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The Neuroendoscopy-Assisted Microscopic Hematoma Evacuation in the Treatment of Hypertensive Brainstem Hemorrhage

Zhang Z[1], Zhang X[2], Yang W[2] and Wang Z[2*]

[1]Wuhu Integrated Traditional Chinese and Western Medicine Hospital, China

[2]Department of Neurosurgery, Inner Mongolia Autonomous Region People's Hospital, China

[*]Corresponding author:

Zhong Wang,
Department of Neurosurgery, Inner Mongolia Autonomous Region People's Hospital, Hohhot 010000, China

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Keywords:

Microscopic hematoma evacuation; Hypertension; Brainstem hemorrhage

1. Abstract

1.1. Background: Whether hypertensive brainstem hemorrhage (HBSH) should be managed conservatively or surgically removed remains controversial. This study describes six surgically treated HBSH cases and the ability of surgical treatment to improve postoperative functional outcomes.

1.2. Methods: 6 patients of HBSH (Hematoma volume ≥ 3 ml or hematoma transverse diameter ≥ 2 cm) who have taken the neuroendoscopy-assisted microscopic hematoma evacuation were included between Jan. 2018 and Dec. 2021. All 6 patients had hypertensive pontine hemorrhage, of which 1 case had a small amount of medullary hemorrhage and 1 case had a small amount of midbrain hemorrhage. All patients underwent surgery using a subtemporal approach. We analyzed preoperative and postoperative functional outcomes and modified Rankin Scale scores 1 to 6 months after discharge.

1.3. Results: Except for 1 patient who died of central respiratory and circulatory failure 1 month after operation, the rest of the patients improved in terms of disturbance of consciousness, spontaneous breathing, and modified Rankin Scale score.

1.4. Conclusion: Because of the good results with these 5 patients with PBH, this surgical strategy could serve as a surgical treatment for HBSH. We hope to gather more evidence by increasing the number of patients.

2. Introduction

Primary Brain Stem Hemorrhage (PBSH) refers to spontaneous brain stem hemorrhage that excludes traceable secondary factors such as trauma, vascular malformation, and tumor. Among the untraceable PBSH, most of them are accompanied by hypertension, which is often called hypertensive brainstem hemorrhage (HBSH) in China and is the deadliest subtype of hypertensive intracerebral hemorrhage. HBSH is caused by the rupture of small blood vessels damaged by chronic hypertension or amyloid angiopathy [1]. Brainstem hemorrhage occurred in 0.5% of all stroke patients [2]. HBSH is a devastating neurosurgical emergency characterized by severe neurological deficits and high mortality, especially in severe cases with low GCS on admission [3]. Brainstem hemorrhage is mainly caused by hypertension, accounting for 5.0%-13.4% of patients with cerebral hemorrhage. It has the clinical characteristics of acute onset, rapid progression, high mortality (70%-80%), and high disability rate. Pontine hemorrhages account for 90% of brainstem hemorrhages [4]. Patients with pontine hemorrhage are relatively young, with the most common age being 40-60 years old [5]. Due to the complexity and functional importance of brainstem anatomy, the difficulty and risks of brainstem treatment are generally considered to be difficult and risky, and thus have been viewed as a restrictive area of surgery. Patients with brainstem hemorrhage can rapidly develop coma and exhibit vegetative dysfunction (respiratory disturbances, arrhythmias, hyperthermia, hypertension), neuro-ophthalmic symptoms such as miosis, and flaccid tetraplegia; in addition, blood may enter the ventricles and block cerebrospinal fluid path [6]. In the past, patients were mostly treated conservatively, with a mortality rate of 70-80% [3, 7, 8].

