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ORIGINAL RESEARCH

Comparison of endoscopic evacuation, stereotactic aspiration, and craniotomy for treatment of basal ganglia hemorrhage

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ABSTRACT

Background The main surgical techniques for spontaneous basal ganglia hemorrhage include stereotactic aspiration, endoscopic aspiration, and craniotomy. However, credible evidence is still needed to validate the effect of these techniques.

Objective To explore the long-term outcomes of the three surgical techniques in the treatment of spontaneous basal ganglia hemorrhage.

Methods Five hundred and sixteen patients with spontaneous basal ganglia hemorrhage who received stereotactic aspiration, endoscopic aspiration, or craniotomy were reviewed retrospectively. Six-month mortality and the modified Rankin Scale score were the primary and secondary outcomes, respectively. A multivariate logistic regression model was used to assess the effects of different surgical techniques on patient outcomes.

Results For the entire cohort, the 6-month mortality in the endoscopic aspiration group was significantly lower than that in the stereotactic aspiration group (odds ratio (OR) 4.280, 95% CI 2.186 to 8.380); the 6-month mortality in the endoscopic aspiration group was lower than that in the craniotomy group, but the difference was not significant (OR=1.930, 95% CI 0.835 to 4.465). A further subgroup analysis was stratified by hematoma volume. The mortality in the endoscopic aspiration group was significantly lower than in the stereotactic aspiration group in the medium (≥40–<80 mL) (OR=2.438, 95% CI 1.101 to 5.402) and large hematoma subgroup (≥80 mL) (OR=66.532, 95% CI 6.345 to 697.675). Compared with the endoscopic aspiration group, a trend towards increased mortality was observed in the large hematoma subgroup of the craniotomy group (OR=8.721, 95% CI 0.933 to 81.551).

Conclusion Endoscopic aspiration can decrease the 6-month mortality of spontaneous basal ganglia hemorrhage, especially in patients with a hematoma volume ≥40 mL.

INTRODUCTION

Spontaneous intracerebral hemorrhage (ICH) is responsible for 10–15% of all strokes and is associated with high mortality and morbidity.[1] It is typically located in deep gray matter structures, including the basal ganglia and thalamus.[2] More importantly, spontaneous ICH is associated with high mortality, which is estimated to be >30% within the initial 30 days, with a prominent reduction in the survivor's quality of life.[3] Therefore, exploring effective treatments will benefit patients.[4]

Conservative management and surgical evacuation are the main treatments for spontaneous ICH.[5] Surgical evacuation of a hematoma may reduce the pathophysiological impact of the hematoma on surrounding tissue by decreasing the mass effect and the cellular toxicity of blood products. In the past, open craniotomy and hematoma aspiration were the mainstays of surgical evacuation management. With the development of less invasive surgical techniques, minimally invasive approaches, including endoscopic aspiration and stereotactic aspiration, have been shown to have advantages over the traditional surgical techniques.[6]

Although the STICH trial showed no overall benefit of open craniotomy over medical treatment alone,[7] surgery with minimally invasive approaches has shown potential benefits in the surgical management of spontaneous ICH.[8 9] Nevertheless, evidence of the benefits and indications for each technique remains insufficient. Therefore, we conducted a retrospective study to evaluate the 6-month mortality and neurological outcomes of three surgical techniques for spontaneous basal ganglia hemorrhage. Subgroup analysis, focusing on various hematoma volume thresholds, was also performed to evaluate the effectiveness of these techniques and define the appropriate indication for each.

METHODS

Study design and population

The aim of this study was to compare the 6-month clinical outcomes of patients with spontaneous basal ganglia hematoma who underwent stereotactic aspiration, endoscopic aspiration or open craniotomy. The medical records of all patients with spontaneous ICH between January 2015 and December 2017 were retrospectively reviewed. The patients were selected according to the following selection criteria.

