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ORIGINAL RESEARCH

Neuroendoscopic Parafascicular Evacuation of Spontaneous Intracerebral Hemorrhage (NESICH Technique): A Multicenter Technical Experience with Preliminary Findings

Long Wang · Xiaodong Li · Zhongyong Deng · Qiang Cai · Pan Lei · Hui Xu · Sheng Zhu · Tengyuan Zhou · Ran Luo · Chao Zhang · Yi Yin · Shuixian Zhang · Na Wu · Hua Feng · Rong Hu

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ABSTRACT

***Introduction*:** Intracerebral hemorrhage (ICH) is a severe manifestation of stroke, demonstrating notably elevated global mortality and morbidity. Thus far, effective therapeutic strategies for ICH have proven elusive. Currently, minimally invasive techniques are widely employed for ICH management, particularly using endoscopic hematoma evacuation in cases of deep ICH. Exploration of strategies to achieve meticulous surgery and diminish iatrogenic harm, especially to the corticospinal tract, with the objective of enhancing the neurological prognosis of patients, needs further efforts.

***Methods*:** We comprehensively collected detailed demographic, clinical, radiographic, surgical, and postoperative treatment and recovery data for patients who underwent endoscopic hematoma removal. This thorough inclusion of data intends to offer a comprehensive overview of our technical experience in this study.

***Results*:** One hundred fifty-four eligible patients with deep supratentorial intracerebral hemorrhage who underwent endoscopic hematoma removal were included in this study. The mean hematoma volume was 42 ml, with 74 instances of left-sided hematoma and 80 cases of right-sided hematoma. The median Glasgow

Long Wang, Xiaodong Li, Zhongyong Deng, and Qiang Cai have contributed equally to this work.

L. Wang · T. Zhou · R. Luo · C. Zhang · Y. Yin · S. Zhang · H. Feng · R. Hu (✉)
Department of Neurosurgery, Southwest Hospital, Third Military Medical University (Army Medical University), Chongqing 400038, China
e-mail: huchrong@tmmu.edu.cn

X. Li
Department of Neurosurgery, Siping Central People's Hospital, Siping, Jilin Province, China

Z. Deng
Department of Neurosurgery, Wuzhou Gongren Hospital, Wuzhou, Guangxi Province, China

Q. Cai · P. Lei
Department of Neurosurgery, Renmin Hospital of Wuhan University, Wuhan, Hubei Province, China

H. Xu
Department of Neurosurgery, Hejiang County People's Hospital, Luzhou, Sichuan Province, China

S. Zhu
Department of Neurosurgery, Dazhu County People's Hospital, Dazhou, Sichuan Province, China

N. Wu
Department of Epidemiology, College of Preventive Medicine, Third Military Medical University (Army Medical University), Chongqing, China

Coma Scale (GCS) score at admission was 10 (range from 4 to 15), and the median time from symptom onset to surgery was 18 (range 2 to 96) h. The mean hematoma clearance rate was 89%. The rebleeding and mortality rates within 1 month after surgery were 3.2% and 7.8%, respectively. At the 6-month mark, the proportion of patients with modified Rankin Scale (mRS) scores of 0–3 was 58.4%.

***Conclusion*:** Both the reduction of surgery-related injury and the protection of the residual corticospinal tract through endoscopic hematoma removal may potentially enhance neurological functional outcomes in patients with deep ICH, warranting validation in a forthcoming multicenter clinical study.

Keywords: Intracerebral hemorrhage; Endoscopic surgery; Surgical technique

Key Summary Points
Why carry out this study?
At present, there is no definite surgical treatment method to improve the functional outcomes of patients with deep intracerebral hemorrhage
Further exploration is needed on how to achieve precision surgery and minimize iatrogenic injuries to improve the neurological prognosis of patients
What was learned from the study?
Neuroendoscopic parafascicular surgical evacuation can effectively clear hematoma and protect neurological function and has the potential to improve the functional outcomes of patients
Prospective, multicenter, randomized controlled clinical studies are needed to validate this

INTRODUCTION

Intracerebral hemorrhage (ICH) is a substantial contributor to global mortality and disability [1]. Research indicates that individuals afflicted with ICH encounter significant challenges, with morbidity and mortality rates reaching approximately 40% within the initial month and 54% within the inaugural year, respectively. The attainment of long-term functional independence is observed in only a limited proportion of cases, ranging from 12 to 39% [2].

