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Evaluation of three minimally invasive surgical techniques for hematoma removal in elderly patients with hypertensive intracerebral hemorrhage: A pilot randomized study

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Abstract

Objective: To compare the efficacy and safety of three minimally invasive surgical (MIS) techniques—neuroendoscopic hematoma removal, minimally invasive soft channel puncture and drainage, and small bone window microhematoma removal—in elderly patients with hypertensive cerebral hemorrhage. *Methods:* A total of 60 elderly patients with hypertensive cerebral hemorrhage were randomly assigned to one of three groups: neuroendoscopic hematoma removal (n=20), minimally invasive soft channel puncture and drainage (n=20), and small bone window microhematoma removal (n=20). Operative parameters (surgical time, intraoperative bleeding), postoperative complications, and long-term neurological outcomes (National Institutes of Health Stroke Scale -- NIHSS and Glasgow Outcome Scale -- GOS scores) were assessed and compared among the groups. *Results:* Neuroendoscopic hematoma removal was associated with significantly shorter surgical times (141.3±14.9 minutes) and reduced intraoperative bleeding (119.4±22.1 ml) compared to the other techniques (P<0.01). Postoperative complication rates were lower in the neuroendoscopic group (1.59%) compared to the small bone window (30%) and soft channel groups (15%) (P<0.05). Long-term outcomes, measured by NIHSS and GOS scores, were significantly better in the neuroendoscopic group, indicating improved neurological recovery and functional status (P<0.01).
*Conclusion***:** Neuroendoscopic hematoma removal may offer significant advantages over small bone window microhematoma removal and minimally invasive soft channel puncture and drainage in terms of operative efficiency, reduced complications, and improved long-term neurological outcomes. These findings should be validated in future large sample-sized, multi-center, randomized trials.

Keywords: Minimally-invasive: hematoma; soft channel puncture; small bone window

INTRODUCTION

Hypertensive intracerebral hemorrhage (HICH) is a common and severe form of stroke, characterized by bleeding within the brain tissue due to elevated blood pressure.[1] It accounts for approximately 10-15% of all strokes and is associated with high morbidity and mortality rates.[1] The condition often leads to significant neurological deficits and long-term disability, making effective management critical for improving patient outcomes.[2]

The primary goal in the management of HICH is to rapidly reduce intracranial pressure, remove the hematoma, and prevent secondary brain injury.[3] Traditional craniotomy has been the standard surgical intervention for hematoma evacuation; however, it is associated with significant surgical trauma, prolonged recovery times, and high rates of postoperative complications.[4] As a result, there has been a growing interest in minimally invasive surgical (MIS) techniques, which aim to reduce surgical trauma while maintaining effective hematoma clearance.[4,5]

Neuroendoscopic surgery, minimally invasive soft channel puncture and drainage, and small bone window microhematoma removal are three such MIS techniques that have gained attention

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in recent years.[4] Neuroendoscopic surgery, in particular, has shown promise due to its ability to provide excellent visualization, minimize tissue damage, and reduce intraoperative bleeding.[6] Despite the advantages, the optimal surgical approach for HICH remains a topic of ongoing research and debate.

Several studies have compared these techniques in terms of efficacy, safety, and long-term outcomes. For instance, Gui *et al*. (2019)[6] demonstrated that neuroendoscopic surgery results in shorter surgical times, less intraoperative bleeding, and better hematoma clearance compared to small bone window craniotomy. Similarly, studies by Ye *et al*. (2017)[4] and Zhan *et al*. (2023)[7] have reported improved functional outcomes and higher rates of favorable prognosis following neuroendoscopic interventions.

However, despite the growing body of literature, there remains a significant gap in comprehensive, head-to-head comparisons of these three MIS techniques in elderly patients with hypertensive cerebral hemorrhage. Most existing studies have either focused on a single technique or compared two at a time, often with varying patient populations and outcome measures. Furthermore, there is limited data on the long-term outcomes and specific postoperative complications associated with each technique in a standardized setting. This study aims to address this gap by providing a comprehensive comparison of the three MIS techniques—small bone window microhematoma removal, minimally invasive soft channel puncture and drainage, and neuroendoscopic hematoma removal—in elderly patients with hypertensive cerebral hemorrhage.

