

Original Article

Endoscopic surgery for thalamic hemorrhage breaking into ventricles: Comparison of endoscopic surgery, minimally invasive hematoma puncture, and external ventricular drainage

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ABSTRACT

Purpose: Thalamic hemorrhage breaking into ventricles (THBIV) is a devastating disease with high morbidity and mortality rates. Endoscopic surgery (ES) may improve outcomes, although there is no consensus on its superiority. We investigated the efficacy and safety of ES and compared the outcomes of different management strategies by ES, hematoma puncture and drainage (HPD), and external ventricular drainage (EVD) in patients with THBIV.

Methods: We retrospectively analyzed patients with THBIV treated by ES, HPD, or EVD at our hospital from June 2015 to June 2018. Patients were categorized into anteromedial and posterolateral groups based on THBIV location, and then the two groups were further divided into ES, HPD, and EVD subgroups. Individualized surgical approach was adopted according to the location of the hematoma in the ES subgroups. Patient characteristics and surgical outcomes were investigated.

Results: We analyzed 211 consecutive patients. There were no significant differences in clinical characteristics or incidence of perioperative procedure-related complications (postoperative rebleeding and intracranial infection) in either anteromedial or posterolateral groups. Compared with other therapeutic methods, the ES subgroups had the highest hematoma evacuation rate, shortest drainage time, and lowest incidence of chronic ventricular dilatation (all $p < 0.05$). Among the three anteromedial subgroups, ES subgroup had the best clinical outcomes which was assessed by the modified Rankin Scale, followed by HPD and EVD subgroups ($p < 0.01$); while in the posterolateral subgroups, clinical outcomes in the ES and HPD subgroups were similar and better than that in the EVD subgroup ($p = 0.037$).

Conclusion: Individualized surgical ES approach for removal of thalamic and ventricular hematomas is a minimally invasive, safe, and effective strategy for the treatment of THBIV with a thalamic hematoma volume of 10–30 mL.

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Introduction

Thalamic hemorrhage accounts for 10%–15% of cases of intracerebral hemorrhage (ICH) and frequently extends into the ventricles, thus accompanying a high mortality and disability rate.^{1,2} Because the thalamus is located deep within the brain, it is difficult to treat a thalamic hemorrhage successfully by traditional craniotomy or microsurgery, and attempts to do so are associated with serious side effects.^{3,4} External ventricular drainage (EVD) is

routinely performed for a thalamic hemorrhage breaking into ventricles (THBIV),⁵ but this approach alone is often not sufficiently effective in improving the poor prognosis of patients with severe intraventricular hemorrhage.^{6,7} Minimally invasive surgery, including endoscopic surgery (ES) and hematoma puncture and drainage (HPD), has great potential for the treatment of deep cerebral hematomas and may improve patient prognosis.^{8–11} The development of neuroendoscopy technology allows surgery in long and slender channels with good illumination and multi-angle vision, which facilitates the treatment of deep hematomas without increasing the complication rate.^{12–14} Chen et al.^{15,16} used ES to remove ventricular & lateral thalamic hematomas and showed that the incidence of shunt-dependent hydrocephalus was significantly lower compared with EVD surgery. However, there is

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no uniform standard for the treatment of patients with THBIV at present.^{11,13,14,17} Therefore, studies are required to evaluate the effectiveness of the diverse THBIV treatment options.

In the current study, we introduced ES with individualized strategies to protect white matter fibers and the thalamic nucleus as a target for the treatment of THBIV and compared its efficacy with that of HPD and EVD.

Methods

Patient population

We performed a retrospective study on patients with THBIV who were admitted to the Department of Neurosurgery and underwent ES, HPD, or EVD at the Xiangyang No. 1 People's Hospital, China from June 2015 to June 2018. The hospital ethics committee approved the study protocol, and informed consent was obtained from each patient or the patient's family.

Our inclusion criteria were a diagnosis of THBIV and a thalamic hemorrhage volume (THV) of 10–30 mL. The exclusion criteria were (1) hemorrhage caused by a coagulation disorder, aneurysm, vascular malformation or tumor; (2) severe liver, kidney, heart or lung dysfunction; (3) a fourth ventricle hematoma compressing the brainstem as this is an independent risk factor for a poor prognosis after ventricular hemorrhage¹⁸; (4) a hematoma with brainstem extension; and (5) incomplete information or loss to follow-up.