In principle, surgical removal of hematoma may improve neurological function by alleviating mechanical compression and curtailing secondary injury [3]. However, two prominent randomized controlled trials (STICH I and STICH II) failed to demonstrate any advantages of craniotomy over standard care concerning mortality or functional outcomes assessed using the extended Glasgow Outcome Scale [4, 5]. Considering the findings from the STICH trials, a notable paradigm shift has occurred, favoring the adoption of minimally invasive techniques for ICH evacuation to minimize potential iatrogenic harm to the neighboring healthy brain tissue [6, 7]. The guidelines of the American Heart Association/American Stroke Association (AHA/ASA) in 2022 further endorsed that, compared to conventional craniotomy, minimally invasive surgery holds promise for augmenting neurological function in patients [8].

The ENRICH-ICH trial showed that minimally invasive surgery improved functional outcomes in patients with lobar hemorrhage but not in patients with deep intracerebral hemorrhage [9]. Lobar ICH and deep ICH exhibit distinct clinical features and prognostic characteristics. Unlike lobar ICH, the development of deep ICH is predominantly linked to hypertension [10]. The recently published results of the SWITCH trial provide weak evidence that decompressive craniectomy plus best medical treatment might be superior to best medical treatment alone in people with severe deep ICH [11]. Moreover, results from the MISTIE trial underscored that significant improvement in patients' neurological function is only achievable when the hematoma volume is drastically reduced, namely to a

volume of ≤ 15 ml, by the end of treatment [12]. This discovery underscored the significant correlation between substantial reduction in hematoma size and functional improvement. Collectively, these studies emphasize the importance of minimizing brain tissue damage and ensuring a high hematoma clearance rate to enhance the functional outcome of individuals with deep ICH.

Utilization of endoscopic surgery for intracerebral hemorrhage is on the rise, offering increased rates of hematoma removal and effective hemostasis at the bleeding site [13, 14]. To optimize the benefits of endoscopic surgical intervention and improve neurological function, it is imperative to mitigate surgery-associated injury to the corticospinal tract (CST) [15]. Prior research has indicated that hematoma evacuation via an image-guided para-CST approach appears to be safer in patients with ICH with greater functional independence [16]. In this study, we present our experiences across five centers and findings, aiming to establish a standardized procedural approach for this technique. This contribution seeks to enrich the existing literature and enhance the overall comprehension of this method.

METHODS

Patient Selection

Inclusion criteria included patients aged > 18 years, the presence of hemorrhage in the basal ganglia area, hematoma volume > 25 ml, calculated using the 1/2ABC method (A: maximum length in the axial CT section; B: width perpendicular to A on the same CT section; C: the product of the number of slices and slice thickness), absence of brain herniation, and preoperative CT angiography (CTA) ruling out hemorrhage due to aneurysm or vascular malformation. Patients taking anticoagulant medications were excluded, and routine assessments of blood and coagulation parameters were conducted to exclude coagulation-related disorders.

Data Collection

A multicenter retrospective study was performed at five institutions. The study was approved by the Ethics Committee of the First Affiliated Hospital of the Army Medical University (no. KY2020114). Due to its retrospective and non-invasive design, the committee waived the requirement for the patient's informed consent. This was mutually recognized by the other four medical centers. The study was carried out in accordance with the Declaration of Helsinki. We retrospectively reviewed clinical data from patients with ICH who underwent endoscopic surgery between January 2020 and December 2022. We collected data on patient characteristics including hematoma location and volume, the presence of intraventricular hemorrhage (IVH), sex, age, procedure duration, and hematoma clearance. Hematoma volume was determined using the ABC/2 method. mRS scores were ascertained at a 6-month follow-up through outpatient visits or telephone communication. Outcome indicators also included hematoma clearance rate, rebleeding, mortality, and complications. Hematoma clearance rate was calculated as [(preoperative volume − postoperative volume)/(preoperative volume) × 100%]. Mortality was defined as all-cause death occurring within 30 days postoperatively. Rebleeding rate and complications were assessed at 1 month postoperatively [17]. Complications comprised surgical site infections, meningitis, brain abscess, pneumonia, and epilepsy.

Surgical Technique

Step 1: Preoperative Planning of Surgical Approach

The surgical approach is determined based on the hematoma's location. For hematomas situated anterior to the basal ganglia region, the middle frontal gyrus approach is selected (Fig. 1A). The incision is made adjacent to the anterior midline of the coronal suture. In the case of hematomas posterior to the basal