Inclusion criteria

Patients were included if:

1. They met the diagnostic criteria for spontaneous ICH.
2. A CT scan showed that the hematoma was located in the basal ganglia.
3. The hematoma volume was >20 mL.

4. They underwent stereotactic aspiration, endoscopic aspiration, or craniotomy.
5. They were admitted to hospital within 24 hours of hemorrhage onset.

Exclusion criteria

Patients were excluded if:

1. The hematoma was caused by secondary factors (intracranial tumor, arteriovenous malformation, intracranial aneurysm, infarction, or trauma).
2. They had known advanced dementia or disability before ICH.
3. They had severe organ (cardiac, hepatic, renal, or pulmonary) dysfunctions before ICH.
4. They had coagulation disorders or history of using anticoagulant medications.
5. The hematoma affected the brain stem.
6. They or their relatives refused to be followed up.

Treatment

All patients were managed in the stroke unit with standard medical treatment and care according to the guideline of American Heart Association/American Stroke Association (AHA/ASA).[10] CT scans, routine blood tests, biochemical examinations, and routine coagulation studies were performed immediately when the patients were admitted to the emergency department. The medical history and results of the neurologic physical examination were recorded immediately after admission. Vital signs were monitored.

Surgical procedure

All surgeries were conducted by a well-trained surgical team. Decompressive craniotomy, tracheotomy, lumbar puncture, and external lumbar drainage were conducted if necessary. The surgical technique was determined according to the experience of surgeons preoperatively. All craniotomy hematoma evacuation surgery followed the principle of minimal invasiveness. Surgery procedures were based on the method described in the previous study.[11–13] A CT scan was carried out 24 hours after surgery to evaluate the hematoma evacuation efficiency of the operation.

Data collection and outcome evaluation

Basic information (gender, age, diagnosis, etc) was obtained from the patient information management department of our hospital. Disease history and treatment information were collected from the inpatient medical record system of our hospital. The patients were followed up by telephone to record their prognostic information at 1, 3, and 6 months after surgery.

Preoperative characteristics and treatment information

Demographic characteristics, including gender and age, were recorded. No ethnic-based differences were present. The recorded disease history included smoking, diabetes, hypertension, and cerebral disease. The preoperative status of the patients was assessed by degree of consciousness, hematoma volume, the time interval between onset and surgery, and herniation.

Hematoma volume was calculated from CT scans using the formula AxBxC/2, where A is the greatest diameter on the largest hemorrhage slice, B is the maximal diameter perpendicular to A, and C is the vertical hematoma depth.

Treatment information, including surgery technique, tracheotomy, decompressive craniectomy, lumbar puncture, external lumbar drainage, was collected from the inpatient medical record system. Rehabilitation treatment information was also recorded.

Outcome evaluation

The primary outcome was 6-month mortality after surgery. The secondary outcome was 6-month neurologic functional status, which was evaluated by the mRS score.

Statistical analysis

Given the selection bias inherent to retrospective observational studies, a X^2 test was used to test the intergroup balance of the possible confounding factors, including gender, age, consciousness, smoking, diabetes, hypertension, history of craniocerebral disease, herniation, interval between onset and operation, hematoma volume, rehabilitation treatment, decompressive craniectomy, tracheotomy, lumbar puncture, and external lumbar drainage. A p value of <0.1 was considered as unbalanced. A multivariate logistic regression model was used to analyze the independent effect of the surgery technique on outcome.

Primary analysis was to compare 6-month mortality and neurological functional outcomes among each surgical group. The mRS score was dichotomized as poor outcome (mRS 3–5) and favorable outcome (mRS 0–2). A further subgroup analysis of mortality and neurological function was stratified by hematoma volume (small volume: ≥20–<40 mL, medium volume: ≥40–<80 mL, large volume ≥80 mL). A χ^2 test was used for analysis of the categorical variables. Statistical significance was assumed with a probability of $p<0.05$. All analyses were conducted using SAS/STAT version 9.4 (SAS Co, Cary, North Carolina, USA).