The stroke team on duty assessed the surgical criteria and made treatment decisions for each case. Usually, the operation was performed when the patient had decreased consciousness and acute hydrocephalus caused by intraventricular hemorrhage or thalamic hemorrhage.

We categorized the patients into the anteromedial and posterolateral groups based on THBIV location. Then the two groups were further divided into the ES, HPD, and EVD subgroups based on the surgery approaches. We recorded baseline characteristics upon admission for each patient, including sex; age; systolic blood pressure (SBP); THV; Glasgow coma scale (GCS) score

and Graeb score; history of hypertension, diabetes or aspirin intake; and time to surgery after ictus.

Surgery subgroups and procedures

EVD subgroups

Traditional EVDs were performed in an operating room with the patient in the supine position under general anesthesia. Usually, an intraventricular catheter was placed in the frontal horn of the unilateral lateral ventricle at 10 cm H₂O, but when severe casting of both lateral ventricles was present, bilateral EVDs were required.

HPD subgroups

Patients underwent EVD, followed by HPD under general anesthesia. A soft catheter was placed into the hematoma through a burr hole positioned using preoperative computed tomography (CT) image guidance to avoid blood vessels and functional domains. The fluid component of the clot was drained or lightly sucked out using a 5-mL syringe.

ES subgroups

3D slicer software (<http://www.slicer.org>) was routinely used to simulate the surgical approach, and its length and angle were calculated (Fig. 1). Individualized surgical approach was adopted according to the location of hematoma and the rupture. Lateral ventricle frontal angle approach was used for the anteromedial group, and the lateral ventricle triangle approach was used for the posterolateral group. After anesthesia in the operating room, the patient lay in supine position. The patient's head was positioned in the middle or tilted to the opposite side for anteromedial and posterolateral THBIVs, respectively. Then, we made a 5-cm straight scalp incision, developed a bone window (approximately 3 cm in diameter), and incised the dura mater in a cross shape. A transparent endoscopic sheath (Goldbov Optoelectronic Technology Co., Ltd, Wuhan, China) was introduced after successfully puncturing the lateral ventricle, and a rigid neuroendoscope (0° or 30° observation mirror, Richard-wolf Company, Germany) was used. Then, under direct vision, the lateral ventricular hematoma was identified