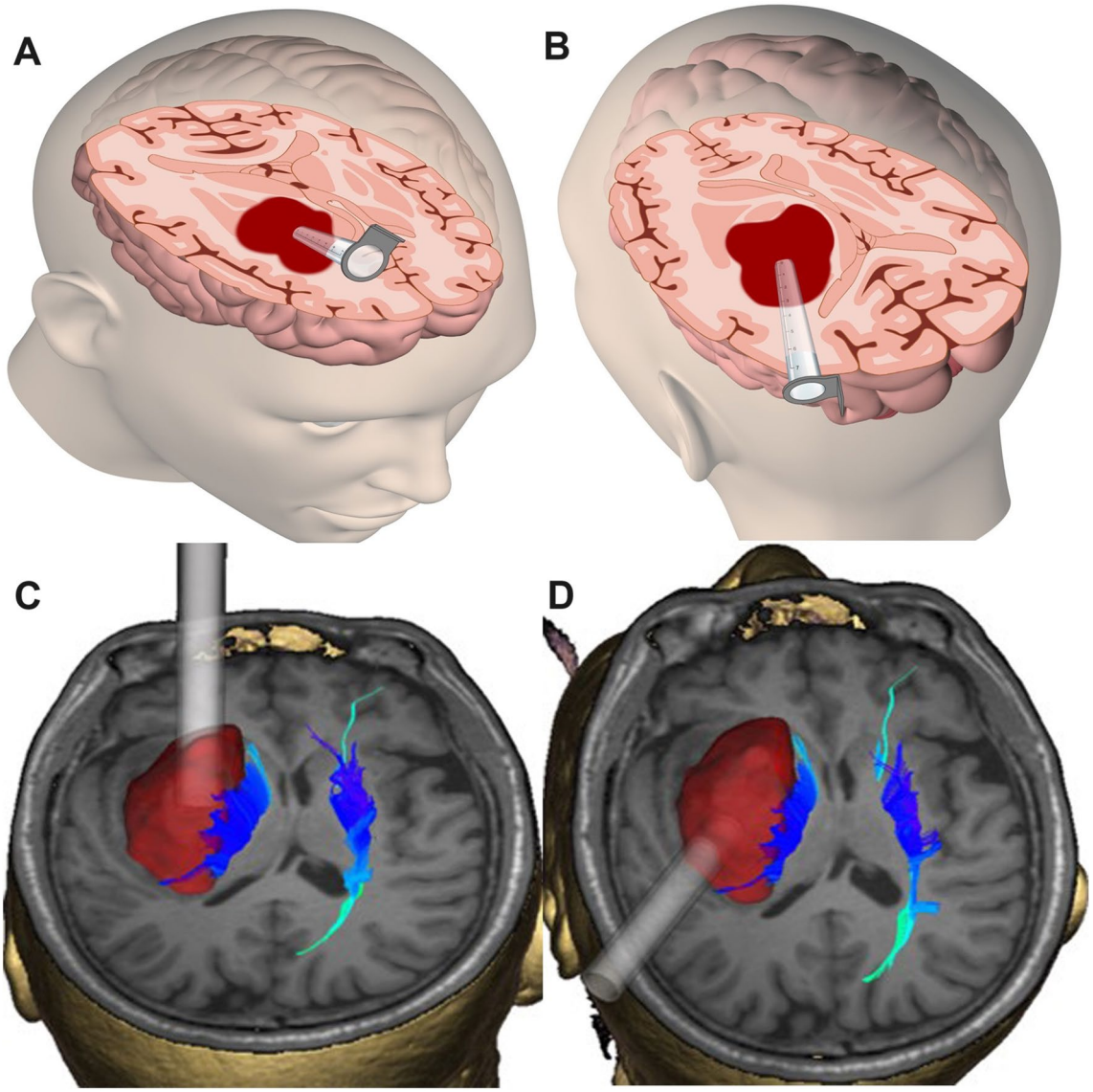

Fig. 1 Surgical approach. **A** Middle frontal gyrus approach. **B** Triangle approach. **C** Middle frontal gyrus approach avoids corticospinal tract. **D** Triangular approach avoids corticospinal tract

ganglia region, the triangle approach is chosen (Fig. 1B). Here, the incision is placed at the posterior aspect of the auricula, below the parietal tubercle. Both of these approaches follow the pathway of the projection fibers and align with the long axis of the hematoma (Fig. 1C, D).

Step 2: Accurate Puncture and Initial Decompression

The trajectory for the tubular retractor is planned using a simplified stereotactic device or neuronavigation system (if applicable) according to the established procedure [18] (Fig. 2A, B). The entry point is determined by the trajectory (see Fig. 2A, B). After making the incision, a keyhole craniotomy is performed with a diameter of approximately 2.5–3 cm,