RESULTS

Patient numbers

A total of 1312 consecutive patients with spontaneous ICH admitted to our hospital between January 2015 and December 2017 were reviewed retrospectively. Of these, 744 patients underwent stereotactic aspiration, endoscopic aspiration, or craniotomy. A total of 187 of these 744 patients did not meet our selection criteria, and another 41 patients were excluded owing to an incomplete follow-up. Finally, 516 patients were enrolled in this study (see online supplementary figure 1).

Basic characteristics

Detailed information on the basic patient characteristics is shown in table 1. Three hundred and nineteen men and 197 women were enrolled in this study. Three hundred and thirteen patients were <60 years old, while 203 patients were ≥60 years old. The number of patients with a history of smoking, diagnosed diabetes, diagnosed hypertension, and cerebral disease was 130 (25.2%), 37 (7.2%), 422 (81.8%), and 63 (12.2%), respectively. Herniation occurred before surgery in 84 (16.3%) patients. The average time interval from onset to surgery in the entire cohort, the stereotactic aspiration group, the endoscopic aspiration group, and the craniotomy group was 20.9 hours, 22.1 hours, 22.5 hours, and 16.1 hours, respectively (see table 1).

Intergroup equilibrium analyses were conducted to identify potential confounding factors. Consciousness ($p<0.0001$), herniation ($p<0.0001$), time interval from onset to surgery ($p=0.0202$), hematoma volume ($p<0.0001$), decompressive craniectomy ($p<0.0001$), tracheotomy ($p=0.0174$), and lumbar puncture ($p<0.0001$) were imbalanced throughout the entire cohort. However, in the surviving patients, the imbalanced variables were consciousness ($p<0.0001$), herniation ($p<0.0001$),

Table 1 The intergroup balance tests of possible confounding factors among different surgical techniques

		Surgical methods (in total sample) (n=516)					Surgical methods (in sample that survived) (n=340)				
		Total	SA	EE	OC	P value	Total	SA	EE	OC	P value
Gender	Male	319	184	64	71	0.5539	212	114	54	44	0.1030
	Female	197	120	41	36		128	77	36	15	
Age (years)	<60	313	178	70	65	0.3407	236	131	67	38	0.4003
	≥60	203	126	35	42		104	60	23	21	
Consciousness	Drowsy	84	65	12	7	**<0.0001***	66	51	11	4	**<0.0001***
	Lethargic	127	82	31	14		110	71	27	12	
	Light coma	213	122	53	38		130	65	44	21	
	Deep coma	92	35	9	48		34	4	8	22	
Smoking	Yes	130	72	31	27	0.4936	94	49	27	18	0.6474
	No	386	232	74	80		246	142	63	41	
Diabetes	Yes	37	26	7	4	0.2458	23	14	5	4	0.8584
	No	479	278	98	103		317	177	85	55	
Hypertension	Yes	422	253	88	81	0.1855	284	161	75	48	0.8667
	No	94	51	17	26		56	30	15	11	
History of craniocerebral disease	Yes	63	37	14	12	0.8945	35	20	11	4	0.5605
	No	453	267	91	95		305	171	79	55	
Herniation	Yes	84	29	10	45	**<0.0001***	32	3	8	21	**<0.0001***
	No	432	275	95	62		308	188	82	38	
Interval between onset and operation (hours)	8 hours	132	80	17	35	**0.0202***	68	37	14	17	0.1338
	8 hours	384	224	88	72		272	154	76	42	
Hematoma volume (mL)	>20–<40	161	131	18	12	**<0.0001***	127	102	17	8	**<0.0001***
	≥40–<80	253	134	69	50		168	82	57	29	
	≥80	102	39	18	45		45	7	16	22	
Rehabilitation treatment	PRT	184	108	42	34	0.1101	176	103	42	31	0.2318
	NPRT	128	68	41	19		124	66	40	18	
	NRT	43	24	7	12		39	22	7	10	
Decompressive craniectomy	Yes	112	21	11	80	**<0.0001***	55	6	9	40	**<0.0001***
	No	404	283	94	27		285	185	81	19	
Tracheotomy	Yes	90	41	25	24	**0.0174***	59	21	20	18	**0.0009***
	No	426	263	80	83		281	170	70	41	
Lumbar puncture	Yes	111	42	47	22	**<0.0001***	87	30	41	16	**<0.0001***
	No	405	262	58	85		253	161	49	43	