METHODS

Study design and population

A total of 60 elderly patients with HICH admitted to the neurosurgery department of the Affiliated Hospital of Chengdu University and West China Hospital of Sichuan University between July 2022 and December 2023 were included in this pilot randomized study (Figure 1). Patients were randomly assigned into three groups: the Small Bone Window Microhematoma Removal Group, the Minimally Invasive Soft Channel Puncture and Drainage Group, and the Neuroendoscopic Hematoma Removal Group, with twenty patients in each group. One patient from the Neuroendoscopy Group withdrew from the study after three months and was classified as a "post-discharge dropout."

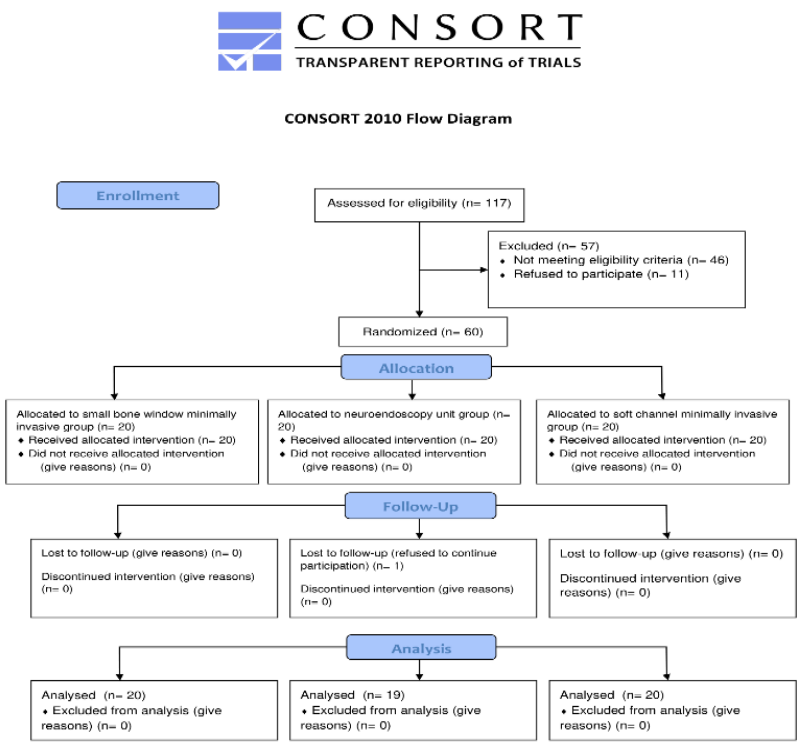

Figure 1. A flow chart showing the recruitment process of patients in this study

Randomization and blinding

Patients were randomly allocated to the three intervention groups using a computer-generated random number sequence. This method ensured that each patient had an equal chance of being allocated to any of the study groups, thereby minimizing selection bias. Due to the nature of the intervention, it was not feasible to blind the patients or the surgeons to the group assignments. However, the outcome assessors were blinded to the group allocations to reduce assessment bias.

Inclusion and exclusion criteria

Patients were included if they had all of the following criteria:

1. Patients aged 60 years and older.
2. Confirmed history of primary hypertension.
3. Admission to the hospital within one day of symptom onset.
4. Diagnosis of cerebral hemorrhage was confirmed by cranial CT according to the guidelines set by the Chinese Stroke Association for intracerebral hemorrhage.[8]
5. Quantification of cerebral hemorrhage volume using Tada's formula.[7]

On the other hand, patients were ruled out if they had any of the following criteria:

1. Patients with cerebral herniation, intraventricular rupture, or hemorrhage in the cerebellum and brainstem.
2. Patients with secondary cerebral hemorrhage (e.g., traumatic brain injury, stroke).
3. Patients with tumors or coagulation disorders.
4. Patients with severe systemic diseases affecting the heart, lungs, liver, or kidneys.