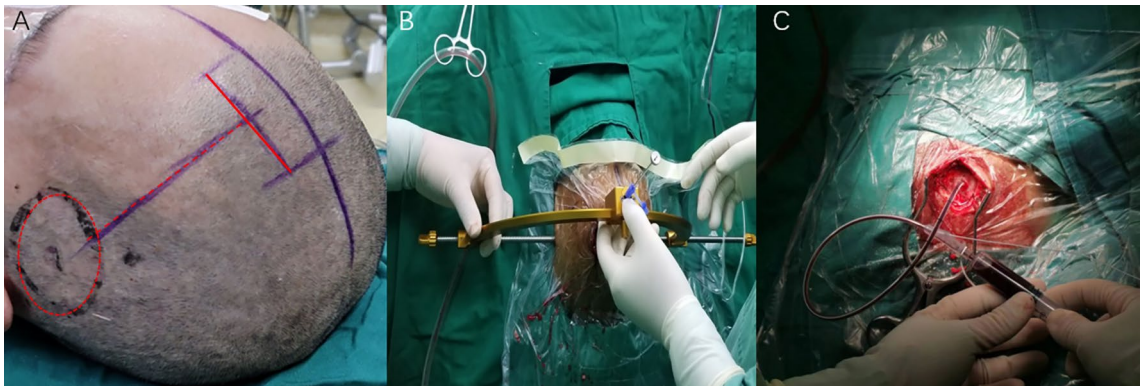

Fig. 2 Intraoperative localization and initial decompression. **A** The solid red line is the incision line, located 3 cm next to the midline (purple line); red dashed line indicates the direction of puncture; elliptical dashed line represents the surface projection of hematoma. **B** Simple directional navigation device. **C** Preceding hematoma puncture to drain the hematoma fluid to reduce intracranial pressure

followed by cruciate durotomy and arachnoid opening. An accurate puncture is made into the hematoma along the trajectory. Once the portal arrives at the hematoma, the liquefied portion of the hematoma flows out, reducing mass effect and intracranial pressure (Fig. 2C).

Step 3: Cannulation Under Endoscopic Visualization

A specific transparent tubular retractor is assembled, consisting of an outer sheath with 10 mm diameter and a hollow sharp-tip obturator (Fig. 3A). During cannulation, the endoscope is inserted into the hollow obturator and advanced slowly into the center of the hematoma cavity along the puncture trajectory. The brain tissues and the hematoma cavity can be carefully observed during cannulation to avoid any displacement (Fig. 3B–D). Once the center of the hematoma is reached, the obturator is withdrawn, leaving the outer sheath as the surgical channel.

Step 4: Hematoma Evacuation and Hemostasis

The hematoma is initially dense and should be fragmented using forceps or other instruments. Subsequently, large clots are aspirated and removed in pieces from the center of the hematoma using a suction device with a 3 mm diameter (Fig. 4A). Saline irrigation is used to gently separate residual hematoma from the surrounding tissue. Active bleeding is identified by flushing with saline, and hemostatic materials or gelatin sponges, with compression using a cotton pad, are employed to stop bleeding. If necessary, weak coagulation is applied using bipolar cautery or a monopole on the aspirator to control pulsatile small arterial bleeding (Fig. 4B, C). Once hemostasis is achieved, the sheath is gradually withdrawn. The dura is sutured, the bone flap is replaced and secured, the scalp is closed, and a dressing is applied.

Postoperative Treatment and Follow-Up

The patient is admitted to the intensive care unit (ICU) for postoperative monitoring and treatment. A CT scan is performed within 6 h after surgery to assess the extent of hematoma clearance and postoperative rebleeding. Postoperative treatments, including strict blood pressure control and nutritional support, are routinely administered. Subsequently, rehabilitation therapy commences at 2 weeks postoperatively. mRS scores are followed up through outpatient visits or video chat or telephone calls at 6 months after surgery.