At present, the management of brainstem hematoma is still conservative, and the initial strict monitoring of neurointensive care is the main method[9]. In China, there were no guidelines for the treatment of brainstem hemorrhage until 2020. The guidelines indicate that craniotomy hematoma removal is an effective method for brainstem hemorrhage, and neuroendoscopic hematoma removal is also an option [10]. In fact, the current treatment of PBSH is mainly conservative, and the effect of surgical treatment such as hematoma removal is uncertain [9, 11-14]. In recent years, with the continuous growth of knowledge of brainstem anatomy and functional areas, as well as the advancement of new technologies and equipment in the fields of neuroimaging, microsurgical techniques, neuronavigation, neuroendoscopy, intraoperative monitoring and neurorehabilitation. This soon strengthened the safety of surgery and provided options and guarantees for "minimally invasive" surgery for brainstem hemorrhage. When HBSH occurs, the normal tissue damage in the brainstem is not serious, but hematoma compression is the main risk factor. Due to the lack of glial cells in the brainstem, the hematoma degrades very slowly, and the brainstem hematoma accumulates rapidly during the onset, destroying the normal anatomical structure and causing irreversible damage. damage, but the clump effect of the hematoma and secondary damage from blood cell degradation products can be alleviated by surgery [15].

In this study, we discussed the surgical treatment of 6 patients with HBSH, as well as the postoperative survival and early recovery of the patients.

3. Materials and Methods

We reviewed data from Jan. 2018 and Dec. 2021 in 6 consecutive HBSH patients admitted to hospital after surgery in the People's Hospital of Inner Mongolia Autonomous Region (Hohhot, China). The patient characteristics are listed in Table 1. Furthermore, 2 patients exhibited haemorrhage leaking into the fourth ventricle. Primary brainstem hemorrhage was classified into the following four types according to the classification system based on the location of the hematoma by CS Chun et al[16]: unilateral-tegmental (1 cases, Figure 1, Patient5); bilateral-tegmental (4 cases, Figure 1, Patient1,3,4,6); basal-tegmental (0 cases); and massive (1 cases, Patient2). The basal tegmental type is defined as the hematoma located at the junction of the bridging base and the bilateral tegmental. The unilateral tegmental type refers to the hematoma confined to one tegment. The bilateral tegmental type is when the hematoma occupies both sides of the tegmental. The massive expresses the bilateral spread of the brainstem hematoma to the pontine base and tegmentum. Of our 6 patients, 3 had bilateral tegmental, 1 had unilateral tegmental and 2 had massive hemorrhage.

The surgical indications included the following: Brainstem hemorrhage confirmed by head CT examination (CTA or DSA if necessary to exclude structural cerebrovascular disease); a clear history of hypertension with systolic blood pressure ≥140 mmHg and/or diastolic blood pressure ≥90 mmHg at onset or admission; obvious disturbance of consciousness (GCS ≤ 8 points); In line with the indications for craniotomy hematoma removal surgery (hematoma volume ≥ 5 ml or hematoma transverse diameter ≥ 2 cm; hematoma distribution is relatively concentrated; GCS score ≤ 8 points; vital signs are relatively stable); first brainstem hemorrhage; complete patient information. Patients were excluded based on the following criteria: brainstem hemorrhage that occurs after trauma (nonhypertensive brainstem hemorrhage); multiple previous intracranial hemorrhages; combined with severe heart, lung, liver and kidney disease; brain stem hemorrhage caused by vascular malformation, cavernous hemangioma, metastases, etc; excessive bleeding and serious damage to the vital center of the brainstem, bilateral mydriasis and extremely unstable vital signs; patients with a small amount of brainstem hemorrhage (≤3ml) and no obvious ventricular system obstruction or unconscious disturbance; and the patient's family refuses surgery.

Of the 6 patients, 2 were women and 4 were men, with an age range of 39-62 years (mean, 49). All 6 patients had hypertensive pontine hemorrhage, of which 1 case had a small amount of medullary hemorrhage and 1 case had a small amount of midbrain hemorrhage.

The hemorrhage volume was calculated from the initial computed tomography (CT) scan using the ABC/2 formula, hematoma volume in ml. Among them: A is the longest diameter of the hematoma, B is the longest wide diameter perpendicular to A, and C was formed by multiplying the number of slices involved by the slice length and thickness to calculate the height of the hematoma, all in cm [17]. The volume of the HBSH ranged from 3.4 to 8.9 mL (mean, 6.2). Three patients had perihematoma edema on preoperative CT images. Three patients had a history of hypertension and all received antihypertensive therapy, but none received antiplatelet or anticoagulant gents. All 6 patients were diagnosed with high blood pressure when they came to the hospital. Preoperative CT or MRI scan showed no repeated bleeding.