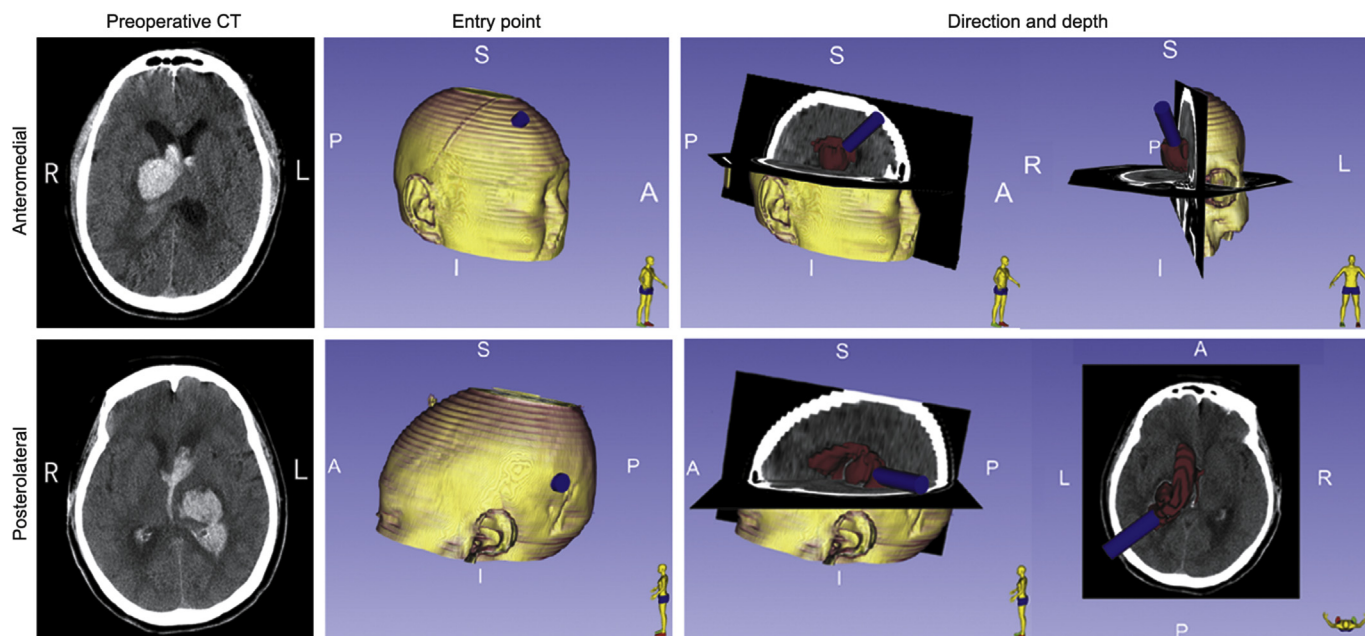


Fig. 1. Surgical approach for endoscopic surgery was simulated using a 3D-slicer software. Preoperative CT image, entry point, direction and depth of the operative passage of THBIV were evaluated. The red block represents the hematoma, and the blue column represents the operative passage. CT: computed tomography.

and cleared, the hematoma rupture of ventricular wall where the thalamic hematoma entered was found, and the thalamic hematoma was removed through this rupture (Fig. 2). If active bleeding occurred, we obtained complete hemostasis using bipolar electrocoagulation and hemostatic materials. One ventricular drainage tube was retained before closing the incision. Posterolateral THBIV cases were routinely treated with combined ES and EVD through the frontal horn of the lateral ventricle.

Postoperative treatment

Postoperative CT was performed to confirm the drainage tube position and evaluate the residual hematoma in all cases. Residual hematomas were liquified using a fibrinolysis agent (20,000 urokinase/5 mL saline solution) injected into the lateral ventricle, the hematoma cavity, or both every 12 h. Urokinase injections were discontinued when the hematoma was eliminated or could no longer be reduced based on the CT scan. When we found no further reduction in the cerebrospinal fluid blood content, the EVD was sequentially weaned in daily increments of 5 cm H₂O and removed. If hydrocephalus or decreased consciousness occurred during the weaning process, we placed a permanent ventriculoperitoneal shunt. Other treatments including blood pressure, cerebral edema, and glycemic control; gastric protection; pneumonia treatment; nutritional support; and prevention of complications were provided as necessary, according to the American Heart Association/American Stroke Association Stroke Council guidelines for the treatment of spontaneous ICH in adults.¹⁹

Therapeutic effect indices

The therapeutic effect was evaluated through the hematoma evacuation rate (ER), drainage time, perioperative complication

rate, incidence of chronic ventricular dilatation, and functional outcome as follows:

- (1) We calculated hematoma volumes using CT scans obtained preoperatively and within 24 h postoperatively and the 3D slicer method described by Xu et al.²⁰ These were used to determine the hematoma ER in each surgery subgroup.
- (2) The drainage time was defined as the number of postoperative days before ventricular drain removal.
- (3) We recorded the incidence of perioperative procedure-related complications including postoperative rebleeding and intracranial infection.
- (4) Chronic ventricular dilatation (CVD) was defined as dilatation occurring after 1 month postoperatively and characterized by chronic hydrocephalus requiring a ventriculoperitoneal shunt or ventricular dilatation caused by brain atrophy without obvious clinical symptoms.
- (5) We assessed functional outcomes by a telephone interview or face-to-face assessment at 6 months after THBIV onset using the modified Rankin Scale (mRS): 0, no symptoms; 1, no significant disability, despite symptoms; 2, slight disability; 3, moderate disability; 4, moderately severe disability; 5, severe disability; 6, dead.

Statistical analysis

Statistical analyses and data management were performed using SPSS version 13.0 (SPSS Inc., Chicago, IL, US). All data were presented as median (IQR), unless specified otherwise. Quantitative data were analyzed between subgroups using one-way analysis of variance, non-normality data analyzed using K-independent samples' nonparametric rank tests, and categorical data were compared