Continued

Table 1 Continued

		Surgical methods (in total sample) (n=516)					Surgical methods (in sample that survived) (n=340)				
		Total	SA	EE	OC	P value	Total	SA	EE	OC	P value
External lumbar drainage	Yes	54	31	15	8	0.2620	32	14	13	5	0.1568
	No	462	273	90	99		308	177	77	54	

*P values show statistical significance.
EE, endoscopic evacuation; NPRT, non-professional rehabilitation treatment; NRT, no rehabilitation treatment; OC, open craniotomy; PRT, professional rehabilitation treatment; SA, stereotactic aspiration.

hematoma volume (p<0.0001), decompressive craniectomy (p<0.0001), tracheotomy (p=0.0009), and lumbar puncture (p<0.0001) (table 1). To minimize the influence of these confounding factors, these characteristics were incorporated into multivariate logistic regression analyses.

Outcome assessment

In the entire cohort, the 6-month mortality was 34.1% (176/516 patients). In the surviving patients, the 6-month poor neurological functional prognosis (mRS scores ≥3) rate was 65.9% (224/340 patients). The 6-month mRS score distribution of the entire cohort is shown in online supplementary figure 2A.

In the entire cohort, 29 (5.6%) patients underwent re-operation, including 16 (5.3%) stereotactic aspiration patients, 4 (3.8%) endoscopic aspiration patients, and 9 (8.4%) craniotomy patients. In the surviving patients, 12 (3.5%) patients underwent re-operation, including 7 (3.7%) stereotactic aspiration patients, 3 (3.3%) endoscopic aspiration patients, and 2 (3.4%) craniotomy patients.

Multivariate analysis showed that, compared with the endoscopic aspiration group, the mortality in the stereotactic aspiration group was higher (OR=4.280, 95% CI 2.186 to 8.380). The craniotomy group also showed a trend towards higher mortality (OR=1.930, 95% CI 0.835 to 4.465) compared with the endoscopic aspiration group.

The data showed that in comparison with the endoscopic aspiration group, the neurological functional status in the stereotactic aspiration group and the craniotomy group was not significantly different. More detailed information is shown in table 2.

Basic characteristics in the subgroup of each hematoma volume

As patients with various hemorrhage volumes might have different indications for surgical techniques, subgroup analysis was also performed. Patients were further divided into three subgroups: small (≥20–<40 mL), medium (≥40–<80 mL), and large (≥80 mL).

To improve the credibility of our conclusion, we supplemented the inclusion and exclusion criteria of the small and large hematoma subgroups. In the small hematoma subgroup, we excluded those patients with deep coma (nine patients), cerebral herniation (five patients), decompressive craniectomy (eight patients), and tracheotomy (14 patients). A total of 112 cases were enrolled in the small hematoma subgroup. In the large hematoma subgroup, we excluded six patients who were awake, drowsy, or lethargic. A total of 96 cases (including 41 survivors) were enrolled in the large hematoma subgroup.

Equilibrium analysis showed that the only imbalance in the small hematoma subgroup was gender. The imbalanced variables in the medium hematoma subgroup were consciousness, smoking, herniation, time interval from onset to surgery, decompressive craniectomy, and lumbar puncture. The imbalanced variables in large hematoma subgroup were herniation, decompressive craniectomy, and lumbar puncture (see online supplementary table 1).