Table 1: Patient Characteristics

Patient	Age (Years)	Sex	Location	Systollic pressure (mmHg)	Diastolic pressure (mmHg)	Extension	Volume (mL)	Medical History	Medication	Perihematomal Edema	Repeat Bleeding
1	51	F	Pons	140	90	bilateral tegmental	6	Yes	Antihypertensive	No	No
2	39	F	Pons medulla	198	107	mssive	8.9	No	No	Yes	No
3	41	M	Pons	145	85	bilateral tegmental	6.2	No	No	No	No
4	62	M	Pons medulla	220	110	bilateral tegmental	6.2	Yes	Antihypertensive	No	No
5	43	M	Pons	166	85	bilateral tegmental	3.4	Yes	Antihypertensive	Yes	No
6	57	M	Pons	152	86	mssive	6.5	No	No	Yes	No

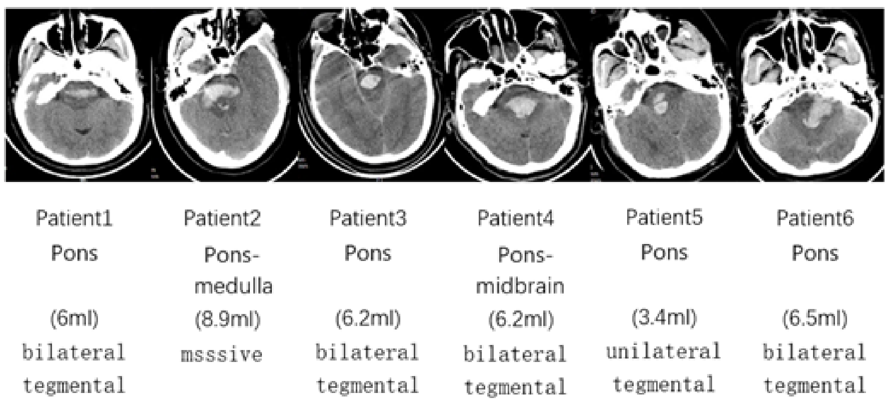

Figure 1: Axial computed tomography images of six HBSH patients. The text below each scan shows the patient's number, location and volume, and type of dilation.

3.1. Surgery for HBSH

The interval from onset to surgery is 3 to 25 hours (mean, 8.7), we try to follow the guidelines (Timing of treatment: 6–24 h after hemorrhage, earlier if possible[10]). One of the patients had a time interval of 25 hours from onset to surgery, because she had been unconscious for nearly 20 hours when he came to the hospital (Table 2).

All patients underwent surgery using a subtemporal approach in the supine lateral position. All six patients underwent intraoperative neurophysiological monitoring of motor and sensory potentials, direct stimulation of the facial nerve, auditory responses to the brainstem, and neuronal navigation. No other lesions (e.g., cavernous hemangioma, metastases, etc) were found on preoperative CT images and intraoperative exploration in all patients. Preoperative and 6-month postoperative outcomes were compared for all 6 patients. The level of consciousness was evaluated using the Glasgow coma scale (GCS), and the degree of neurological recovery was assessed by modified Rankin scale (mRS) scores.

4. Results

Head CT of 6 patients on the first postoperative day showed that the hematoma was mostly removed (Figure 2). Except for 1 patient who died 1 month after surgery, the GCS scores of the other 5 patients were improved to varying degrees after surgery. Of the 5 patients who survived the operation, 4 came to the outpatient clinic for re-examination, and we assessed them face-to-face, and the postoperative condition of the last patient was obtained from a telephone interview with his family. Three patients had improved mRS scores 1-6 months after surgery (Table 3).

With the aid of neuroendoscopy, when microscopic hematzoma evacuation is used to treat hypertensive brainstem hemorrhage, the surgical field of view is clearer, the trauma is smaller, and the impact on nerve function is smaller. At the same time, intraoperative endoscope can enter the hematoma cavity to observe the hematoma. Whether it is completely cleared and the bleeding point is clarified is more accurate to stop bleeding, the trauma is smaller, and it is more conducive to reducing the occurrence of postoperative complications and the functional recovery of patients.