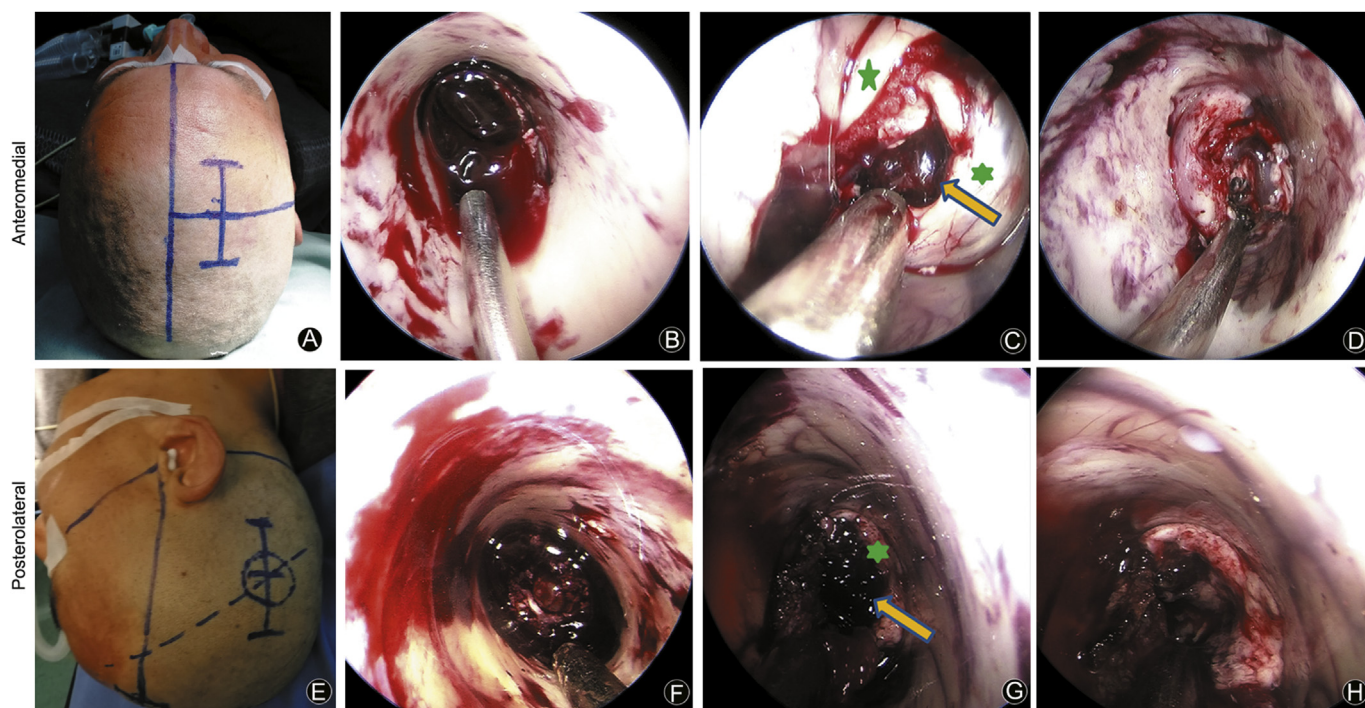


Fig. 2. Steps to remove hematoma using endoscopic surgery. (A, E) First, a 5-cm-long skin incision was cut; (B, F) Then the surgical channel was established showing an endoscopic view through a sheath inserted into the hematoma cavity; (C, G) A breach in the ventricle where thalamic hematoma entered was found after removing the lateral ventricular hematoma; (D, H) Finally, the thalamic hematoma was removed along the breach under the endoscope. The red block represents the hematoma, and the blue column the operative passage. The green pentagram represents the diaphragm, green hexagonal star represents the thalamus, and the yellow arrow points to the break in the ventricle where thalamic hematoma entered.

using chi-square tests. A p value less than 0.05 was considered statistically significant.

Results

We enrolled 211 consecutive cases (male, $n = 106$; age, 60.43 ± 11.68 years, range, 27–87 years). Table 1 shows the baseline clinical characteristics by surgery subgroups. No significant differences were found in sex, age, GCS, THV, Graeb score, SBP, medical history (hypertension, diabetes, and aspirin use), or time to operation after ictus among surgery subgroups regardless the location of the hematoma ($p > 0.05$).

In the anteromedial group, significant differences were observed regarding the drainage time, hematoma ER and CVD incidence among the ES, HPD and EVD subgroups ($p < 0.05$). The ES subgroup had the shortest drainage time (median 5 days), highest ERs (median 62.7%) and lowest CVD incidence (33.3%), followed by the HPD subgroup (data respectively 10 days, 22.7%, 50%) and EVD subgroup (data respectively 12 days, 10.8%, 71.4%). No significant differences were observed in the rates of rebleeding, intracranial infection and mortality ($p > 0.05$). For functional outcomes, assessed by mRS scores, the ES subgroup also showed a superior result ($p < 0.05$ compared with HPD and EVD). Moreover, mRS score in HPD subgroup was much better than EVD subgroup (median 3 vs. 4, $p < 0.05$) (Table 2). CT images of 3 typical cases of anteromedial THBIV is shown in Fig. 3.