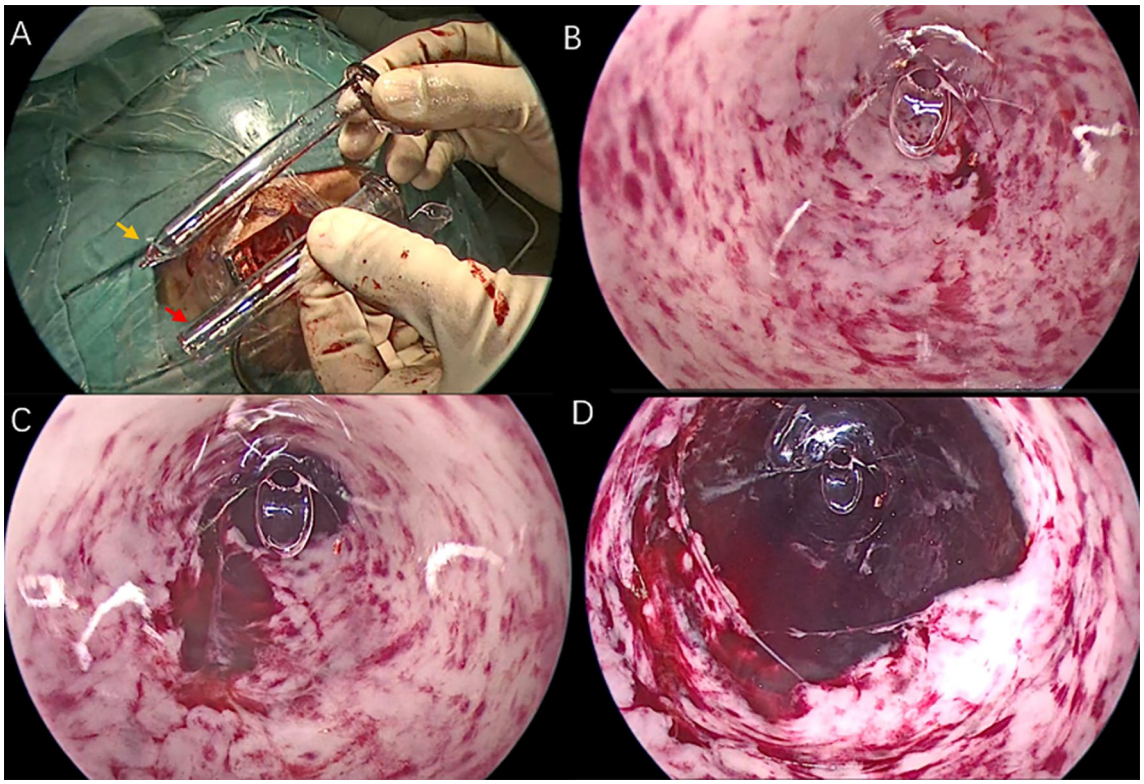

Fig. 3 Visualization of endoscopic sheath placement. **A** The endoscopic working channel is a transparent sheath composed of an inner part (yellow arrow) and outer part (red arrow). **B** Brain tissue around the transparent sheath during puncture. **C** Arriving at the edge of the hematoma cavity. **D** Reaching the hematoma and adjusting catheter position to the central part of the hematoma

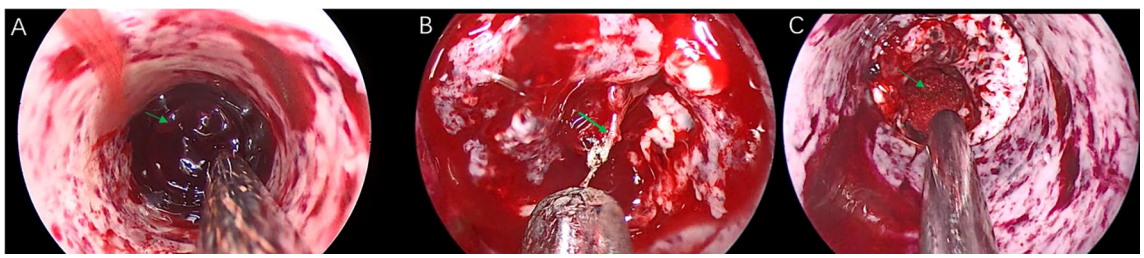

Fig. 4 Hematoma clearance process and hemostasis. **A** Removing the hematoma with an aspirator (green arrow). **B** Weak electrocoagulation for hemostasis, responsible blood vessel (green arrow). **C** Gelatin sponge (green arrow) compression of the hematoma cavity for hemostasis

RESULTS

In this study, we enrolled 154 patients, comprising 117 men and 37 women, with a median age of 56 years. Among these patients, 74 (48%) had left-side ICH and 80 (52%) had right-side ICH. The mean preoperative ICH volume was 42 ml, and the mean time from symptom onset to surgery was 23 h. Additional patient details are presented in Table 1. The surgical procedure led to a hematoma clearance rate of 89%. Three cases of infection, 5 instances of postoperative rebleeding, and 12 fatalities (7.8%)

Table 1 Characteristics of study population

Characteristics	*N* = 154 patients
Sex	
Male	117
Female	37
Age (years)	
Range	19–91
Mean (SD)	56
Median (IQR)	56
Preoperative GCS score	
13–15	39
9–12	69
3–8	46
Hematoma volume (ml)	
25–30	35
30–40	60
> 40	59
Side of hemorrhage	
Left	74
Right	80
Time to evacuation (hours)	
Range	2–96
Mean (SD)	18
Median (IQR)	23

Table 2 Outcome of surgery

Outcomes	*N* = 154 patients
Surgery time (min)	
Range	91–180
Mean (SD)	142
Median (IQR)	140
Hemostatic method	
Electric coagulation hemostasis	82
Hemostasis by compression	72
Evacuation rate (%)	
Range	25–98.9
Mean (SD)	89
Median (IQR)	92.5
30-day mortality	12
Recurrent bleeding	5
mRS score, *n* (%)	
0	0 (0)
1	18 (11.7)
2	27 (17.5)
3	45 (29.2)
4	42 (27.2)
5	10 (6.5)
6	12 (7.8)
Favorable outcome (mRS 0–3), *n* (%)	90 (58.4)

due to pulmonary infection were reported (see Table 2).