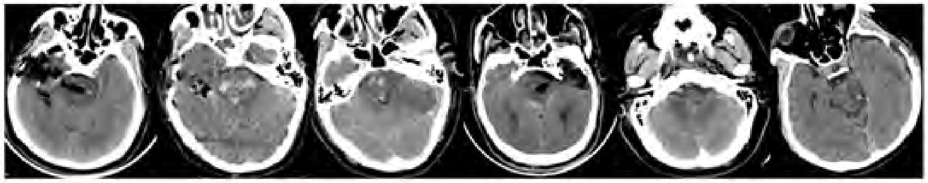

Figure 2: Axial computed tomography images of 6 patients with HBSH on the first postoperative day.

Table 2: Surgery for Hypertensive Brainstem Hemorrhage

Patient	Location	Interval to Surgery (hours)	Position	Approach
1	Pons	3	Supine lateral	subtemporal
2	Pons-medulla	25	Supine lateral	subtemporal
3	Pons	5	Supine lateral	subtemporal
4	Pons-midbrain	5	Supine lateral	subtemporal
5	Pons	6	Supine lateral	subtemporal
6	Pons	8	Supine lateral	subtemporal

Table 3: Postoperative ICU stay, total hospital stay and functional recovery

Consciousness Level (GCS)						Postoperatively Neurological recovery Degree (mRS)			Spontaneous Respiration	ICU-stay time (days)	Hospital-stay time (days)
Patient	Preoperatively	Postoperatively									
		1 weeks	1 month	3 months	6 months	1 month	3 months	6 months			
1	5	5	5	6	6	V	V	V	Improved	19	34
2	3	3	3	NA	NA	VI	VI	VI	NA	29	37
3	3	3	4	4	4	V	V	V	Improved	8	52
4	3	3	4	4	5	V	V	IV	Improved	12	59
5	7	11	12	12	13	V	V	III	Improved	4	25
6	5	7	10	10	12	V	V	IV	Improved	19	30

GCS, Glasgow coma scale; mRS, modified Rankin scale; NA, not applicable.

5. Case Reports

5.1. Patient 1

A 51-year-old woman with a history of hypertension was admitted to the emergency department of our hospital with sudden headache, dizziness, and disturbance of consciousness. The patient had a history of hypertension for 5 years. He had been treated with oral antihypertensive drugs for half a year and then stopped the drug. The blood pressure on admission was 140/90 mmHg. A CT scan revealed a primary hemorrhage in the pons (Figure 1, Patient1). On admission, she showed disturbance of consciousness (GCS score, 5), no light reflex in both pupils, no voluntary movement of extremities, and positive bilateral pathological signs. 3 hours after onset, she underwent surgery through a subtemporal approach in a supine lateral position (Table 2) with written informed consent from her family. Most of the hematoma in the brainstem was removed during the operation, and neuroendoscopy was used to remove the hematoma that was deep and difficult to find. After 19 days of treatment in the NICU, the patient was transferred to the general ward for treatment. After 34 days of total hospitalization, the patient was lethargic (GCS score, 7), had bilateral pupillary light reflexes, flexed limbs when stimulated, and could pronounce but not speak. At the same time, the patient's family requested to be discharged from the hospital.

5.2. Patient 2

A 39-year-old female was sent to our hospital with a sudden disturbance of consciousness for 20 hours. She has a history of high blood pressure for many years without any treatment. She had a history of hypertension for many years without any treatment and had a blood pressure of class III at the time of onset (Table 1). Her brainstem hemorrhage was the most of the 6 patients at 8.9ml. On admission, he presented with deep coma (GCS score, 3), bilateral unequal pupils, 3 mm left pupil and 3.5 mm right pupil, positive pathological signs on both sides, and no movement of both limbs. CT scan shows the presence of hypertensive brain stem hemorrhage into the ventricle (Figure 1, Patient2). Since she had been unconscious for 20 hours when she was admitted to the hospital, she did not undergo surgery until 25 hours after the onset of symptoms (Table 2). Therefore, she was the latest of the 6 patients to undergo surgery. She also had the longest ICU stay due to all of the above reasons. During hospitalization, due to long-term bed rest, improper nursing and other reasons, the patient's lungs were infected, and the patient finally died of central respiratory and circulatory failure.