In the posterolateral group, similar result was found. Significant differences were revealed in terms of drainage time, hematoma ER

and CVD incidence among three different subgroups ($p < 0.05$). The ES subgroup had the shortest drainage times (median 6 days), highest ERs (median 59.9.7%) and lowest CVD incidence (28.6%), followed by HPD (median 8 days, 28.3%, 33.3%) and EVD (median 12 days, 5.3%, 77.8%). No significant differences were obtained in the rates of rebleeding, intracranial infection and mortality ($p > 0.05$). However mRS score was slightly different from anteromedial group. The data between ES and HPD subgroups showed no difference (both median 3), which were much better than those in EVD subgroup (median 3.75, $p < 0.05$) (Table 2). CT images of 3 typical cases of posterolateral THBIV is shown in Fig. 4.

Discussion

In this study, we proposed an individualized ES strategy for minimally invasive treatment of THBIV. To our knowledge, no definite ES strategy for THBIV based on the classification of thalamic hematoma has been reported in the current literature. Furthermore, we compared the efficacy and safety of ES with conventional HPD and EVD and found that the effect of ES with individualized strategies was better than that of HPD and EVD.

ES treatment strategy

The purpose of ICH surgery is to relieve pathological damage caused by hematoma and improve the prognosis of patients. THBIV has two important pathological effects. Firstly, because the thalamus is inside the internal capsule separated from the lateral and

Table 1
Clinical baseline parameters.

Clinical parameters	Anteromedial type				Posterolateral type			
	ES ($n = 33$)	HPD ($n = 36$)	EVD ($n = 35$)	p value	ES ($n = 35$)	HPD ($n = 36$)	EVD ($n = 36$)	p value
Male gender	17 (51.5)	18 (50.0)	20 (57.1)	0.819	18 (51.4)	17 (47.2)	18 (50.0)	0.937
Age (years)	57 (52, 67)	62 (54, 70)	61 (52, 68)	0.538	60 (53, 68)	63 (52, 69)	60 (51, 64)	0.599
SBP (mmHg)	170 (142, 196)	172 (140, 196)	174 (133, 199)	0.799	176 (150, 204)	176 (156, 200)	174 (148, 202)	0.600
THV (mL)	20 (13, 26)	19 (13, 26)	18 (13, 23)	0.671	21 (15, 26)	19 (16, 25)	19 (12, 25)	0.374
Graeb score	6 (4, 9)	7 (4, 10)	6 (5, 9)	0.378	8 (4, 9)	8 (5, 10)	7 (4, 9)	0.196
GCS score	7 (5, 12)	7 (5, 9)	8 (6, 11)	0.697	8 (7, 9)	9 (7, 10)	8 (7, 10)	0.115
Hypertension	24 (72.7)	22 (61.1)	26 (74.3)	0.422	27 (77.1)	29 (80.6)	25 (69.4)	0.531
Diabetes	7 (21.2)	6 (16.7)	5 (14.3)	0.746	7 (20.0)	5 (13.9)	6 (16.7)	0.789
Taking aspirin	5 (15.2)	6 (16.7)	6 (17.1)	0.974	4 (11.4)	5 (13.9)	6 (16.7)	0.817
Time to operation (h)	11 (5, 16)	11 (6, 18)	12 (8, 19)	0.263	13 (7, 17)	13 (8, 18)	13 (7, 20)	0.774

Data are expressed as median (IQR) or n (%).

ES: endoscopic surgery; HPD: hematoma puncture and drainage; EVD: external ventricular drainage; SBP: systolic blood pressure; THV: thalamic hemorrhage volume; GCS: Glasgow coma scale.

Table 2
Comparison of observation indices among three surgical approaches in anteromedial and posterolateral groups.

Groups	Therapeutic effect						
	Drainage time (d)	ER (%)	Rebleeding	Intracranial infection	CVD	mRS score	Case fatality
Anteromedial group							
ES ($n = 33$)	5 (3, 7)	62.7 (56.1, 69.0)	5 (15.2)	4 (12.1)	11 (33.3)	2 (1, 3) ^{a,b}	1 (3.0)
HPD ($n = 36$)	10 (7, 13)	22.7 (13.6, 23.7)	6 (16.7)	5 (13.9)	18 (50.0)	3 (2, 4) ^a	2 (5.7)
EVD ($n = 35$)	12 (8, 14)	10.8 (6.3, 14.9)	8 (22.9)	9 (25.7)	25 (71.4)	4 (3, 5)	4 (11.4)
p value	<0.001	<0.001	0.680	0.267	0.007	<0.001	0.363
Posterolateral group							
ES ($n = 35$)	6 (4, 7)	59.9 (54.6, 63.2)	4 (11.4)	3 (8.6)	10 (28.6)	3 (2, 4) ^a	1 (2.9)
HPD ($n = 36$)	8 (7, 9)	28.3 (20.6, 30.5)	7 (19.4)	6 (16.7)	12 (33.3)	3 (2, 5) ^a	2 (5.6)
EVD ($n = 36$)	12 (9, 13)	5.3 (1.8, 10.3)	7 (19.4)	7 (19.4)	28 (77.8)	4 (2, 5)	3 (8.3)
p value	<0.001	<0.001	0.582	0.412	<0.001	0.037	0.605