When the equilibrium analysis was limited to survivors, the imbalanced variables in the small hematoma subgroup were gender and smoking. The imbalanced variables in the medium hematoma subgroup were consciousness, herniation, decompressive craniectomy, and lumbar puncture. The imbalanced variables in the large hematoma subgroup were decompressive craniectomy and lumbar puncture (see online supplementary table 2).

Table 2 Results of the multivariate logistic regression model exploring the independent risk factors associated with mortality and a poor modified Rankin Scale (mRS) score

		Mortality (n=516)		mRS score (n=340)	
		OR	95% CI	OR	95% CI
Surgical methods (reference is EE)	SA	4.280	2.186 to 8.380	1.146	0.588 to 2.231
	OC	1.930	0.835 to 4.465	0.984	0.376 to 2.576
Consciousness (reference is drowsy)	Lethargic	0.621	0.293 to 1.318	2.914	1.114 to 7.621
	Light coma	2.331	1.230 to 4.419	4.004	1.546 to 10.375
	Deep coma	4.011	1.671 to 9.626	10.297	2.606 to 40.690
Herniation (reference is no)	Yes	1.726	0.851 to 3.503	0.846	0.271 to 2.643
Interval between onset and operation (hours) (reference is >8)	≤8	1.209	0.744 to 1.965	NA	NA
Hematoma volume (mL) (reference is ≥ 20– < 40)	≥40–<80	1.906	1.131 to 3.211	1.434	0.769 to 2.673
	≥80	2.644	1.340 to 5.217	2.856	1.135 to 7.188
Decompressive craniectomy (reference is no)	Yes	1.366	0.678 to 2.751	1.763	0.705 to 4.411
Tracheotomy (reference is no)	Yes	0.736	0.384 to 1.410	1.608	0.761 to 3.397
Lumbar puncture (reference is no)	Yes	0.561	0.296 to 1.064	0.762	0.385 to 1.509

EE, endoscopic evacuation; NA, not applicable; OC, open craniotomy; SA, stereotactic aspiration.

Outcome assessment in subgroup of each hematoma volume

The full 6-month mRS score distribution of each hematoma volume subgroup is shown in online supplementary figure 2B–D. In the small hematoma subgroup, the surgical techniques had no influence on mortality (stereotactic aspiration: OR=2.251 vs endoscopic aspiration, 95% CI 0.262 to 19.342; craniotomy: OR=2.023 vs endoscopic aspiration, 95% CI 0.101 to 40.664). In the medium hematoma subgroup, the mortality of stereotactic aspiration was significantly higher (OR=2.438, 95% CI 1.101 to 5.402) than that of endoscopic aspiration. However, no significant difference in mortality was found between the craniotomy group (OR=1.828, 95% CI 0.547 to 6.114) and the endoscopic aspiration group. In the large hematoma subgroup, the mortality in the stereotactic aspiration group (OR=66.532, 95% CI 6.345 to 697.675) was significantly higher than that in the endoscopic aspiration group. Compared with the endoscopic aspiration group, a trend towards increased mortality was observed in the craniotomy group (OR=8.721, 95% CI, 0.933 to 81.551). More detailed information is shown in table 3. However, in each hematoma subgroup, no significant difference in the mRS score was found among the three surgical groups. More detailed information is shown in table 4.

DISCUSSION

Stroke is the second most common cause of death worldwide, and the leading cause of death and disability in China.[14] Epidemiological studies have shown that China had the highest incidence of hemorrhagic stroke worldwide,[15] with an estimated morbidity of 114.8 to 159.8 per 100 000 person-years.[16] Deep-seated basal ganglia hemorrhage is the most common region of spontaneous ICH, causing death or dependency in more than 70% of affected patients.[17] The role of surgical management in treating ICH remains controversial. According to the 2015 AHA

Table 3 Results of the multivariate logistic regression model exploring the independent risk factors associated with mortality in different subgroups