6. Discussion

Arseni et al.[18] defined "bleeding" as "diffuse and expansive" and "hematoma" as "localized". Only patients with "brain stem hematoma" require surgery because the hematoma can develop into an intracranial space-occupying lesion. Guidelines issued by the American Heart Association and the European Stroke Organization do not provide clear guidelines for the management of patients with spontaneously hypertensive brainstem hemorrhage.[19, 20] Some surgeons believe that for the majority of HBSH patients who are in a coma, surgery does not work because the results are always catastrophic [21]. Although the role of surgery in the management of HBSH is unclear and controversial, several case-control studies and case reports suggest that surgery can reduce mortality and improve functional outcomes in patients with PBH (Table 3) [3, 22-28]. Derong XU et al [29] believed that surgical treatment also depends on the location and volume of the hematoma, the patient's level of consciousness, general condition and related complications. The findings of Chen LH et al [24] also suggest that surgical treatment is a life-saving approach, with an overall mortality rate of 12% in their series. And they believe that surgery is suitable for patients with brainstem compression and cannot tolerate the extension of the hematoma to the fourth ventricle resulting in the obstruction of the fourth ventricle. Ichimura S et al [23] performed surgery on 5 patients with HBSH, and these 5 patients with HBSH had a good prognosis and they believed that this surgical strategy could be encouraged as an exclusion criterion for early initiation of rehabilitation strategies.

Summary of the eight studies in Table 4, the incidence was significantly higher in men than in women. All 10 HBSH patients collected by AlMohammedi RM et al [2] were male, and they considered male as a risk factor for hemorrhagic stroke including brainstem hemorrhage. Of our 6 patients, 4 were male and 2 were female. The significantly higher incidence in men than in women may be due to personal lifestyle habits and pre-onset health conditions [30].

Hypertension is the most important risk factor for HBSH, other related factors include anticoagulation therapy, amyloid angiopathy, etc [30]. All six of our patients had a history of hypertension and all had higher than normal blood pressure on admission. Age plays an important prognostic role in intracerebral hemorrhage and is an important factor in intracerebral hemorrhage score [31, 32]. A study conducted in Japan showed that patients with pontine hemorrhage were older, and the older the age, the worse the prognosis and the higher the mortality rate [33]. Ding WL et al [25] concluded that younger age was significantly associated with better 30-day functional outcome (Table 4). Because of our small number of cases, the conclusion that age is associated with prognosis was not reflected in our 6 patients. Previous studies have examined the association between BMI and stroke and have shown that high BMI is a risk factor for hemorrhagic and ischemic stroke [34]. AlMohammedi RM et al [2] showed that higher BMI was associated with brainstem hemorrhage. Ding WL et al [25] divided 136 patients with brainstem hemorrhage into early tracheostomy group and late tracheostomy group. Compared with the late tracheostomy group, patients in the early tracheostomy group had significantly shorter hospital stays (overall and survival) in the neurosurgical intensive care unit. Good prognosis (modified Rankin score ≤3) was higher in the early tracheostomy group. Our patients all had tracheostomy in the early postoperative period, which may be related to the improvement of the condition of 5 patients. A retrospective study by Chen D et al [35] showed that initial level of consciousness and bleeding volume were identified as important prognostic factors for HBSH. They believe that patients with a score of 2 to 3 based on the new primary pontine hemorrhage score may benefit from surgery. However, high-level evidence regarding the safety and efficacy of surgical treatment of HBSH is still lacking.