Data are expressed as median (IQR) or n (%).

ES: endoscopic surgery; HPD: hematoma puncture and drainage; EVD: external ventricular drainage; CVD: chronic ventricular dilatation; ER: evacuation rate.

^a Means $p < 0.05$ compared with EVD group.

^b Means $p < 0.05$ compared with HPD group.

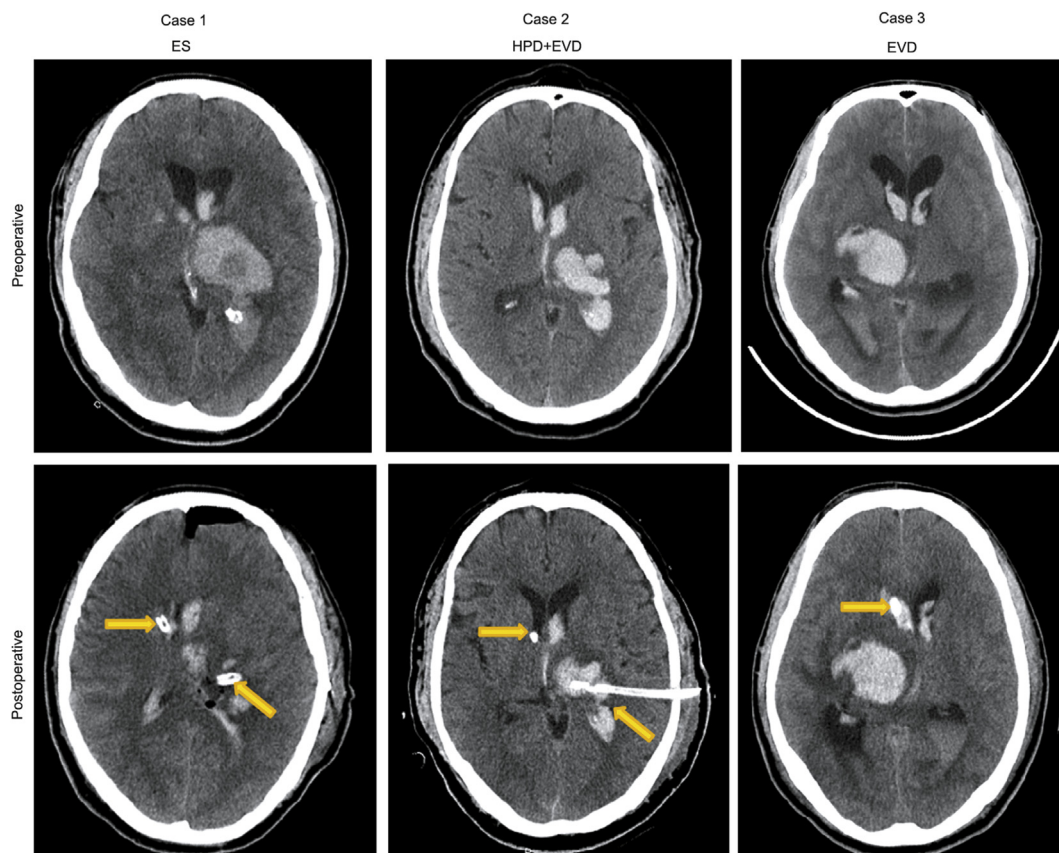


Fig. 3. THBIV patient specimens in the anteromedial group. Case 1. A 69-year-old man with an acute spontaneous right THRIV treated with ES. Case 2. A 51-year-old woman with an acute spontaneous right THRIV treated with HPD + EVD. Case 3. A 50-year-old man with an acute spontaneous right THRIV treated with EVD. Comparative preoperative (A, B, C) and postoperative (D, E, F) CT images of all the three patients are presented. The yellow arrow pointed to the position of the drainage tube. THBIV: thalamic hemorrhage breaking into ventricles; ES: endoscopic surgery; HPD: hematoma puncture and drainage; EVD: external ventricular drainage; CT: computed tomography.