Of the patients, 64 individuals (41.5%) had a modified Rankin Scale (mRS) score of ≥ 4 points, signifying a more severe neurological outcome. Conversely, 90 patients (58.4%) experienced favorable outcome (mRS 0–3, Fig. 5). We divided patients into a good outcome group (0–3) and a poor outcome group (4–6) based on the mRS score. Comparative analysis between the two groups showed significant differences in age, hematoma volume, residual hematoma volume, preoperative GCS score, onset to surgery time, and whether the hematoma had broken into the ventricle (Table 3).

DISCUSSION

To date, conventional craniotomy with hematoma removal has not exhibited any enhancement in the functional outcomes of patients with ICH. Neuroendoscopic surgery has emerged as an alternative to craniotomy and other treatments, demonstrating superior outcomes in

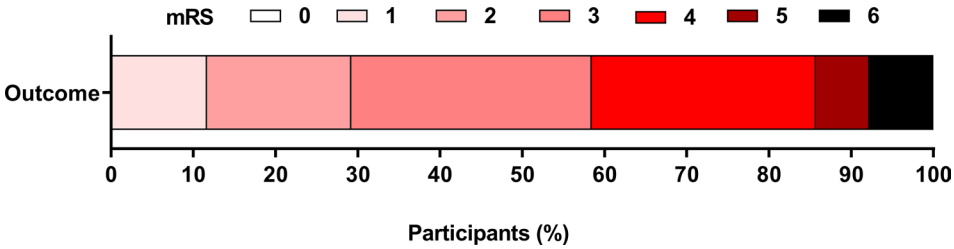

Fig. 5 Distribution of functional outcome

terms of functional recovery, mortality rate, hematoma clearance, bleeding, operating time, complications, length of hospital stay, and ICU stay [19, 20]. However, many details regarding neuroendoscopic surgery are poorly defined. In this study, we established a systemic and standard operational procedure across multicenters and displayed a remarkable advantage with high favorable outcome in patients with ICH (58.4% with mRS 0–3). A retrospective analysis revealed that among 100 patients with ICH who underwent endoscopic surgery, 46% achieved an mRS score of 0–3 at the 6-month mark [21]. The MISTIE trial indicated that patients with a clot volume < 15 ml post-treatment were more likely to have an mRS score > 3 during follow-up [12]. In our study, the mean hematoma clearance rate was 89%, surpassing the results of both the MISTIE III trial (63%) and the ENRICH study (73.2±37.8%) [9, 22]. In the MISTIE III trial, 42% had a clot volume > 15 ml at the end of treatment, while in our study, 13 patients (8.4) had a residual clot volume > 15 ml. Importantly, 58.4% of patients in our cohort achieved an mRS score of 0–3 at the 6-month follow-up, further supporting the safety and effectiveness of our endoscopic procedure.

Despite the promise of endoscopic clot removal for deep intracerebral hemorrhage, several challenges persist. One of these is the potential damage to normal brain tissue during endoscopic access (Fig. 6C, D). Minimizing damage to normal brain tissue, especially important fascicular fibers, and preserving the patient's neurological function are critical in the treatment of deep brain hemorrhage. To address this concern, appropriate surgical instruments are necessary. The diameter of the transparent sheath we use is 10 mm, which is smaller than the channel diameter reported in other literature [23, 24]. When bipolar hemostasis is required, a sheath tube with 13 mm diameter is used. A transparent sheath is employed to prevent positional deviation during cannulation and to enable clear identification of the boundary between the hematoma and surrounding tissue. The tip of the inner part is conical. When inserting into the hematoma cavity, the brain tissue is mainly pushed around rather than cut directly, which can reduce the damage caused by the establishment of the endoscopic working channel.

Additionally, selecting an appropriate surgical approach that facilitates hematoma removal while minimizing brain tissue damage is of paramount importance. Surgical access principles involve avoiding functional areas and critical vessels and identifying the shortest pathway to the center of the hematoma. For hematomas located in the basal ganglia region, the parafascicular approach is employed (Fig. 1A), avoiding Broca's area, running parallel to the projection fibers of the pathway and positioning anterior to major projection fibers such as the corticospinal tract (Fig. 1C, D). In cases where the primary body of the hematoma predominantly lies in the posterior limb of the internal capsule, the trans-triangular approach is deemed appropriate (Fig. 1B). This approach offers a shorter distance to the hematoma pathway and avoids damage to the lingual cortex and projection fibers. During hematoma removal, efforts are made to minimize damage to brain tissue near the attachment of the internal capsule. In summary, multiple surgical techniques and considerations aim to reduce damage to normal brain tissue and preserve important neural structures and function. However, further research and clinical studies are necessary to refine and optimize this approach