The surgeon's surgical approach to removing the hematoma should be based on the location and size of the brainstem hematoma. Improving the surgical approach and method, selecting the best surgical method to reduce brainstem tissue damage, and postoperative rehabilitation are still an important task in the treatment of brainstem hemorrhage [29]. The complex neuroanatomy of the brainstem and peripheral vasculature must be considered when planning the optimal route of the hematoma [6]. HBSH is located in the functional area of the brainstem, so the choice of surgical approach should be minimally invasive to the normal brain tissue surrounding the hematoma. However, due to its anatomical complexity, the brainstem approach requires experience and careful dissection [24]. To optimize lesion resection while reducing risk to the patient, surgeons must choose a method of direct access to the lesion, preferably within the shortest distance and with minimal disturbance to adjacent neural pathways, although this is not always possible [36]. The surgical path should be as short as possible, following the two-point rule, i.e., draw a line from the center of the hematoma to the flattest point on the surface of the hematoma and brainstem, and extend appropriately outward for the best surgical approach [37]. Surgical treatment should try to remove the thrombus and minimize damage to the surrounding brain to reduce local and global intracranial pressure and maintain cerebrospinal fluid circulation [38].Of all the types of brainstem hemorrhage, the ventral brainstem hemorrhage is the most challenging because of its proximity to the pyramidal tract [26]. Open lateral and dorsolateral approaches to this region have been described in previous literature, [3, 23, 39] while ventral brainstem hemorrhage remains a thorny problem. Fortunately, none of our 6 patients had ventral brainstem hemorrhage. This may be one of the reasons why our surgery is relatively successful. Ichimura S, Lan ZG and Liu B et al [3, 23, 26] introduced several different surgical approaches for different types of brainstem hemorrhage, but only Liu B used neuroendoscopy (Table 4). Although we used neuroendoscopy to remove hematoma in 6 cases of HBSH patients with different bleeding types, but the approach is single (Table 2), which is why we need to continue to strengthen study and research.

AlMohammedi RM et al[2]made statistics on 1921 stroke patients, 219 cases were hemorrhagic stroke (11.4%), of which 10 cases were brainstem hemorrhage (4.6%), accounting for 0.5% of stroke patients. All patients were male; mean age was 58.5 years. The most common symptoms were headache (70%), unilateral weakness (60%), and loss of consciousness (50%). All patients had pontine hemorrhage, 5 cases had cerebellar hemorrhage (50%), 1 case had medullary hemorrhage, and 1 case had midbrain hemorrhage (10% each). Their 10 patients with brainstem hemorrhage had an average ICU stay of 17 days and an average total hospital stay of 58 days. Our 6 patients had an average ICU stay of 15 days and an average total hospital stay of 40 days. (Table 3). AlMohammedi RM performs conservative medical treatment for HBSH patients, but we are surgical treatment. From the perspective of length of stay, our patients had a shorter hospital stay, so microsurgery may be beneficial in HBSH patients, but these findings require further validation with more comprehensive and comparative studies.

Yu-Jia Zhou et al[40] admitted a woman with a history of hypertension for many years who had not received systematic diagnosis and treatment. The patient had a GCS of 3 on admission. The patient underwent "posterior median craniotomy with a trans-cerebellomedullary fissure approach, evacuation of hematoma and suboccipital decompression." Two weeks later, the patient was transferred to the general ward. At the 6-month follow-up, the patient was fully awake with no apparent neurological disease. Basel Index: 85. After analysis, the hemorrhage mainly flowed into the ventricle, but there was less hemorrhage in the brainstem parenchyma. Lan ZG, Chen LH and Ding WL[3, 24, 25] also mentioned that the size of the hematoma is related to the prognosis of HBSH patients(Table 4). Of our 6 patients, patient 5 had relatively good prognosis due to smaller hematomas, while patient 2 had the most bleeding and the worst prognosis (Table 1 and 3). Zhang HT et al [27] performed surgery on 28 patients with HBSH, of which 11 died within 3 months after surgery. The mean preoperative hematoma volume in these dead patients was 11.5 ml. Moreover, they concluded that for patients with bleeding volume of 5 ~ 10 mL, the GOS score at 3 months postoperatively was higher in the surgical group than in the conservative group ($P < 0.05$), and for patients with bleeding volume greater than 10 ml, the difference in GOS score at 3 months postoperatively between the two groups was not statistically significant ($P > 0.05$).[27] Huang K et al[22] suggested that patients with HBSH volume <5 mL had a better chance of survival, while patients with HBSH volume >10 mL tended to die early. For patients with HBSH volumes between 5-10ml, those with a GCS score of 3-4 were highly lethal, while those with a GCS score of 8 - 15 were more likely to experience functional recovery than those with a score of 5-7. Zhang S et al [41], believe that for patients in the 5 to 10 mL subgroup, surgery can improve patient outcomes and is strongly recommended. For the 10 to 20 mL subgroup, surgery may improve outcomes in some patients, but postoperative mortality and morbidity remain high. For patients > 20 mL subgroup, overall mortality can be as high as 100%. In this subgroup, surgery may improve outcomes if the PBH is focal or unilateral. If PBH is lateral and diffuse, surgery may not reduce patient mortality. Therefore, it is unwise to recommend this surgery as routine treatment. Chen LH et al[24] concluded that volumes less than 10 ml always resulted in better outcomes, whereas massive and bilateral hematomas were associated with poor prognosis. Hao G et al [28], concluded that survival was highest for the small unilateral tegmental type and lowest for the massive type. Obviously, our patient 5 fits Hao G 's point of view.

