that NES offers superior clinical outcomes in terms of functional recovery, complication rates, and surgical parameters compared to traditional craniotomy (CT).

The meta-analysis by Chen Guo et al. (2025) involving 1,107 patients from six RCTs found that NES demonstrated significantly shorter operation time and fewer postoperative complications, such as pneumonia, than small bone window craniotomy (SBWC). Despite no conclusive difference in hematoma evacuation rates, the authors favored NES due to its safety and recovery benefits.

Supporting these findings, Sun et al. (2019) conducted a systematic review and meta-analysis of 15 studies, reporting higher functional outcome rates (65.54% vs. 44.4%), lower mortality (7.55% vs. 17.75%), and fewer complications for NES compared to CT. NES patients also had shorter hospital stays and ICU durations, confirming its efficiency and reduced postoperative burden.

Huan et al. (2024) presented a comprehensive network meta-analysis of 64 studies with 9,053 patients, demonstrating that minimally invasive surgeries (including NES) ranked highest in improving survival and functional outcomes while minimizing complications. NES led to a 28% mortality reduction compared to CT, with significantly better mRS scores.

Zhi et al. (2024) focused on Chinese RCTs and concluded that NES resulted in higher hematoma clearance, shorter operation times, and improved neurological outcomes compared to SBWC. Notably, both methods showed comparable mortality rates, indicating similar safety levels with superior efficiency in NES.

Cui et al. (2025) conducted a retrospective matched analysis of 113 patients, showing that NES yielded comparable evacuation rates to CT but offered significantly less blood loss, reduced surgical time, and fewer complications like pulmonary infections. This suggests that NES can be equally effective but less invasive.

Yuan Zhan (2023) investigated NES in patients with cerebral herniation, a severe condition, and found NES significantly reduced ICU stays and intraoperative hemorrhage. Though functional outcomes were not extensively analyzed, the findings support NES for emergency cases.