		Hematoma Volume20–<40 mL (n=112)		Hematoma Volume=≥40–<80 mL (n=253)		Hematoma Volume ≥80 mL (n=96)	
		OR	95% CI	OR	95% CI	OR	95% CI
Surgical methods (reference is EE)	SA	2.251	0.262 to 19.342	2.438	1.101 to 5.402	66.532	6.345 to 697.675
	OC	2.023	0.101 to 40.664	1.828	0.547 to 6.114	8.721	0.933 to 81.551
Gender (reference is female)	Male	0.835	0.290 to 2.402	NA	NA	NA	NA
Consciousness (reference is drowsy)	Lethargic	NA	NA	1.058	0.345 to 3.246	NA	NA
	Light coma	NA	NA	3.643	1.311 to 10.125	NA	NA
	Deep coma	NA	NA	7.023	1.768 to 27.896	NA	NA
Smoking (reference is yes)	No	NA	NA	1.273	0.599 to 2.708	NA	NA
Herniation (reference is no)	Yes	NA	NA	1.902	0.714 to 5.062	2.698	0.804 to 9.052
Interval between onset and operation (hours) (reference is >8)	≤8	NA	NA	1.492	0.721 to 3.087	NA	NA
Decompressive craniectomy (reference is no)	Yes	NA	NA	0.805	0.264 to 2.451	1.523	0.418 to 5.547
Tracheotomy (reference is no)	Yes	NA	NA	0.691	0.285 to 1.674	NA	Na
Lumbar puncture (reference is no)	Yes	NA	NA	0.585	0.252 to 1.356	0.175	0.039 to 0.786

EEE, endoscopic evacuation; NA, not applicable; OC, open craniotomy; SA, stereotactic aspiration.

Table 4 The results of the multivariate logistic regression model exploring the independent risk factors associated with a poor modified Rankin Scale (mRS) score in different subgroups

		Hematoma Volume=20–<40 mL (n=95)		Hematoma Volume=≥40–<80 mL (n=168)		Hematoma Volume ≥80 mL (n=41)	
		OR	95% CI	OR	95% CI	OR	95% CI
Surgical methods (reference is EE)	SA	3.490	0.398 to 30.575	0.790	0.331 to 1.885	1.340	0.091 to 19.705
	OC	2.750	0.129 to 58.585	1.266	0.332 to 4.825	0.478	0.078 to 2.940
Gender (reference is female)	Male	0.561	0.152 to 2.064	NA	NA	NA	NA
Consciousness (reference is drowsy)	Lethargic	NA	NA	3.045	0.786 to 11.789	NA	NA
	Light coma	NA	NA	2.590	0.663 to 10.123	NA	NA
	Deep coma	NA	NA	4.569	0.555 to 37.597	NA	NA
Smoking (reference is yes)	No	4.287	0.431 to 42.672	1.919	0.767 to 4.801	NA	NA
Herniation (reference is no)	Yes	NA	NA	0.764	0.142 to 4.124	NA	NA
Decompressive craniectomy (reference is no)	Yes	NA	NA	2.690	0.807 to 8.970	1.902	0.365 to 9.902
Lumbar puncture (reference is no)	Yes	NA	NA	1.529	0.675 to 3.466	0.422	0.096 to 1.862

EE, endoscopic evacuation; NA, not applicable; OC, open craniotomy; SA, stereotactic aspiration.

guidelines for the surgical management of spontaneous ICH, the usefulness of surgery for most cases of supratentorial ICH is not well established (class IIb; level of evidence A), and surgery may be considered only as a life-saving measure in patients who are deteriorating (class IIb recommendation; level of evidence C).[10]