Apoptosis was detected within 6 hours of onset, increased at 12 hours, and peaked at 24 hours. To observe pathological changes, surgery very early (within 6 hours) may be more beneficial to preserve normal brain tissue and reverse primary brain injury [24, 42]. Prompt surgical removal of the hematoma can effectively reduce secondary injury [42]. However, the appropriate timing of surgery has been controversial [43]. If surgery is performed too soon after bleeding, rebleeding may occur, and some patients are admitted to the hospital with dyspnea requiring mechanical ventilation.Therefore, some authors prefer to delay evacuation within 2-7 days of onset [38]. Chen LH et al [24] showed that some HBSH patients died in the acute phase, so they were more inclined to undergo surgery earlier. 12-48 h after the onset is the best time for microsurgery to remove the effect of HBSH hematoma and reduce the increase in intracranial pressure. Lan ZG et al [3] believe that if the HBSH occurs within 6 hours, the prognosis of surgical intervention is good. I think our patient 2 has a poor prognosis because of the long delay before surgery (Table 3). Of course, this also requires a lot of experiments to verify my conjecture.

Neuroendoscopy-assisted microscopic hematoma evacuation is controversial, with only a few known reports on this topic [26]. According to Hellwig D et al[44] even if the endoscope is flexible and maneuverable, it is very difficult to remove the hematoma with neuroendoscopy through the midbrain aqueduct into the pons, which has a median diameter of 1 mm at its rostral end , and in the majority of acute hydrocephalus cases, no enlargement of the midbrain aqueduct was seen; therefore, it seems almost impossible for us to guide the steerability of the fiberscope without destroying viable peri-aqueductal structures end into the hemorrhagic pons. Although endoscopy-assisted minimally invasive transcranial approach is known to improve surgical visualization and illumination of the surgical field, one of its limitations is the two-dimensional view, which prevents the surgeon from gaining sufficient depth perception. Although the development of 3D endoscopy has solved this problem to some extent, the use of the microscope view in the transcranial approach is still considered essential when manipulating the nerve tissue surrounding the pathology [45, 46]. Our patient's head CT on postoperative day 1 showed that the hematoma was mostly cleared (Figure 2). This result also proves that neuroendoscopy-assisted microscopic hematoma evacuation has certain advantages in the treatment of brainstem hemorrhage.

Although the AHA guidelines do not explicitly recommend resection of spontaneous brainstem haemorrhage, due to a limited database and lack of high-quality evidence, this recommendation may be biased because randomized clinical trials of surgery versus conservative treatment are unlikely to be conducted in this patient population [9, 47]. High-level clinical studies of HBSH are difficult. Patient prognosis largely depends on the location and volume of the hematoma, and it is difficult to obtain a sufficient sample size for analysis due to the large number of groups [48].

Table 4. An overview of eight studies included in HBSH articles in recent years.