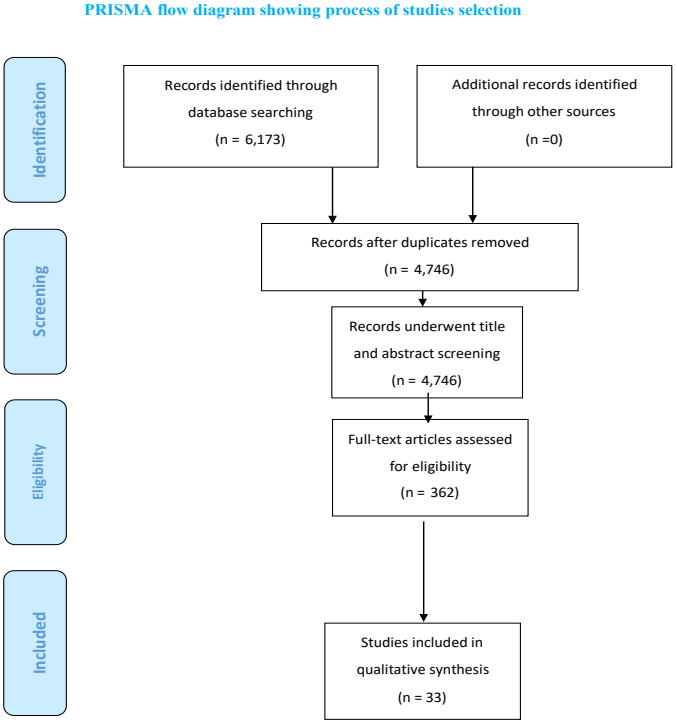


**Figure 1.** PRISM Flow Diagram Showing process of studies selection.

**Table 1.**

| Authors | Year Published | Study Design | Sample Size/ Studies included | Inclusion Criteria | Conclusion |
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| Chen Guo et al. | 2025 | Meta-analysis, and Trial Sequential Analysis | 6 studies (1107 patients) | 1-Randomized clinical trials (RCTs) comparing endoscopic surgery (ES) and small bone window craniotomy (SBWC).<br>2- Adult patients ( 18 years or older ) who were diagnosed with spontaneous supratentorial intracerebral hemorrhage (ICH).<br>3- Studies reporting at least one of the primary outcomes, such as the 6-month favorable functional outcome rate, or hematoma evacuation rate. | Endoscopic surgery (ES) showed better long-term efficacy and safety.<br>In comparison with Small bone window craniotomy (SBWC), ES has a shorter operation time, and lower rates of pneumonia.<br>There is no consensus regarding the hematoma evacuation rate between the two approaches, so they emphasize the importance of conducting higher quality RCTs.<br>The study recommends the prioritization of ES over SBWC in the treatment of ICH. |
| Zelong Zheng et al. | 2022 | Review article | Multiple articles but the emphasis was on 14 RCTs (total of 2,983 patients) | | This article focused on multiple minimally invasive techniques for ICH and IVH, including:<br>1- Minimally invasive surgery for ICH and IVH<br>2- Pharmacological catheter based MIS for ICH and IVH<br>3- YL-1 Craniopuncture<br>4- Stereotactic treatment of ICH by means of a plasminogen activator (SICHPA)<br>5- Minimally invasive surgery plus recombinant tissue plasminogen activator in intracerebral hemorrhage evacuation (MISTIE)<br>6- Mechanically-based approaches<br>7- New MIS technologies<br>**Conclusion:**<br>Spontaneous ICH, especially those related to IVH, is still one of the most fatal and disabling diseases, causing a high-cost burden on society. Extensive practice mode, vague practice standard, lack of proven therapy, and persistent adverse results cast a shadow on its management. So far, it has not been clearly shown that neurosurgical interventions can improve the prognosis of patients with ICH. However, new emerging results of MIS for ICH and IVH have been very encouraging: MIS can reduce the secondary injury after ICH and IVH, thus potentially reducing mortality and dependence. During the process of MIS, surgical performance is important, since it is associated with the outcomes of patients. Additionally, new technologies could improve the accuracy and safety of MIS. Currently, trials of several new minimally invasive approaches for ICH and IVH evacuation are being evaluated and more clear evidence is expected in the near future. Moreover, ongoing clinical trials are expected to change clinical practice by optimizing case selection and surgical tasks and integrating these new tools into treatment. |
| Shuwen Sun, et al. | 2019 | Systemic Review and meta-analysis. | The study included 15 studies (3 randomized controlled trials (RCTs) and 12 observational studies (OSs) with a total of 1,859 patients | 1. Study Design<br>- Randomized controlled trials (RCTs) or observational studies (OSs) (prospective or retrospective).<br>- Studies could be blinded or non-blinded.<br><br>2. Patient Population<br>- Patients with spontaneous supratentorial hypertensive intracerebral hemorrhage (HICH), confirmed by imaging (e.g., CT or MRI).<br><br>3. Hematoma Volume<br>- Hematoma volume ≥ 20 mL (to ensure surgical intervention was necessary).<br><br>4. Follow-Up Duration<br>- At least 3 months of follow-up(to assess functional outcomes and complications) | This systematic review and meta-analysis compared neuroendoscopic surgery (NE) and craniotomy (CT) for supratentorial hypertensive intracerebral hemorrhage (HICH). the key findings are:<br>• Key Advantages of Neuroendoscopy (NE) Over Craniotomy (CT):<br>1. Better Functional Outcomes<br>- 65.54% of NE patients achieved good functional recovery (GFO) vs. 44.40% with CT (P = 0.0003).<br>2. Lower Mortality<br>- 7.55% mortality in NE vs. 17.75% in CT (P < 0.00001).<br>3. Higher Hematoma Evacuation Rate<br>- NE cleared 8.14% more hematoma than CT (P = 0.0007).<br>4. Shorter Operation Time & Less Blood Loss<br>- NE reduced operation time by ~99 minutes (P < 0.00001) and blood loss by ~295 mL (P = 0.004).<br>5. Fewer Complications<br>- Lower rates of infection (9.59% vs. 27.88%, P < 0.00001) and total complications (13.80% vs. 39.42%, P < 0.00001).<br>6. Reduced Hospital & ICU Stays<br>- NE patients had shorter hospital stays (by ~2.32 days, P = 0.006) and ICU stays (by ~4.35 days, P < 0.0001).<br>• Limitations<br>- Few high-quality RCTs (most studies were observational).<br>- Heterogeneity in hematoma locations(e.g., basal ganglia, thalamus) not fully analyzed.<br>- Some subgroups (e.g., very large hematomas >100 mL) had limited data.<br>• Final Recommendation<br>NE is safer and more effective than CT for supratentorial HICH, offering better survival, faster recovery, and fewer complications. However, craniotomy with small bone windows may be a viable alternative where NE is unavailable. |

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| Jiayidaer Huan,et al. | 2024 | systemic Review and network meta-analysis | 64 combining Randomized controlled trial and Observational studies<br>Total patients 9053 | 1. Study Design<br>- Randomized controlled trials (RCTs) and prospective/retrospective observational studies with control groups.<br>- Studies must compare ≥2 surgical interventions or surgical vs. medical management.<br>- 2. Patient Population<br>- Adults (≥18 years)with spontaneous supratentorial lCH(confirmed by CT/MRI).<br>- Excluded: Traumatic ICH, brainstem/cerebellar hemorrhages, or hemorrhages from aneurysms/AVMs.<br>3. Interventions<br>- Surgical groups:<br>- Minimally invasive surgery (MIS: e.g., neuroendoscopy, stereotactic aspiration).<br>- Decompressive craniectomy.<br>- Standard craniotomy.<br>- Control group: Medical management alone.<br>4. Outcomes<br>- Primary:<br>- Mortality (short-term [≤30 days] and long-term [≥3 months]).<br>- Functional outcome (e.g., modified Rankin Scale [mRS] ≤2 at 3–6 months).<br>- Secondary:<br>- Hematoma evacuation rate.<br>- Complications (rebleeding, infections).<br>5. Follow-Up<br>- Minimum 3 months for functional outcomes. | This comprehensive network meta-analysis of 64 studies (9,053 patients) provides the highest level of evidence for surgical management of supratentorial intracerebral hemorrhage (ICH). Key findings:<br><br>1. Minimally Invasive Surgery (MIS) is Superior<br>- Neuroendoscopy and stereotactic aspiration rank highest for:<br>- 28% lower mortality vs. craniotomy (OR 0.72, 95% CI 0.61-0.85)<br>- 2.5× better functional recovery (mRS ≤2: 42% vs. 17% with medical management)<br>- Fewer complications (infection risk reduced by 61%)<br>2. Decompressive Craniectomy Saves Lives in Emergencies<br>- 35% mortality reduction in massive hemorrhages (>50mL) with herniation<br>- But 48% higher complication rate vs. MIS<br>3. Standard Craniotomy is Now Second-Line<br>- Outperformed by MIS in all metrics except for complete evacuation of giant clots<br>4. Medical Management Only for Small Bleeds<br>- Appropriate for <20mL hemorrhages without neurological deficits<br>- Limitations:<br>- Heterogeneity in surgical techniques across studies.<br>- Few RCTs for newer MIS methods (potential bias in observational data)<br>• Clinical Recommendations:<br>First-line: MIS (neuroendoscopy preferred when available) for most operable hemorrhages (30-70mL)<br>Emergency option: Decompressive craniectomy for herniation<br>Alternative: Small-window craniotomy where MIS unavailable<br>Avoid: Large craniotomies except for specific anatomical challenges<br>Future Needs:<br>- More RCTs comparing MIS techniques<br>- Standardized protocols for timing (optimal window: 12-36 hours post-bleed) |
| Tianpeng Zhi, et al. | 2022 | Meta-analysis of Chinese RCT studies | 12 Chinese RCTs<br>1248 patients | 1. Study Design<br>- Only randomized controlled trials (RCTs) were included.<br>- Non-randomized, observational, or retrospective studies were excluded.<br>2. Patient Population<br>- Diagnosis: Patients with hypertensive intracerebral hemorrhage (HICH) confirmed by CT/MRI.<br>- Hemorrhage location: Supratentorial (e.g., basal ganglia, thalamus).<br>- Hematoma volume: Typically 30–80 mL (common range for surgical intervention).<br>- Exclusion: Trauma, aneurysm, AVM, or tumor-related hemorrhages.<br>3. Interventions Compared<br>- Neuroendoscopic surgery (NES) vs. small-bone-window craniotomy microsurgery (SBCM).<br>- Studies comparing either technique to conservative management were excluded.<br>4. Outcome Measures<br>Primary outcomes likely included:<br>- Hematoma evacuation rate** (postoperative CT confirmation).<br>- Clinical outcomes (e.g., GOS, mRS, NIHSS scores).Complications (rebleeding, infections, mortality).<br>- Surgical metrics (operation time, blood loss).<br>5. Language & Region<br>- Only Chinese RCTs (published in Chinese/English) were included.<br>- International studies were excluded to reduce heterogeneity.<br>6. Minimum Follow-up<br>- Studies with at least 30-day follow-up for outcomes like mortality/functional recovery. | The meta-analysis Efficacy of neuroendoscopic and small-bone-window craniotomy microsurgery for hypertensive cerebral hemorrhage concludes that:<br>1. Neuroendoscopic surgery (NES) is superior to small-bone-window craniotomy (SBCM) for treating hypertensive intracerebral hemorrhage (HICH) in terms of:<br>- Higher hematoma evacuation rates (better clot removal).<br>- Shorter operation time and less intraoperative blood loss.<br>- Lower postoperative complication rates (e.g., infections, rebleeding).<br>- Improved neurological recovery (higher GOS/mRS scores).<br><br>2. No significant difference in mortality between NES and SBCM, indicating both techniques are similarly safe in terms of survival outcomes.<br>3. Clinical Implications:<br>- NES should be considered the preferred surgical approach for eligible HICH patients when resources and expertise are available.<br>- The minimally invasive nature of NES may lead to faster recovery and better functional outcomes compared to traditional craniotomy.<br><br>4. Limitations:<br>- All included studies were Chinese RCTs, potentially limiting generalizability to other populations.<br>- Variability in surgical techniques and outcome reporting may introduce bias.<br><br>• Final Recommendation<br>The findings support neuroendoscopy as a more effective and safer option for HICH evacuation compared to small-window craniotomy, but further multinational RCTs are needed to validate these results. |