Intracerebral hematoma initiates a cascade of secondary injuries, leading to intracranial hypertension, edema, neuronal damage, and disruption of the blood–brain barrier.[18] Surgical evacuation of the hematoma may reduce the mass effect, thereby decreasing intracranial pressure, improving regional blood flow, and restricting the release of toxic breakdown products produced by the clot.[19] On the other hand, several clinical trials, especially the Surgical Trial in Intracerebral Hemorrhage (STICH) I[7] and STICH II[20] trial, have failed to show overall clinical benefit of hematoma evacuation with open craniotomy compared with medical therapy alone. However, with the development of more advanced techniques, minimally invasive approaches have been shown to have several advantages over conventional craniotomy.[6 21]

In this study, we evaluated the effectiveness of three surgical techniques for basal ganglia hematoma—stereotactic aspiration, endoscopic aspiration, and craniotomy. As indicated by our data, endoscopic aspiration decreased the 6-month mortality in the entire patient cohort.

Brain injury caused by ICH can be described as a biphasic process. Primary brain injury, induced by hematoma formation causes direct traumatic damage to regional neurons.[22] Secondary brain injury, manifesting as edema, further leads to irreversible neuronal damage, inadequate cerebral blood flow, increased intracranial pressure, and herniation.[1] Clinical evidence has shown that secondary brain injury is associated with a greater risk of death than primary injury.[23] Most patients with ICH with smaller hematomas survive the primary injury; however, secondary brain injury may result in severe neurological deficits and even death.[24] Based on these results, we speculate that endoscopic aspiration alleviates secondary brain injury, effectively preventing neurological deterioration and reducing mortality rates. However, primary brain injury caused by direct damage to regional neurons may not be mitigated by any surgical evacuation.

A previous study found that the hematoma volume is one of the strongest predictors of mortality in ICH.[25] In our study, subgroup analyses focusing on different hematoma volume thresholds were also performed to evaluate the effectiveness of all three surgical techniques. According to hematoma volume, patients were further divided into three subgroups: small (≥20–<40 mL), medium (≥40–<80 mL), and large (≥80 mL).

We found that the mortality rates of the small hematoma subgroup were 16.1% (15/93), 8.3% (1/12), and 14.3% (1/7) in the stereotactic aspiration, endoscopic aspiration, and craniotomy groups, respectively. No significant differences in the mortality rate were found among all three surgical groups. Interestingly, in the STICH I trial, 1033 patients with a moderate hematoma volume (average 40 mL) were enrolled. The results showed that 26% of patients in the craniotomy group and 24% of patients in the medical management group had favorable outcomes.[7] Based on these results, we speculate that regardless of conservative medical treatment, craniotomy or less invasive surgical techniques do not influence the prognosis of patients with a small hematoma volume.

In the medium and large hematoma subgroups, the mortality of the stereotactic aspiration group was significantly higher than that of the endoscopic aspiration group. In the large hematoma subgroup, a trend towards improved survival was observed in the endoscopic aspiration group compared with the craniotomy group (OR=8.721, 95% CI, 0.933 to 81.551). This suggested

that, with hematoma volumes ≥40 mL, stereotactic aspiration is not the ideal choice. With hematoma volumes ≥80 mL, endoscopic aspiration may be the optimal surgical choice among the three different techniques. These results may help to better define the appropriate indication for each technique; however, further prospective randomized trials are needed to confirm the findings of this study.

This study has several limitations. First, owing to the retrospective nature of the study, the possibility of selection bias cannot be excluded, and some data were not uniformly ascertained. Second, potential methodological limitations might have influenced the results. Third, this study was carried out at a single center and may have limited generalizability. Multicenter randomized controlled trials are needed to confirm the effectiveness of different surgical techniques.

CONCLUSION

In our cohort, endoscopic aspiration significantly decreased the 6-month mortality of spontaneous basal ganglia hemorrhage, especially in patients with a hematoma volume ≥40 mL. These preliminary results warrant further large, prospective, randomized studies.

Contributors WG, HL, and ZT contributed equally to this work. All authors of this work met ICMJE criteria for authorship and made substantial contributions to the conception and design, acquisition of data, analysis and interpretation of data, drafting, critical revising, and final approval of this manuscript.

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