third ventricles only by the ventricular wall, the hematoma usually extends into the ventricular system, damages the posterior limb of the internal capsule, and compresses the midbrain and cerebral aqueduct, which can lead to acute obstructive hydrocephalus, paralysis, or even death. Secondly, the effects of the thalamic hematoma (especially of those over 10 mL) and its associated edema progress over time, resulting in secondary injury and neurological deterioration after the first day.^{21,22} Examples include the occurrence of chronic hydrocephalus caused by long periods of poor cerebrospinal fluid circulation and the toxic effects of blood decomposition products on the ventricular wall.⁶ Therefore, managing both ventricular and thalamic hematomas at the same time relieves the cerebrospinal fluid circulation disorder caused by the hematoma and third ventricular compression, which substantially improves the prognosis of patients with THBIV.

Therefore, we used the transventricular approach to remove intraventricular and thalamic hematomas. This approach is parallel to the nerve fibers to protect white matter fibers and thus can minimize nerve damage.²³ The procedures were also based on the location of the thalamic hematoma and the rupture. Lateral ventricle frontal angle approach was used for the anteromedial group, and the lateral ventricle triangle approach was used for the posterolateral group. First, the ventricular hematoma should be cleared, then the thalamic hematoma should be removed through the rupture of the hematoma, which would avoid new damage to the thalamic nucleus. In this way, not only the hematoma can be cleared to the maximum extent, but also the damage to brain tissue can be minimized. As the thalamus has complex nerve nuclei and is located in the medial part of the internal

capsule, the transtemporal approach will damage the capsule, and thalamotomy through the corpus callosum to remove a hematoma also destroys the thalamic nuclei.

Comparison of operative methods

Definitive operative treatments for intracerebral hematomas have not been established until the present. In the past several decades craniotomy with hematoma evacuation was the treatment of choice.²⁴ However, several recent randomized trials that compared operative and conservative medical treatments failed to show that surgery led to a greater improvement in neurological outcomes.^{3,4} The injury to brain tissue that accompanies a craniotomy may offset the benefit of surgical hematoma evacuation and intracranial pressure reduction. The lack of clear benefit after a craniotomy has led many surgeons to choose minimally invasive techniques for intracerebral hematoma evacuation. Three minimally invasive surgical procedures are commonly used to treat THBIV, i.e. EVD alone, HPD + EVD and ES + EVD.

In the present study, EVD alone successfully treated acute hydrocephalus. However, blood cleared slowly from the ventricles, so the effects of the blood clot mass and toxic blood breakdown products were not addressed.^{6,7,25} Moreover, the mass effect of the thalamic hematoma and surrounding edema caused persistent compression of the third ventricle, resulting in chronic obstruction of the cerebrospinal fluid circulation that required long-term (generally over a week) EVD, which increased the risk of complications and poor outcome.²⁶ HPD removes both ventricular and