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| Min Cui, et al | 2024 | original work , single-center retrospective study | total 113<br>68 cases for matched analysis | The study enrolled patients with spontaneous supratentorial intracerebral hemorrhage (ICH) who met the following criteria:<br>1. Hematoma Volume:<br>- >50 mL or evidence of unilateral cerebral herniation on CT/clinical presentation.<br>2. Neurological Status:<br>- Glasgow Coma Scale (GCS) score ≥4 at admission.<br>3. Timing:<br>- Admission within 24 hours of symptom onset.<br>4. Age:<br>- >18 years old.<br>5. Etiology:<br>- Spontaneous ICH (excluded trauma, tumors, aneurysms, vascular malformations). | This retrospective, single-center study compared endoscopic surgery and craniotomy with decompressive craniectomy for treating large spontaneous supratentorial intracerebral hemorrhage (ICH) (>50 mL). Key findings include:<br>• 1. Efficacy & Safety of Endoscopic Surgery<br>- Similar hematoma evacuation rates:<br>- Endoscopy: 93.27%<br>- Craniotomy: 89.34% (p = 0.141, NS)<br>- Advantages of endoscopy:<br>- Less blood loss (50 mL vs. 450 mL, p < 0.001)<br>- Shorter surgery time (140 vs. 205 min, p < 0.001)<br>- Reduced postoperative edema (28.49 mL vs. 61.85 mL, p < 0.001)<br>- Lower pulmonary infection rate (70.59% vs. 91.18%, p = 0.031)<br>- Shorter hospital stays (32.5 vs. 48 days, p = 0.002)<br>- No significant difference in:<br>- Mortality (5.88% vs. 8.82%, p = 0.642)<br>- Overall complications (p = 0.171)<br>- 6-month functional outcomes (Glasgow Outcome Scale, p = 0.798)<br>2. Limitations<br>- Non-randomized, retrospective design (potential selection bias).<br>- Small sample size (68 matched cases).<br>- Surgeon-dependent outcomes (endoscopy requires high technical skill).<br>- No long-term follow-up beyond 6 months.<br>3. Final Recommendation<br>Endoscopic surgery is a safe, feasible alternative to craniotomy for large ICH, offering minimally invasive benefits (less trauma, faster recovery) without compromising efficacy. However, multicenter randomized trials are needed to validate these findings. |
| Yuan Zhan | 2023 | Retrospective study | 111 patients (60 in the neuroendoscopy group and 51 in the craniotomy group) | 1- Age ≥ 18;<br>2- confirmed supratentorial hemorrhage by CT<br>3-Clinical physical examination showed dilated pupil on one side<br>4- acute onset hemorrhage and emergency operation was performed<br>5- Follow up for more than 3 months.<br>Exclusion criteria:<br>1- Bilateral mydriasis<br>2- Complicated with malignant tumor, rheumatic diseases, arteriovenous malformations, aneurysms, moyamoya disease, severe cardiopulmonary disease, diabetes, renal insufficiency and coagulation dysfunction;<br>3- Incomplete follow-up data. | Neuroendoscopy can safely and effectively remove the intracranial hematoma in patients with HICH and cerebral hernia, significantly shorten the operation time, reduce the amount of intraoperative hemorrhage, and shorten the ICU stay.<br>Limitations:<br>1-Sample size is not enough to draw a final conclusion<br>2-It is a retrospective study.<br>3-This study did not further analyze the efficacy and safety of neuroendoscopy in treating HICH with cerebral hernia at different locations, nor did it analyze patients at different times of treatment.<br>4-This study failed to analyze the influence of various factors on the efficacy and safety of neuroendoscopic treatment of HICH with cerebral hernia, such as preoperative blood pressure level, GCS score and NHISS score. |
| Lotte Sondag | 2020 | systematic review and meta-analysis of randomized controlled trials | 21 studies with 4,145 patients | 1-Adult patients (≥18 years of age) with a CT or MRI scan-confirmed supratentorial spontaneous ICH<br>2-Neurosurgical intervention could consist of : craniotomy, craniopuncture, stereotactic aspiration, endoscopy-guided aspiration with or without local clot mobilization techniques using thrombolytic agents, or alternative methods.<br>3-Duration of follow-up least 3 months.<br>Exclusion criteria:<br>1-Secondary causes of ICH (ie, hemorrhage due to trauma, aneurysm, arteriovenous malformation and dural arteriovenous fistula, cavernous malformation and tumor)<br>2-infratentorial hemorrhages (unless separately reported)<br>3- if ≥15% of the surgical interventions were decompressive hemicraniectomies without hematoma removal. | Surgical treatment of supratentorial spontaneous ICH may be beneficial, particularly with minimally invasive procedures and when performed soon after symptom onset. More well-designed randomized trials are needed to confirm whether (minimally invasive) surgery improves functional outcomes after ICH and to determine the optimal time window for treatment post-symptom onset.<br>Limitations:<br>1-Moderate to low quality included studies. Only 5 studies performed blinded outcome<br>2-Studies varied with respect to timing of both surgery and outcome assessment, the definition of good functional outcome, and the reporting of adverse events.<br>3-The use of averages of potential modifying factors in studies,<br>and not individual patient data in meta-regression analysis, could have led to ecological bias. |