This study was approved by the Ethics Committee of our hospital (registration code NO:2022ZZ143 and date of approval: 01/03/2022). All participants provided informed consent for surgery. This research was conducted in line with the recommendations set by the Declarations of Helsinki.

Treatment protocol

Basic treatment

Upon hospital admission, patient history, including onset, past medical history, and life history, was documented. Symptomatic treatments such as oxygen therapy, dehydration to reduce intracranial pressure, and correction of water and electrolyte imbalances were administered. Once stabilized, patients underwent head CT scans, Glasgow Coma Scale (GCS), and National Institutes of Health Stroke Scale (NIHSS) evaluations.

Surgical procedures

Small bone window microhematoma removal group

A 5 cm scalp incision was made, and the soft tissues and scalp fascia were retracted. A cranial window measuring approximately 3 cm x 2 cm was created. Under microscopic guidance, the dura mater was gently peeled back, exposing the hematoma. The hematoma was evacuated using a hematoma cavity approach, where a No. 12 soft channel drainage tube was inserted into the hematoma cavity based on the predefined direction and depth, and after pulling out the guide core, drainage was gently done with a 5 mL syringe. This was followed by repeated saline irrigation, hemostasis using electrocoagulation, and placement of intracerebral drainage tubes. The dura was sutured, and drainage tubes were removed after approximately three days.

Minimally invasive soft channel puncture and drainage group

A 10-mm incision was made at the puncture site, and a burr hole was drilled in the skull. A silicone tube (F12-F14) was carefully inserted to avoid damaging important nerves and vessels. A disposable intracranial hematoma puncture needle (YL-1) was used to aspirate the hematoma with a 10 ml syringe, altering the angle to maximize hematoma removal. After pressure reduction, the syringe was removed.

Neuroendoscopic hematoma removal group

A 5 cm scalp incision was made, and the bone flap was drilled. The dura mater was peeled back, and a tube-core lens set was used to access the hematoma cavity. The tube core was removed, and a rigid observation lens was inserted to aspirate the hematoma gently and from multiple angles. Hemostasis was achieved using electrocoagulation and a gelatin sponge.

Postoperative care

Postoperatively, all patients were monitored in the intensive care unit (ICU) for one day and received symptomatic treatments such as oxygen therapy and measures to reduce intracranial pressure. Patients were then transferred to specialized wards for regular monitoring of consciousness and wound healing. Family members were educated on preventing complications and postoperative rehabilitation strategies.

Outcome assessment

Efficacy was assessed based on surgical data (operation time, intraoperative bleeding, hospitalization duration). Functional outcomes were evaluated using the NIHSS at three months postoperatively to reflect neurological deficit improvements, with higher scores indicating more severe deficits. The Glasgow Outcome Scale (GOS) was used to assess clinical outcomes, with the following categories:

- Five points: good recovery along with the return to normal life.
- Four points: Mild disability, able to live independently and work with some protection.
- Three points: Severe disability, requiring daily care.
- Two points: Vegetative state, minimal responses such as sleep-wake cycles, and eye-opening.
- One point: Death.

Meanwhile, safety was assessed in terms of postoperative complications (i.e., intracranial infection, pulmonary infection, stress ulcers, renal failure, rebleeding).

Statistical analysis

Statistical analyses were performed using SPSS 26.0 software. Data were assessed for normal distribution and variance homogeneity. Continuous data were expressed as mean ± standard deviation (x±s) and analyzed using one-way ANOVA for comparisons among the three groups. Post-hoc analyses were conducted using the LSD-t test for significant ANOVA results (P<0.05). Categorical data were expressed as frequencies (n) and analyzed using chi-square tests, with P<0.05 considered statistically significant.

RESULTS

Baseline data of the three groups

Table 1 summarizes the baseline characteristics and clinical data of included patients in all groups. All patients had a mean age of 68.15 (4.95) with the majority of patients being males (61.01%). No significant differences were observed between all groups regarding age (P=0.36), gender (P=0.69), timing of hypertension (P=0.07), GCS score (P=0.17), and volume of cerebral hematoma (P=0.08). The thalamic region accounts for the majority of hemorrhagic sites (49.15%) followed by basal ganglia (32.20%). No differences in hemorrhagic sites were noted between the three intervention groups (P=0.31).