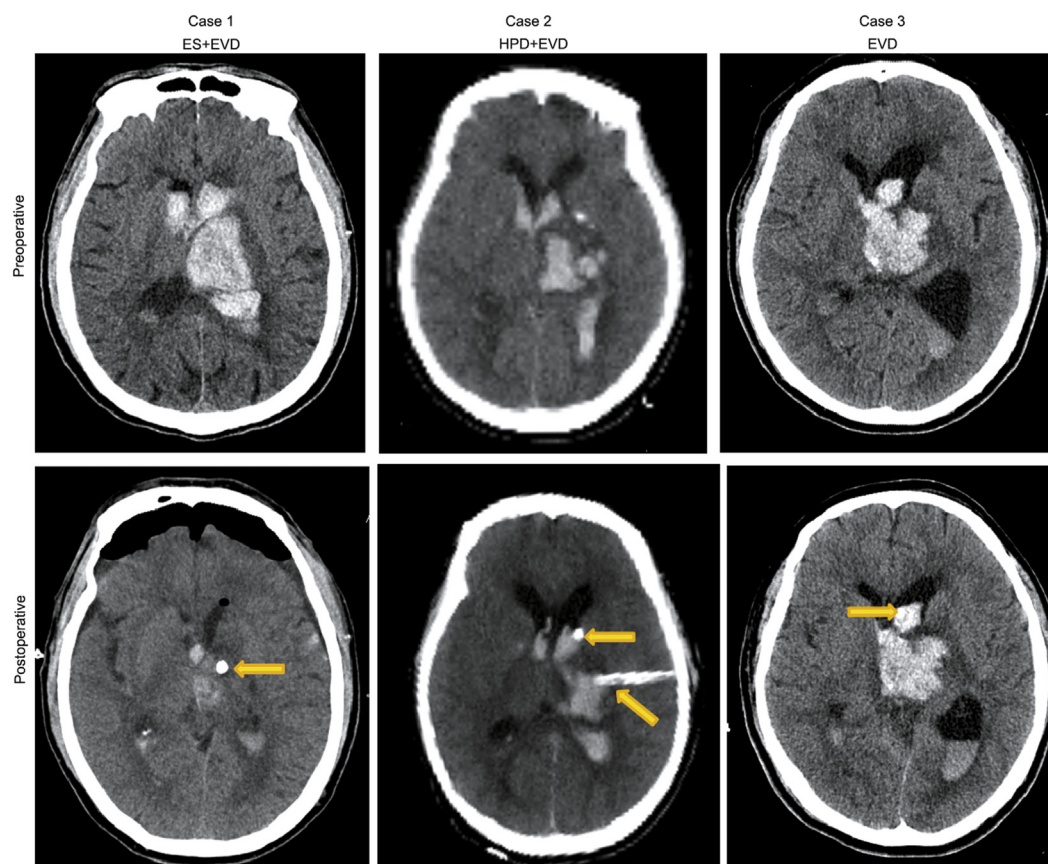


Fig. 4. THBIV patient specimens in the posterolateral group. Case 1. A 62-year-old man with an acute spontaneous left THBIV treated with ES + EVD. Case 2. A 60-year-old woman with an acute spontaneous left THBIV treated with HPD + EVD. Case 3. A 47-year-old man with an acute spontaneous left THBIV treated with EVD. Comparative preoperative (A, B, C) and postoperative (D, E, F) computed tomography images of all the three patients are presented. The yellow arrow pointed to the position of the drainage tube. THBIV: thalamic hemorrhage breaking into ventricles; ES: endoscopic surgery; HPD: hematoma puncture and drainage; EVD: external ventricular drainage; CT: computed tomography.

thalamic hematomas and alleviates hydrocephalus and the hematoma mass effect to some extent. In our study, the outcome after HPD was better than that after EVD, consistent with the findings of Liu et al.¹⁰ However, HPD had low clearance efficiency, usually taking approximately 3–7 days, which increased the risk of secondary hematoma-related brain injury.

ES quickly and effectively removes a hematoma and stops the related bleeding under direct vision. Our research showed that ES could minimize hematoma-related brain tissue damage, thus reducing the incidence of CVD and improving the neurological outcome without increasing patient complications. Chen et al.¹⁶ also investigated endoscopic and EVD treatment in patients with a lateral THBIV and showed that ES reduces the occurrence of chronic hydrocephalus, similar to our findings. However, in their study, ES did not improve patient prognosis, which is not consistent with our results. This inconsistency may be related to the difference in case selection criteria between the studies. Chen et al.²⁷ only required THBIV, while we included only patients with a thalamic hematoma volume greater than 10 mL because hematoma volume is a factor that influences the prognosis in patients with an ICH.

Our preliminary study shows that, compared to EVD and HPD, ES can achieve faster hematoma clearance with less trauma, decrease ventricular drainage time and the incidence of CVD, and achieve better outcomes in patients with THBIV. Although there is still no high-quality, evidence-based medical evidence, we believe that with the development of science and technology, minimally invasive surgery and neuroendoscopy will be more widely used in the future.

Study limitations

Our study has several limitations. It was a retrospective study and included a relatively small number of cases from a single center. Therefore, a well-designed prospective trial with a larger number of cases is essential to clarify these issues and provide more convincing results.

Conclusion

Neuroendoscopy is a minimally invasive, rapid, and efficient technique for the treatment of THBIV. Our preliminary results showed that ES with individualized strategies should be performed in patients with THBIV and a thalamic hematoma volume of 10–30 mL to reduce the drainage time and probability of CVD and improve outcomes without increasing mortality, especially in anteromedial cases.

Funding

Nil.

Ethical statement

The hospital ethics committee approved the study protocol, and informed consent was obtained from all patients or the patient's family.

Conflicts of interest

The authors declare that the article content was composed in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cjtee.2019.08.003>.

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