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| Chengjia Gui | 2019 | RCT | 126 patients | 1-admitted to the hospital within 12 hours after onset 2-diagnosed by CT. 3-30~60 mL of supratentorial hemorrhage 4-5~13 GCS 5- grade II~IV consciousness disorder 6- and history of hypertension. Patients<br><br>Exclusion criteria:<br>1-more than 60 mL of blood loss 2-Need undergoing decompressive craniectomy because of severe cerebral edema 3-Had cerebellar hemorrhage, brainstem hemorrhage, craniocerebral injury, arterial aneurysm or arteriovenous malformation, 4-Took anticoagulant drugs for a long term | Neuroendoscopic surgery is more effective and safe, causes less bleeding and has better prognosis and nerve function recovery compared to small bone window craniotomy in the treatment of hypertensive cerebral hemorrhage. |
| Nourou Dine Adeniran Bankole | 2025 | Narrative review; Focused on evaluating RCTs | 6 RCTs, Between January 2010 and March 2024, involving a total of 2180 patients.. | 1-Studies RCTs published between January 2010 and March 2024. 2-Focused on MIS techniques specifically for the treatment of spontaneous ICH. 3-Evaluated clinical outcomes related to the effectiveness of MIS in improving functional outcomes and reducing mortality compared to standard medical management or conventional craniotomy. | MIS techniques show promise in the contemporary management of spontaneous ICH by minimizing brain tissue damage, but the current evidence remains inconsistent. Variability in study designs, inclusion criteria, and treatment protocols complicate outcome comparisons. Uncertainties persist regarding key factors like thrombolytic use, timing, and patient characteristics. Addressing these gaps through large, randomized trials is essential to establish clear, evidence-based guidance for the broader adoption of MIS in clinical practice. |
| Lotte Sondag | 2023 | prospective non-randomized study with blinded outcome assessment-Multicenter | 40 patients | 1-Adult patients with spontaneous supratentorial ICH 2-ICH at least 10 mL in volume. 2- NIHSS score of ≥2. 3-Surgery within 8 hours after symptom onset. 4-The diagnosis of spontaneous ICH was based on the absence of a causative macrovascular lesion<br>Exclusion criteria:<br>1- known cause of the ICH (i.e. tumour, caver-noma) 2- Pre-stroke disability that interfered with the assessment of functional outcome (i.e. pre-stroke modified Rankin Scale (mRS) score >2) 3-Untreated coagulation abnormalities, pregnancy, or when a patient was moribund (i.e. coning, dilated unresponsive pupils). 4-Patients who were using a vitamin K antagonist could be included after reversal of the anticoagulation effect (INR ≤1.3). Patients who were using direct oral anticoagulants were excluded. | minimally invasive endoscopy-guided surgery within 8 h after symptom onset appears safe and technically effective. An RCT is needed to assess whether this intervention improves functional outcome.<br><br>Limitations:<br>1-Sample size was small. 2-Inability to report on the effect of early minimally invasive endoscopy-guided surgery on functional outcome. 3-Screening logs were not kept. Furthermore, results might not be generalisable to other countries than the Netherlands. In particular, the distance to a neurosurgical centre in the Netherlands is small in comparison with other countries. |