Operative parameters

Operative parameters are detailed in Table 2. The surgical time was significantly different among the groups, with the Soft Channel Minimally Invasive Group having the shortest mean surgical time (79.9±16.3 minutes), followed by the Neuroendoscopy Unit (141.3±14.9 minutes), and the Small Bone Window Minimally Invasive Group (187.4±23.7 minutes) (P<0.01). Similarly, surgical bleeding was significantly lower in the Soft Channel Minimally Invasive Group (39.2±19.6 ml) compared to the Neuroendoscopy Unit (119.4±22.1 ml) and the Small Bone Window Minimally Invasive Group (176.8±42.9 ml) (P<0.01). Hospitalization time was also significantly reduced in the Soft Channel Minimally Invasive Group (8.9±1.8 days) compared to the other groups (P<0.01).

Postoperative complications

Postoperative complications are shown in Table 3. There were no significant differences among the groups in terms of intracranial infection, pulmonary infection, stress ulcer, renal failure, or rebleeding rates. The incidence of intracranial infection was 1 (5%) in the Small Bone Window Minimally Invasive Group, 2 (10%) in the Soft Channel Minimally Invasive Group, and 0 (0%) in the Neuroendoscopy Unit (P=0.4). Pulmonary infection rates were 6 (30%), 4 (20%), and 3 (15.78%) in the respective groups (P=0.68). Stress ulcer occurrence was similar across all groups, with rates of 4 (20%), 3 (15%), and 3 (15.78%), respectively (P=0.93). Renal failure was observed in 2 (10%) patients in both the Small Bone Window Minimally Invasive and Soft Channel Minimally Invasive Groups, while no cases were reported in the Neuroendoscopy Unit (P=0.4). Rebleeding occurred in 3 (15%), 4 (20%), and 2 (10.52%) patients, respectively (P=0.8).

Table 1: Comparison of baseline information among the three groups

Group	Age (years)	Gender		History of primary hypertension (years)	GCS score (points)	Cerebral hematoma volume (ml)	Hemorrhage site		
		Male	Female				Thalamic region	Basal ganglia region	Lobar region
Small Bone Window Minimally Invasive Group (n=20)	67.42±4.26	12 (60%)	8 (40%)	11.6±3.34	7.94±2.07	46.9±7.34	9 (45%)	7 (35%)	4 (20%)
Soft Channel Minimally Invasive Group (n=20)	66.93±5.14	11 (55%)	9 (45%)	13.1±2.42	6.71±1.86	42.4±6.81	12 (60%)	7 (35%)	1 (5%)
Neuroendoscopy Unit (n=19)	69.04±4.94	13 (68.42%)	6 (31.58%)	13.5±1.97	7.46±2.24	47.2±8.08	8 (42.1%)	5 (26.31%)	6 (31.58%)
F (χ^2) Value	1.03	(0.75)		2.82	1.81	2.6		(4.76)	
P Value	0.36	0.69		0.07	0.17	0.08		0.31	

Functional outcomes

Functional outcomes are summarized in Table 4. The NIHSS scores significantly improved in all groups postoperatively, with the Neuroendoscopy Unit showing the greatest improvement (preoperative: 16.71±4.06, postoperative: 9.39±3.42; P<0.01). In terms of postoperative values, the neuroendoscopy unit had the lowest NIHSS score followed by soft channel and small bone window minimally invasive groups (9.39 vs. 12.79 vs. 13.01), respectively. The GOS prognostic grading indicated that the Neuroendoscopy Unit had the highest number of patients with good recovery (14 patients, 73.68%) and no deaths. In comparison, the Small Bone Window Minimally Invasive Group had 9 patients (45%) with good recovery and 2 deaths (10%), while the Soft Channel Minimally Invasive Group had 12 patients (60%) with good recovery and 1 death (5%). The differences in GOS prognostic grading among the groups were not statistically significant (P>0.05).