Table 3 Comparison of clinical characteristics between two groups of patients with different outcome

Variable	Good outcome $N=90$	Poor outcome $N=64$	*P* value
Age, years	54 ± 12	58 ± 10	0.021
Age, years			
< 60	60	33	0.059
≥ 60	30	31	
Sex			
Male	66	51	0.363
Female	24	13	
Hematoma volume (ml)	39.2 ± 11.9	46.3 ± 14.2	0.001
Hematoma volume (ml)			
< 60	79	48	0.040
≥ 60	11	16	
Intraventricular hemorrhage			
Yes	18	30	0.000
No	72	34	
Hematoma location			
Left	41	33	0.462
Right	49	31	
Time from onset to operation			
≥ 24	38	20	0.166
< 24	52	44	
Preoperative GCS score			
9–15	73	34	0.000
3–8	17	30	
Residual hematoma (ml)			
< 15	90	51	0.000
≥ 15	0	13	

for the effective and safe management of intracerebral hemorrhage.

Our study reported the intraoperative identification of active bleeding vessels in 82 patients (53.2%). When the hematoma stabilizes, the bleeding is stopped, but during the surgical removal of the hematoma, the surgical operation or decompression of the hematoma may cause the responsible blood vessel to rupture and bleed again, and these were determined to be the vessels responsible for the bleeding. Gelatin sponge compression and electrocoagulation