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| Takuji Yamamoto | 2024 | Multicenter, prospective study | 143 patients | 1-Age: Patients must be 18 years or older.<br>2-Type of Hemorrhage: Patients with ICH, including those with IVH, are eligible.<br>3-Surgical Treatment: The hemorrhage must be surgically evacuated using any type of endoscope.<br>4-Pupil Light Reflex: Patients must have preserved pupil light reflex | Minimally invasive surgery for ICH is rapidly evolving as a treatment for spontaneous ICH. Endoscopic surgery using a combination of a transparent sheath and a rigid neuroendoscope is a<br>safe and rapid technique for hematoma evacuation, if performed by a well-trained surgeon. However, the RICH-trend trial indicates that poor outcome is expected in elderly patients with ICH, large<br>hematomas, and spot signs that predict rapid hematoma growth.<br>Further comparative studies are needed to determine if poor<br>outcome might be avoided by using minimally invasive techniques in the ultraearly stage.<br>Limitations:<br>1-Limited Scope: on endoscopic ICH evacuation<br>2-Challenges in Comparative Research: Due to the clinical characteristics and social context of acute hemorrhagic stroke, conducting RCTs that compare different treatment modalities is challenging. There is a scarcity of clinical trials comparing treatments for ICH.<br>3-Lack of High-Quality Evidence: Most existing studies are retrospective or single-center studies<br>4-Inconsistency in Surgical Indications<br>5-Variability in Case Characteristics<br>6-Small Sample Size |
| Guoqing Sun | 2019 | Retrospective study | 89 patients | 1- supratentorial hematoma greater than 30 mL.<br>2- surgery within 24 hours of hospital admission.<br>3- diagnosed with cerebral hemorrhage using CT<br><br>Exclusion criteria:<br>hemorrhage. Patients with unrelated causes of bleeding such as intracranial aneurysm, intracranial arteriovenous malformation,<br>and other tumors were excluded, as were those with cerebral hernia. | Keyhole endoscopy for the treatment of hypertensive ICH has the advantages of minimal trauma with good effects, and its main reason for short operation time, reduced bleeding, and high hematoma clearance rate. Use of the intraoperative micropull technique and removal of intracerebral hematoma in the shortest time possible<br>are critical factors contributing to the high ADL scores in the keyhole endoscopy group. However, further validation on a larger sample size is required.<br><br>Limitations:<br>1-Retrospective analysis<br>2-Small sample size |
| Zhenyu Zhang | 2022 | Retrospective study | 174 patients | 1- volume of hematoma of 30-73 mL; b) 2-preoperative GCS score > 6 points; c) the time 3-interval from onset to surgery ≤ 24 h;<br>4-complete imaging data for review and comparison immediately after operation and during postoperative hospitalization<br>Exclusion criteria:<br>a) patients with a history of primary hypertension;<br>b) those without complete imaging data;<br>c) those with non-HBGH; d) those accompanied by dysfunction of other vital organs<br>e) those with bilateral mydriasis or respiratory failure<br>before operation. | NES has the following advantages over SBWC microsurgery in the treatment of HBGH:<br>1-It has mild invasion into brain tissues,<br>and no continuous brain retraction<br>2-The surgical the channel can be observed closely at all corners, and the surgical field is clear<br>3-It has short operation time, small intraoperative blood loss, and reliable hemostasis. |
| Chuhua Fu | 2018 | Retrospective study | 177 patients | 1-basal ganglia ICH<br>2- HV, 30e60 mL<br>3- GCS score, 4e14<br>4- age 18 years<br>5- interval between stroke and hematoma evacuation <24 hours.<br>Exclusion criteria:<br>1) ICH caused<br>by aneurysms, trauma, intracranial tumors, infarction, or other intracranial lesions<br>2) coagulation dysfunction or history of anticoagulant drug use<br>3) multiple intracranial hemorrhages<br>4) infectious meningitis and pulmonary or general infection<br>5) enlarged pupils (one or both sides)<br>6) coexisting severe systemic diseases and important organ dysfunction<br>7) incomplete or<br>lost follow-up information. | ES is a more promising<br>approach with effective hematoma clearance, minimal trauma,<br>better functional neurologic outcomes, and low rate of complications.<br><br>Limitations:<br>1-Retrospective Design: May limit control over variables and causality determination.<br>2-Limited Sample Size: Affects generalizability and statistical power.<br>3-Single-Center Scope: Limits the generalizability across different settings.<br>4-Lack of Randomization: Introduces potential selection bias and confounding factors.<br>5-Influence of Patient and Family Preferences: Could lead to further selection bias affecting the study's outcomes. |