DISCUSSION

In this study, we compared the outcomes of three different minimally invasive surgical techniques for the removal of cerebral hematomas in elderly patients with HICH: small bone window microhematoma removal, minimally invasive soft channel puncture and drainage, and neuroendoscopic hematoma removal. Our findings suggest that neuroendoscopic hematoma removal is superior in terms of surgical time, surgical bleeding, and hospitalization time, as well as having fewer postoperative complications and better long-term outcomes.

Our results align with several previous studies that have demonstrated the efficacy and safety of neuroendoscopic surgery in treating intracerebral hemorrhage. Gui *et al.* (2019)[6] found that neuroendoscopic surgery resulted in shorter surgery times, less intraoperative bleeding, and higher hematoma clearance rates compared to small bone window craniotomy.[6] Similarly, Zhan *et al.* (2023)[7] reported that neuroendoscopic surgery had the highest hematoma clearance rate and the shortest operation time compared to conventional craniotomy. The consistency of these findings across multiple studies highlights the reliability and robustness of neuroendoscopic techniques in managing cerebral hemorrhages.

Moreover, studies by Nam *et al.* (2019)[9] and Zhan *et al.* (2023)[7] have shown that patients undergoing neuroendoscopic surgery experience

Table 2: Comparison of operative time; operative bleeding; and operative anesthesia time among the three groups

Group	Surgical time	Surgical bleeding	Hospitalization time
Small Bone Window Minimally Invasive Group (n=20)	187.4 ± 23.7	176.8 ± 42.9	14.1 ± 2.9
Soft Channel Minimally Invasive Group (n=20)	79.9 ± 16.3	39.2 ± 19.6	8.9 ± 1.8
Neuroendoscopy Unit (n=19)	141.3 ± 14.9	119.4 ± 22.1	9.7 ± 2.6
F Value	165.19	104.75	25.48
P Value	$P<0.01$	$P<0.01$	$P<0.01$

Table 3: Comparison of postoperative complications among the three groups

Group	Intracranial infection	Pulmonary infection	Stress ulcer	Renal failure	Rebleeding
Small Bone Window Minimally Invasive Group (n=20)	1 (5%)	6 (30%)	4 (20%)	2 (10%)	3 (15%)
Soft Channel Minimally Invasive Group (n=20)	2 (10%)	4 (20%)	3 (15%)	2 (10%)	4 (20%)
Neuroendoscopy Unit (n=19)	0 (0%)	3 (15.78%)	3 (15.78%)	0 (0%)	2 (10.52%)
χ^2 Value	1.83	0.76	0.14	1.84	0.5
P Value	0.4	0.68	0.93	0.4	0.8

Table 4: Comparison of pre- and postoperative NIHSS scores and postoperative Glasgow scores among the three groups

Group	Comparison of NIHSS scores before and after surgery		GOS Prognostic Grading				
	preoperative	postoperative	Good recovery	Mild disability	Severe disability	Vegetative survival	Death
Small Bone Window Minimally Invasive Group (n=20)	17.53 ± 4.28	13.01 ± 2.69	9 (45%)	6 (30%)	2 (10%)	1 (5%)	2 (10%)
Soft Channel Minimally Invasive Group (n=20)	18.29 ± 2.47	12.79 ± 1.99	12 (60%)	6 (30%)	1 (5%)	0 (0%)	1 (5%)
Neuroendoscopy Unit (n=19)	16.71 ± 4.06	9.39 ± 3.42	14 (73.68%)	3 (15.78%)	2 (10.52%)	0 (0%)	0 (0%)
F (χ^2) Value	0.9	10.53	(0.86)	(0.85)	(0.41)	(1.89)	(1.83)
P Value	0.41	P<0.01	0.65	0.65	0.82	0.39	0.4

better overall recovery and functional outcomes compared to those treated with other methods. These studies collectively suggest that neuroendoscopic surgery not only provides immediate surgical benefits but also contributes to improved long-term patient health.[6] This also goes in line with the results of a recent systematic review and meta-analysis which demonstrated that minimally invasive surgery, including neuroendoscopic techniques led to significantly better outcomes compared to conservative treatment and craniotomy.[10] Specifically, it was associated with a higher GCS score and lower mortality rate, further validating the superiority of this approach in managing HICH.