Auther		Huang K		Ichimura S	Zhang HT	Lan ZG	Hao G	Chen LH	Ding WL	Liu B
Year		2017		2018	2018	2019	2019	2020	2020	2020
Design		R	P	CR	R	NRCCT	CR	NRCCT	R	CR
Sample size		171	98	5	28	46	1	52	136	1
Sex	Male	126	72	2	20	35	1	33	104	1
	Female	45	26	3	8	11		19	32	
Mean age (years)		53.8±11.9	52.66±12	66±12.28	62.4 ± 8.3	51.5	54	50.2± 12.7	51.25± 11.22	37
History of hypertension		74.27%	75.51%	40%	93%	All	Yes	All	NA	Yes
Patient inclusion		GCS 3-15	GCS 3-15	NA	GCS 3-9	GCS 3-8	GCS 3	GCS 3-9	GCS 3-8	GCS 3
Hemorrhage location (n)	MES			1		12		2	15	
	PON-MES					3		5		1
	PON	171	98	3	28	21	1	15	108	
	PON-MED					4		2		
	MED			1		6			13	
Hemorrhage types	unilateral tegmental	47	16					15		
	Bilateral tegmenta	32	16							
	Basal-tegmental	46	25					7		
	Massive	46	40	2			1	8		
HV (ml)		NA	NA	1.92±1.3	9.3 (7.8-18)	8.7±0.5		8.5± 3.1	NA	9.6
<10ml		34	83	5		39		43	47	1
≥10ml		137	15			7	1	9	89	
Approach		NA	NA	Lateral suboccipital(n=1) Rhomboid fossa(n=1) Subtemporal(n=1) Midline suboccipital(n=1) Lateral suboccipital(n=1)	subtemporal (n=28)	Poppen's suboccipital transtentorial(n=4) Subtemporal-tentorium(n=10) Suboccipital retrosigmoid(n=20) Posterior fossa midline(n=12)	suboccipital midline (n=1)	suboccipital (n=52)	NA	endonasal transclival (n=1)
Interval to Surgery (hours)		NA	NA	196.8	8.16±2.20	12±0.5	3	12-48	NA	3
ICU stay-overall (days); mean (± SD)		NA	NA	NR	NA	NA	NR	NA	17.04 ± 9.78	NR
Hospital stay (days); mean (± SD)		NA	NA	NR	NA	NA	NR	NA	26.60 ± 15.23	NR
Follow-up		3 months	3 months	6 months	3 months	6 months	3 months	3-57 months	30 days	30 days
N death (duration to		68(30 days)	33(30 days)		11(3 months)	14(6 months)		7(3 months)	7(in-hospital)	
N good functional outcomes		74(mRS 0-3)	50(mRS 0-3)	4(mRS 0-2)	8(GOS 4-5)	NA	1(GOS 3)	19(GOS 4-5)	30(mRS 0-3)	1(GCS 11)
Independent predictors for mortality		GCS score Hemorrhage size	NA	NR	GCS score coma on admission	NA	NR	NA	NA	NR
Independent predictors for functional outcomes		NA	NA	NR	NA	Timing of surgery GCS score Hemorrhage volume	NR	GCS score Hemorrhage volume Location of hemorrhage	Hemorrhage size GCS score Age Tracheostomy	NR

N, number; R, retrospective; P, prospective; CR, case report; NA, not available; GCS, Glasgow Coma Scale; mRS, modified Rankin Scale; HV, hematoma volume; MED, medullary; MES, mesencephalic; PON, pontine.

7. Conclusions

This study has some limitations. This study was retrospective and conducted by a single institution and surgeon. The number of patients was limited, 1 patient died, and the remaining patients recovered neurologically. In addition, without surgery, it is difficult to compare the outcomes of their postoperative recovery with that of conservative treatment.Due to the small number of patients with brainstem hemorrhage, some correlations could not be statistically verified. We hope that neuroendoscopy-assisted microscopic hematoma evacuation is a good treatment for HBSH. The small sample size of this study is the limitation of this study, and further research is needed to formulate reasonable surgical guidelines for HBSH. In the future, we will cooperate with other physicians to collect more clinical data of HBSH surgery patients and HBSH medical conservative treatment patients, and perform statistical analysis to verify our conjecture.

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