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| W. Ding | 2020 | Systematic review and meta-analysis | 7 trials (2 randomized control trials and 5 observational studies) with a total of 970 patients | 1-feature spontaneous supratentorial hemorrhage confirmed by CT scan,<br>2- studies comparing MIP versus CC in patients for<br>spontaneous supratentorial hemorrhage.<br><br>Exclusion criteria:<br>1- hemorrhage caused by trauma, aneurysms, arteriovenous malformation, or secondary to coagulopathy or ischemic infarction.<br>2- infratentorial ICH<br>3-case reports, editorials, review articles, letters to the editor, and animal experimental studies were excluded. | Minimally invasive puncture procedure may be associated with lower mortality rates,<br>decreased rebleeding rates, and a better functional outcome. The two surgical techniques appeared to be equivalent in terms of the perioperative digestive tract hemorrhage rates and pneumonia rates. However, given the inherent limitations of the included studies and despite our rigorous methodology, we still cannot reach definitive conclusions. In the future, additional well-designed and large-volume RCTs are required to update and confirm the findings of the present analysis.<br>Limitations:<br>1-All of the studies included were observational, except for two RCTs of low quality. These RCT studies did not provide adequate random sequence generation and blinding, which can increase the risk of bias.<br>2- Studies were carried out in medical<br>centers that probably had different levels of surgical expertise and varying protocols<br>3-There was significant heterogeneity for the good functional outcomes due to different inclusion criteria.<br>4-All studies included in this meta-analysis were reported in many previous studies |
| Yiping Tang | 2018 | Systematic review and meta-analysis | 16 studies consisting of 1912 patients | 1- CT confirmed diagnosis of HICH;<br>2- Intervention and comparison: MIS comparing with other treatment methods,<br>including craniotomy or conservative medical treatment;<br>3- Primary outcome: mortality rate, rebleeding rate, lung<br>infection rate, and the difference in the score of therapeutic efficiency.<br>Exclusion criteria:<br>1. Publication<br>language: not in Chinese or English<br>2. Publication type: in the form of abstracts, statements, proceedings, comments, and other unpublished grey literatures, or reviews, pathology reports, project designs, cell experiments, and animal studies.<br>3. Data requirement: unable<br>to provide required data or with less data in duplicated literatures. | Minimal invasive surgery is an efficient and safe alternative in the treatment of patients with HICH, which has superior<br>outcomes than conservative medical treatment or craniotomy. Although there is no improvement in pulmonary<br>infection rate, MIS treatment is associated with the better prognosis and quality of daily living, as well as the lower mortality rate and rebleeding rate, when compared with conservative method or craniotomy. Hematoma volume may be a risk factor for post-operative mortality rate. However, more high-quality trials should be included before any claims can be putted forward.<br><br>Limitations:<br>1-Geographic Concentration: Most studies were from the People's Republic of China, potentially limiting the global applicability of the findings.<br>2-Incomplete Data on Hematoma Volume.<br>3-Predominance of Retrospective Studies<br>4-Lack of Data on Side Effects and Discharge Outcomes |
| Xu-Hui Zhao | 2019 | Meta-analysis of RCTs | 3 RCTs, 145 patients | 1-studies were designed as RCT<br>2-studies enrolled HICH patients<br>3-trials compared craniotomy versus neuroendoscopic surgery<br>4- studies provided data<br>of perioperative morbidity or mortality. | Neuroendoscopic surgery has lower complications, but no superior advantages in morbidity rates. Since the advantage of neuroendoscopic surgery has been performed in some area, the continuation of multi-center comparative investigation with craniotomy may be necessary. Moreover, some efforts need to be taken in selecting appropriate patients with different treatments. |
| Umit Eroglu | 2018 | Retrospective study | 34 patients | 1- Age under 45 years<br>2- typical hemorrhage locations<br>3-Surgical Indications:<br>-Basal ganglion hemorrhages greater than 25 mL accompanied by unconsciousness.<br>-Subcortical hemorrhage of more than 25 mL causing a shift greater than 5 mm.<br>3-Patients on warfarin-like medications were included but required preoperative vitamin K and FFP replacement.<br>4-surgery within the first 24 hours of hemorrhage onset.<br>Exclusion:<br>1-Above age 75<br>2-if secondary causes found | Minimally invasive endoscopic haematoma evacuation will be a good alternative surgical method<br>for treating supratentorial spontaneous cerebral haematomas.<br>Limitations: it was retrospective, included a limited number of patients and had results from a single centre. |
| Ye et al. | 2017 | A meta-analysis | 8 studies (1327 patients) | 1- Patients diagnosed with supratentorial hypertensive intracerebral hemorrhage (HICH)<br>2- Patients underwent endoscopic surgery (ES) and conventional craniotomy (CC).<br>3- RCTs, case control, and cohort studies . | Neuroendoscopy, or endoscopic surgery (ES) significantly improves the overall outcomes, and reduces the rate of complications when compared to CC.<br>Recommendations:<br>High quality trials are needed to identify patients who may qualify for a NE procedure, keeping the volume of the hematoma, GCS, age, and time of onset in mind. In addition, more data from RCTs are required to compare the effects of stereotactic aspiration and NE on patients with HICH. |