Operative time and bleeding

The significantly shorter operative times and reduced intraoperative bleeding associated with neuroendoscopic surgery observed in our study are consistent with those reported by Wei *et al.* (2021)[11] and Xu *et al.* (2017)[12], who highlighted the advantages of neuroendoscopy in minimizing surgical trauma and improving recovery times. Shorter operative times reduce the duration of anesthesia exposure, which is particularly beneficial for elderly patients who are at greater risk of anesthesia-related complications.[13] Additionally, reduced intraoperative bleeding minimizes the risk of perioperative blood transfusions and associated complications.[14]

Our data show that the neuroendoscopic group had an average surgical time of 141.3±14.9 minutes and an intraoperative bleeding volume of 119.4±22.1 ml, significantly lower than the other two groups. These findings are corroborated by the work of Wang *et al.* (2024)[15], who found that neuroendoscopic techniques result in significantly lower blood loss and shorter operation times compared to traditional craniotomy and minimally invasive puncture methods. The ability to achieve better hemostasis and visualization with neuroendoscopy likely contributes to these improved intraoperative outcomes. These findings go in line with the results of an updated systematic review/meta-analysis study that included 15 high-quality randomized trials examining 2,152 patients with intracerebral hemorrhage.[16] The authors concluded that the minimally invasive approach, particularly the neuroendoscopic surgery, showed superiority over traditional methods (conservative medical and conventional craniotomy approaches either with or without the small bone window flap) by improving surgical efficiency while minimizing intraoperative complications.

Postoperative complications

Our findings on postoperative complications indicate that neuroendoscopic surgery results in fewer complications such as intracranial and pulmonary infections, stress ulcers, and renal failure compared to the other techniques. This observation is supported by Ye *et al.* (2017)[4], who demonstrated that neuroendoscopic evacuation of hematomas significantly reduces the risk of postoperative infections and other complications. The lower complication rates can be attributed to the minimally invasive nature of neuroendoscopic procedures, which cause less damage to surrounding brain tissue and reduce the risk of secondary injury.[6] The reduced trauma to brain tissues and the ability to perform precise and controlled hematoma evacuation likely contribute to the decreased incidence of complications.[17]

Long-term outcomes

In terms of long-term neurological outcomes, our study shows that patients treated with neuroendoscopic surgery had better NIHSS and GOS scores compared to those treated with other methods. This is in line with the results of Wang *et al.* (2021)[18], who reported improved functional outcomes and higher rates of favorable prognosis following neuroendoscopic interventions. The enhanced visualization and precision offered by neuroendoscopic tools likely contribute to the better preservation of neurological function and overall recovery.[19]

The neuroendoscopic group in our study demonstrated significantly lower postoperative NIHSS scores and higher GOS scores, indicating better neurological recovery and overall functional status. Studies by Wei *et al.* (2021)[11] and Jiang *et al.* (2024)[19] have similarly shown that neuroendoscopic techniques are associated with improved long-term outcomes and reduced neurological deficits. These findings underscore the long-term benefits of neuroendoscopic surgery in preserving neurological function and enhancing patient quality of life.

Despite the promising results, our study has several limitations. The relatively small sample size and short follow-up period may limit the generalizability of our findings. Future research should focus on larger, multicenter trials with longer follow-up periods to validate these results and provide more comprehensive insights into the long-term benefits and potential risks associated with different minimally invasive techniques for hematoma removal.

Moreover, while our study did not involve blinding, it is an aspect that should be considered in future trials to minimize bias and improve the reliability of the findings. The inclusion of patient-reported outcomes and quality-of-life measures would also provide valuable information on the impact of these surgical techniques from the patients' perspective.

Our study demonstrates that neuroendoscopic hematoma removal may offer significant advantages over small bone window microhematoma removal and minimally invasive soft channel puncture and drainage in terms of operative time, intraoperative bleeding, postoperative complications, and long-term neurological outcomes. These findings support the conduct of multi-center, large sample-sized, triple-blinded trials to further validate the short- and long-term benefits.

DISCLOSURE

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Conflicts of interest: None

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