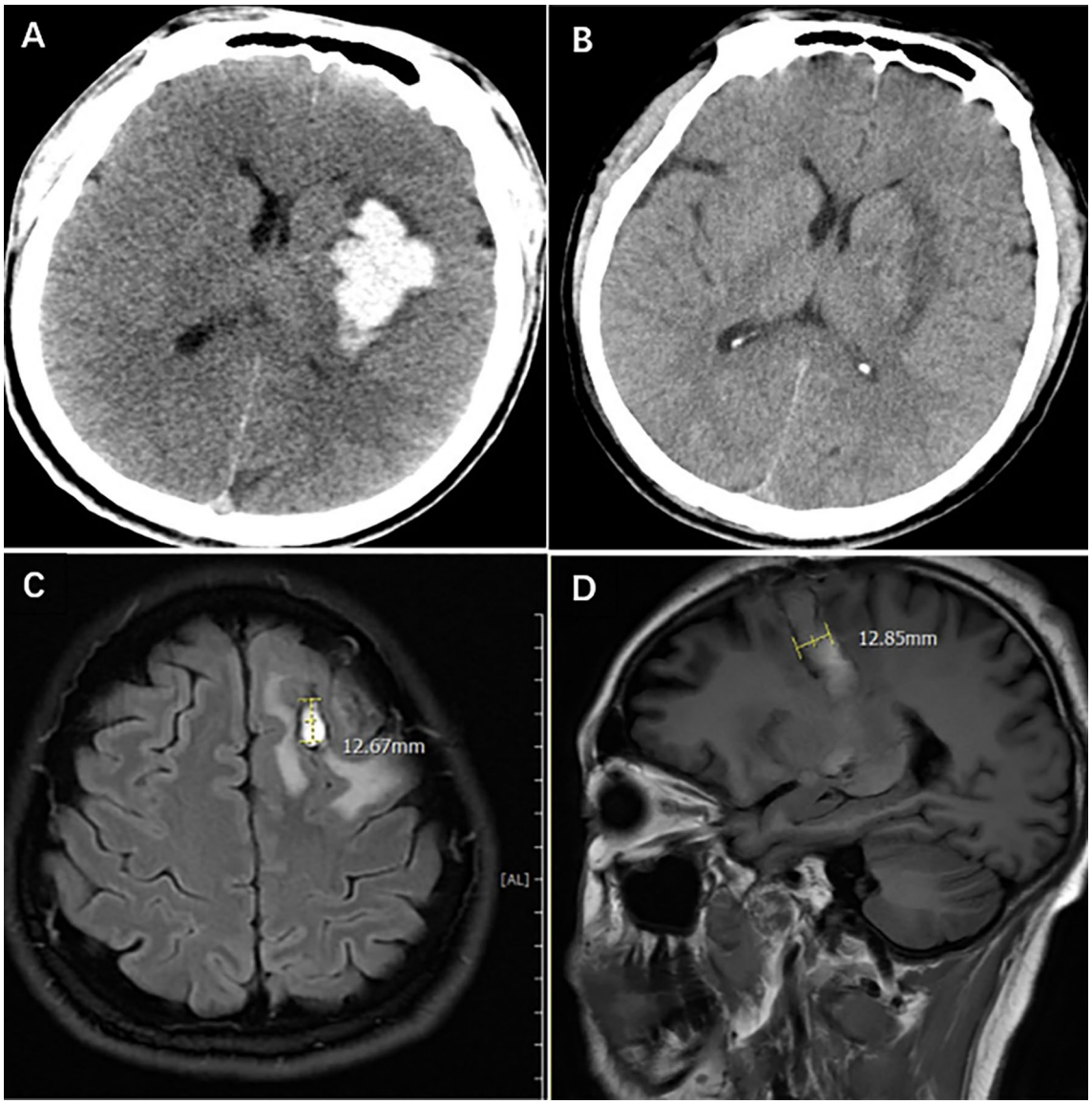

Fig. 6 Brain injury after hematoma clearance. **A** Preoperative CT. **B** Postoperative review CT. **C** Diameter of the cortical incision is about 13 mm. **D** Diameter of the cerebral sheath channel is about 13 mm

were subsequently used to control bleeding in 46.8% and 53.2% of patients, respectively. Postoperative rebleeding occurred in five patients (3.2%). Three of the five patients experienced rebleeding 4 h after surgery with significant bleeding requiring surgical intervention. The other cases of rebleeding occurred 2 days postoperatively with minimal bleeding and were managed conservatively. The incidence of postoperative rebleeding in our study aligns with a previous report where 5% of patients experienced postoperative rebleeding [21]. In conventional craniotomy, the presence of CT angiographic speckle signs has been linked to increased intraoperative bleeding, higher postoperative rebleeding rates, and greater residual intracerebral hemorrhage volume [25]. Similarly, in endoscopic surgery, a multifactorial analysis has indicated that the speckle sign is the sole independent predictor of postoperative recurrent bleeding and a significant risk factor for intraoperative bleeding [26]. Nevertheless,

in our study, five patients who experienced postoperative rebleeding did not display significant speckle signs on preoperative CTA. The occurrence of postoperative rebleeding may be attributed to incomplete hemostasis of the responsible bleeding vessel or could be associated with unstable postoperative blood pressure management. Infection has been associated with 30-day readmission and increased mortality in the majority of intracerebral hemorrhage cases [27]. In our study, we observed three cases of intracranial infection, resulting in an incidence rate of 1.9%. Additionally, eight patients succumbed to pulmonary infections. Importantly, no deaths directly attributed to the surgical procedure were noted.

Despite the encouraging outcomes reported in this series, it is essential to acknowledge the limitations of this retrospective study aimed at evaluating the safety and efficacy of the NESICH technique. First, the study is based on a relatively small sample size of patients who met strict inclusion and exclusion criteria. Second, the study lacks a control arm employing the best medical treatment. Further research is warranted to verify the performance and potential superiority of this technique over conservative management.

CONCLUSION

In conclusion, surgical intervention for intracerebral hemorrhage has demonstrated the potential to reduce patient mortality. Minimally invasive approaches, with a focus on minimizing brain tissue damage, particularly in critical functional areas and fibers, have the potential to improve the neurological prognosis for patients. In this study, we observed favorable functional outcomes with endoscopic surgical treatment for deep intracerebral hemorrhage in five medical centers, motivating us to address the limitations of this study through a multicenter, randomized, controlled trial (NESICH). The objective of this trial is to further substantiate the effectiveness and safety of endoscopic surgical intervention for deep intracerebral hemorrhage.

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Author Contributions. Long Wang, Xiaodong Li, Zhongyong Deng, and Qiang Cai performed data analysis, interpretation, and wrote the manuscript. Rong Hu designed and supervised the study and revised the manuscript. Pan Lei, Hui Xu, Sheng Zhu, Tengyuan Zhou, Ran Luo, Chao Zhang, Yi Yin, Shuixian Zhang, Na Wu, and Hua Feng collected the data and participated in the study design and data analysis. All authors read and approved the final manuscript.

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Data Availability. The datasets of this study are available from the corresponding author upon reasonable request.

Declarations

Conflict of Interest. Long wang, Xiaodong Li, Zhongyong Deng, Qiang Cai, Pan Lei, Hui Xu, Sheng Zhu, Tengyuan Zhou, Ran Luo, Chao Zhang, Yi Yin, Shuixian Zhang, Na Wu, Hua Feng, and Rong Hu declare that they have no competing interests.

Ethical Approval. The study was approved by the Ethics Committee of the First Affiliated Hospital of the Army Medical University (no. KY2020114). Due to its retrospective and non-invasive design, the committee waived the requirement for the patient's informed consent. This was mutually recognized by the other four medical centers. The study was carried out in accordance with the Declaration of Helsinki.

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