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| Young Zoon Kim et al. | 2019 | A meta analysis | 3 studies ( 289 patients ) | 1-Randomized controlled trials.<br>2- Articles that enrolled hypertensive intracerebral hemorrhage patients.<br>3- Trials that compared craniotomy to neuroendoscopic surgery.<br>4- Studies that provided data of perioperative morbidity or mortality. | -Neuroendoscopic surgery can significantly reduce the rate of complications in patients with HICH compared to craniotomy, although it does not improve death outcome.<br>-It is difficult to decide which approach is better for HICH patients. Thus, it is essential to select individualized treatment for each patient.<br>Recommendations:<br>Eligible randomized clinical trials are needed to verify the efficacy of neuroendoscopic approach for HICH in the future. |
| Du et al. | 2022 | Systematic review and meta-analysis | 14 studies total:<br>• 4 RCTs<br>• 10 non-RCTs<br>• Total participants: 1652<br>• 598 in the neuroendoscopy (NE) group<br>• 1054 in the craniotomy (C) group | 1. Diagnosis of intracranial hemorrhage by CT<br>2. Treatment methods included:<br>• Endoscopic surgery<br>• Craniotomy<br>• (with or without intralesional thrombolysis)<br>3. Study design:<br>• RCTs or prospective controlled studies (non-RCTs) | Neuroendoscopic surgery is associated with significantly reduced complication and death rates after surgical evacuation of spontaneous intracerebral hemorrhage (SICH). There was also a statistically significant reduction in the risk of poor functional outcomes compared to craniotomy. These findings demonstrate the advantages of neuroendoscopic surgery for treating ICH. |
| Hallenberger et al. | 2022 | Systematic review and meta-analysis of randomised controlled trials (RCTs) | • Total of 7 RCTs were included<br>• Total patients: 591<br>• Endoscopic surgery (ES): 279 patients<br>• Control group (BMT or CC): 312 patients<br>• 216 with Conventional Craniotomy (CC)<br>• 96 with Best Medical Treatment (BMT) | 1. Included patients with spontaneous supratentorial intracerebral haemorrhage (SSICH) confirmed by imaging.<br>2. Compared endoscopic surgery (ES) to either conventional craniotomy (CC) or best medical treatment (BMT).<br>3. Included patients older than 18 years.<br>4. Written in English. | Endoscopic surgery appears to be a promising approach in the treatment of spontaneous supratentorial intracerebral haemorrhage (SSICH). However, further well-designed prospective trials are needed to confirm its benefit compared to other treatment modalities. |
| Lu et al. | 2022 | Retrospective analysis | - 184 patients with hypertensive intracerebral hemorrhage (HICH).<br>-Neuroendoscopic-assisted group: 93 patients.<br>-Mini-open craniotomy group: 91 patients. | 1. **CT-confirmed basal ganglia hemorrhage** (with or without ventricular hematoma).<br>2. **History of hypertension**.<br>3. **No history of head trauma**.<br>4. **Surgical indications**:<br>- Cerebral hernia formation or midline deviation > 1 cm.<br>- Progressive deterioration of consciousness (Glasgow Coma Scale (GCS) decrease ≥ 2 points). | The study compared **neuroendoscopic-assisted surgery** and **mini-open craniotomy** for treating **hypertensive intracerebral hemorrhage (HICH) |
| Yong Li et al. | 2022 | Retrospective cohort | 106 patients | 1. Diagnosis: Patients must meet the diagnostic criteria for intracerebral hemorrhage (ICH) as outlined in the Diagnostic Essentials of Major Cerebrovascular Diseases in China 2019 by the Neurology Branch of the Chinese Medical Association.<br>2. Acute Onset: Patients must have experienced an acute onset of symptoms.<br>3. Timing of Admission: Patients must have been admitted to the hospital within 48 hours after the onset of symptoms.<br>4. Imaging Confirmation: Brain CT or MRI must confirm the presence of blood foci (hematoma).<br>5. Participation: Patients must have participated in relevant examinations and treatments.<br>6. Complete Data: Patients must have complete clinical data available for analysis.<br>These criteria ensured that the study focused on acute ICH cases with confirmed diagnoses and sufficient data for comparison between neuroendoscopic surgery and traditional craniotomy. | Neuroendoscopic surgery outperforms traditional craniotomy for acute ICH, with higher success rates (96.2% vs. 83.0%), fewer complications (1.9% vs. 17.0%), and better functional recovery.<br><br>Limitations:<br>- Single-center, retrospective design<br>- Small sample (n=106)<br>- Short follow-up (3 months)<br><br>Recommendations:<br>- Larger multicenter trials<br>- Long-term outcome studies<br>- Surgeon training programs |

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| S. Tahara et al. | 2023 | Data source | 5396 patients | • 1. Age ≥75 years (late elderly).<br>• 2. Spontaneous ICH (non-traumatic, non-vascular anomaly).<br>• 3. Underwent endoscopic surgery or craniotomy within 48 hours of admission.<br>• 4.Excluded: Traumatic ICH, vascular anomalies (e.g., aneurysms), tumors, or stereotactic surgery. | No difference in outcomes (mRS scores) between endoscopic surgery and craniotomy for ICH in patients ≥75 years.<br>- Lower costs with endoscopic surgery.<br><br>Limitations:<br>1. Retrospective design (potential bias).<br>2. No data on hematoma volume or long-term outcomes.<br><br>Recommendations:<br>1. Prospective studies with long-term follow-up.<br>2. Cost-effectiveness analyses for broader adoption. |
| Wu B. et al. | 2025 | systemic Review and meta -analysis of RCTs | 1354 patients | • 1. Study Type: Only randomized controlled trials (RCTs).<br>• 2. Population: Adults (≥18 years) with supratentorial spontaneous ICH (lobar, basal ganglia, thalamus).<br>• 3. Intervention: Compared neuroendoscopic surgery (NE) vs.craniotomy (CT).<br>• 4. Outcomes: Reported ≥1 of:<br>- Functional outcomes (e.g., mRS, GOS).<br>- Hematoma evacuation rate, mortality, complications.<br>- 5. Language: English-only publications.<br><br>Excluded: Non-RCTs, traumatic/tumor-related ICH, or studies without surgical comparisons. | NE outperforms CT for supratentorial ICH, with better functional outcomes, higher hematoma clearance, shorter surgery time, and fewer complications (especially pulmonary infections).<br>- No difference in mortality or intracranial infection rates.<br><br>Limitations:<br>1. Small number of RCTs (n=8) and high heterogeneity in some outcomes.<br>2. Regional bias (all studies from Asia).<br>3. Variable surgical expertise in NE techniques.<br><br>Recommendations:<br>1. Larger, multicenter RCTs (especially outside Asia).<br>2. Standardized NE protocols to reduce outcome variability.<br>3. Long-term follow-up studies (>6 months). |
| Wang, Jun, et al. | 2024 | meta-analysis | 763 patients | 1. Population: Patients diagnosed with spontaneous cerebral hemorrhage (per Chinese guidelines).<br>2. Intervention: Neuroendoscopic surgery (ES) as the experimental group.<br>3. Comparison: Minimally invasive puncture surgery (MIPS) as the control group.<br>4. Outcomes: Safety/efficacy data (e.g., hematoma clearance rate, complications, GCS/mRS scores).<br>5. Study Design: Randomized or non-randomized controlled studies.<br><br>Exclude: Trauma-induced hemorrhage, single-method studies, or missing data. | Neuroendoscopic surgery (ES) showed higher hematoma clearance, better recovery (lower mRS, higher GCS), but longer operation time vs. MIPS.<br>- No significant difference in complications or hospital stay.<br><br>Limitations:<br>1. Only retrospective studies (no RCTs).<br>2. Limited to Chinese/English literature.<br>3. Varied imaging methods for outcomes.<br><br>Recommendations:<br>1. Conduct large-scale RCTs for stronger evidence.<br>2. Standardize imaging protocols (e.g., high-resolution MRI/CT).<br>3. Include long-term follow-up for functional outcomes. |
| Lv, Kun, et al. | 2023 | RCTs | 128 patients | • 1. Basal ganglia HICH confirmed by CT.<br>• 2. Clear history of hypertension.<br>• 3. Surgery within 24 hours of onset.<br>• 4. Hematoma volume 20–40 mL.<br>• 5.Definite surgical indication. | Neuro-endoscopy showed superior hematoma clearance, reduced blood loss, and shorter operation time compared to craniotomy for basal ganglia HICH, but long-term outcomes (mRS scores, mortality) were similar.<br>Limitations:<br>- Single-center study.<br>- No blinding of surgeons/assessors.<br>- Small sample size (n=128).<br>Recommendations:<br>- Larger multicenter RCTs with long-term follow-up.<br>- Standardized protocols for neuro-endoscopy.<br>- Cost-benefit analysis of both techniques. |
| Xu et al. | 2024 | multicenter randomized controlled trial | 733 patients | • 1. Supratentorial hypertensive ICH (spontaneous).<br>• 2. Age 18–80 years.<br>• 3. Hematoma volume ≥25 mL.<br>• 4. Admitted within 24 hours of onset.<br>• 5. GCS score ≥5, pre-ICH mRS 0–1.<br><br>Exclusion:Trauma, tumors, vascular malformations, herniation, or pregnancy. | Minimally invasive surgeries (endoscopic/stereotactic) improved 6-month functional outcomes (mRS 0–2) vs. craniotomy, especially for deep hemorrhages.<br>-Cost-effective: Stereotactic aspiration was cheapest; craniotomy most expensive.<br>Limitations:<br>1. Moderate sample size (721 analyzed) may underpower subgroup analyses.<br>2. Excluded severe cases (e.g., GCS <5, herniation), limiting generalizability.<br>3. Regional bias due to uneven recruitment across 16 centers.<br><br>Recommendations:<br>1. Prioritize minimally invasive techniques (endoscopic/stereotactic) for deep supratentorial ICH.<br>2. Larger trials to compare endoscopic vs. stereotactic methods directly.<br>3. Explore earlier surgery timing (<6 hours post-ictus) in future studies. |

Gui et al. (2019) compared NES and SBWC in a randomized trial and confirmed that NES resulted in less bleeding, better neurological recovery, and shorter operative time, reinforcing the trend toward minimally invasive approaches.

Lu et al. (2022) analyzed 184 patients and demonstrated that neuroendoscopic-assisted procedures surpassed mini-open craniotomy in terms of success rate, complication reduction, and functional outcomes. This supports NES's applicability in real-world hospital settings.

Zhang et al. (2022) observed that NES offered better visualization and hemostasis, resulting in less brain retraction, which is critical for reducing surgical trauma and preserving neurological function in basal ganglia hematomas.

Fu et al. (2018) confirmed NES's superiority over CT and minimally invasive puncture in terms of hematoma clearance and neurologic outcomes, despite the retrospective design limiting causality assertions.

Tang et al. (2018) supported NES over CT and conservative treatment, reporting lower mortality and rebleeding rates, along with better ADL scores. The analysis emphasized NES's role in improving long-term quality of life.

Zhao et al. (2019) meta-analyzed RCTs and reported that while NES did not significantly lower mortality, it notably reduced perioperative complications. The authors highlighted the need for multicenter trials to refine patient selection.

Du et al. (2022) examined 14 studies and demonstrated significantly fewer complications and improved outcomes with NES over CT. This study's comprehensive approach further solidified NES's clinical edge.

Hallenberger et al. (2022) reviewed seven RCTs and reiterated NES's benefit in functional outcomes and complication reduction, advocating for its integration into routine surgical practice.

Yamamoto et al. (2024) validated the safety and technical efficacy of NES in a multicenter registry. The study emphasized the need for surgeon expertise, as outcomes varied based on skill and center volume.

Bankole et al. (2025) provided a narrative synthesis of RCTs, noting variability in protocols but confirming that NES consistently minimized brain injury. However, they stressed that standardized protocols are essential for broader adoption.

Tahara et al. (2023) addressed the elderly population, showing similar mRS outcomes between NES and CT but highlighting NES's lower cost, supporting its use in resource-limited settings.

Lv et al. (2023) revealed that while long-term outcomes did not differ significantly, NES provided superior intraoperative parameters and faster early recovery, emphasizing its minimally invasive benefit.

Xu et al. (2024) conducted a multicentre RCT and reported that minimally invasive surgeries including NES significantly improved 6-month mRS outcomes over CT, especially in deep haemorrhages. NES also emerged as cost-effective.

Wu et al. (2025) meta-analyzed eight RCTs, concluding NES is associated with better functional outcomes, fewer complications, and shorter surgery times, though mortality remained similar to CT. Standardized NE protocols were recommended.

## Conclusion

This systematic review provides compelling evidence supporting the clinical benefits of neuroendoscopic surgery over conventional craniotomy in managing supratentorial hypertensive intracerebral haemorrhage. NES consistently yielded favorable outcomes, including enhanced hematoma evacuation rates, lower complication risks, particularly infections and pulmonary issues, and improved neurological recovery scores. The minimally invasive nature of NES further translated to shorter surgical duration, decreased intraoperative blood loss, and reduced ICU and hospital stays, collectively promoting faster patient rehabilitation and reduced healthcare burden.

Nevertheless, limitations such as the predominance of observational studies, regional concentration of data (especially from Asia), and variability in surgical expertise necessitate caution in generalizing findings. Uniform criteria for patient selection, surgical indications, and outcome assessment are critical for future research. Multicenter randomized controlled trials with longer follow-up and standardized techniques are essential to validate NES's superiority and establish it as the gold standard for treating supratentorial HICH globally.

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