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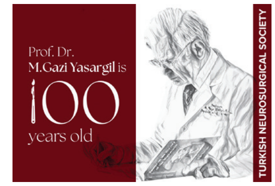

Original Investigation

Cerebrovascular-Endovascular

Neuroendoscopic Surgical Treatment of Hypertensive Brainstem Hemorrhage

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To watch the surgical videoclip, please visit https://www.turkishneurosurgery.org.tr/submit/pdf-files/in/48176-JTN-case3.rev-1.mp4

ABSTRACT

AIM: To investigate the clinical effect of neuroendoscopic surgery on 15 patients with hypertensive brainstem hemorrhage (HBSH).

MATERIAL and METHODS: A retrospective analysis was conducted on the clinical data collected from 15 patients with HBSH and treated with neuroendoscopy between January 2021 and March 2023. Prior to surgery, head computed tomography (CT) data were imported into 3D-slicer software to reconstruct the hematoma in three dimensions, allowing for the calculation of hematoma volume. During surgery, neuroendoscopy was used to clear the hematoma, after which the hematoma clearance rate, along with 30-day and 90-day mortality rates, was calculated. Three months after surgery, the Glasgow Outcome Scale (GOS) was used to evaluate patient prognosis, calculate the good recovery rate, and assessed surgical efficacy.

RESULTS: Re-examination of head CT images within 24 hours post-surgery revealed a hematoma clearance rate of > 90% in 11 cases and over 80–90% in four cases, with a mean hematoma clearance rate of 90.52±3.85%. There were no complications associated with postoperative rebleeding, intracranial infection, or the leakage of cerebrospinal fluid. Mortality rates on days 30 and 90 post-surgery were 26.7% (4/15) and 40% (6/15), respectively. After a 3-month follow-up period, GOS prognostic scoring revealed that one case had recovered well and could live a normal life, two cases had mild disability, and two cases had severe disability. Four patients survived in a vegetative state while six patients died; the good prognostic rate was 20% (3/15).

CONCLUSION: Neuroendoscopic technology is safe and effective for the treatment of HBSH. This method has a high hematoma clearance rate and a good clinical treatment effect with few postoperative complications.

KEYWORDS: Neuroendoscopy, Hypertension, Brainstem hemorrhage, Surgical treatment, Endoport technology

ABBREVIATIONS: HBSH: Hypertensive brainstem hemorrhage, **CT:** Computed tomography, **GOS:** Glasgow outcome scale, **GCS:** Glasgow coma scale, **CTA:** Computed tomography angiography

INTRODUCTION

Hypertensive brainstem hemorrhage (HBSH) is an acute cerebrovascular disease characterized by rapid onset, rapid progression, high mortality and disability rates, and an extremely poor prognosis (6,11,14). Due to the complex anatomical structure of the brainstem and the difficulty associated with performing surgery after hemorrhage, there is still considerable debate regarding whether surgical treatment can improve the prognosis of patients with brainstem hemor-

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rhage (17). Therefore, from a global perspective, conservative treatment is normally provided to patients with HBSH. With the continuous improvement of surgical techniques, some patients with HBSH have achieved symptom improvement following surgical treatment (7,8), although the safety and efficacy of such surgery have yet to be fully determined. In the present study, we retrospectively analyzed the clinical data of 15 patients with HBSH who admitted to our hospital between January 2021 and March 2023. For each patient, we used neuroendoscopic technology to remove the hematoma and then determined the specific clinical efficacy of this technique.

MATERIAL and METHODS

The research has been approved (Ethics Review Number: WDRY2022-KS002, Date: January 10, 2022)

Study Population

We retrospectively analyzed the clinical data of 15 patients with HBSH who had been admitted to the Department of Neurosurgery at our institution between January 2021 and March 2023. Detailed information related to the patient cohort is provided in Table I. The inclusion criteria were as follows: 1) a clear history of hypertension and surgery performed within 24 hours of onset; 2) parenchymal hemorrhage of the brainstem indicated by head CT; 3) hematoma volume ≥5 mL; and 4) progressive neurological dysfunction with a Glasgow coma scale (GCS) score <8 points. The exclusion criteria were as follows: 1) late cerebral hernia due to bilateral pupil dilation; 2) bleeding caused by other factors such as tumors, trauma, vascular malformations, and aneurysms; 3) abnormal coagulation function; and 4) inability to tolerate anesthesia or surgery. The study protocol conformed to the ethical guidelines of the Declaration of Helsinki, and was approved by the Ethics Committee of our hospital. All patients underwent surgery with informed consent signed by their families.

Acquisition of Three-dimensional (3D) Images

Following hospital admission, we first performed head CT examination. Data acquired by head CT were then imported into 3D-Slicer system in DICOM format (The version 3D Slicer 4.10.2. link: https://slicer.org). Segment Editor, Threshold, Island, Volume Rendering, Segment Statistics and other functional modules were run sequentially in 3D-Slicer software to reconstruct the brainstem hematoma and calculate hematoma volume.

Neuroendoscopic Hematoma Evacuation

We selected the appropriate surgical approach for each patient in accordance with the different shapes and locations of the hematoma, as reconstructed by 3D-Slicer software: the subtemporal transtentorial approach (suitable for posterolateral pontine hematomas), and the suboccipital posterior median approach (suitable for medulla bulbar and inferior dorsal pontine hematomas). Of the 15 patients, the subtemporal transtentorial approach was selected for nine patients, the suboccipital posterior median approach for two patients, the frontal approach for one patient, and the retrosigmoid sinus approach for three patients. Two patients with acute obstructive hydrocephalus underwent external ventricular drainage initially. In these cases, cerebrospinal fluid was fully released during routine craniotomy. Once cerebral pressure had fallen, we used the advantages of neuroendoscopy (good deep illumination, and a clear visual field) to reveal the rupture of brainstem hematomas. A bespoke transparent working sheath (Endoport) was then inserted into the hematoma cavity and the hematoma was removed by neuroendoscopy. In cases of obvious and active bleeding, we applied weak bipolar electrocoagulation for hemostasis, and the surgical area was irrigated with warm physiological saline. When there was no evidence of obvious active bleeding, we placed a drainage tube into the hematoma cavity, sutured the dural membrane, and closed the cranium using a routine method.

Observation and Evaluation Indicators

Head CT was re-examined within 24 hours of surgery, and 3D-Slicer software was used to calculate the residual hematoma volume and the hematoma clearance rate. The hematoma clearance rate was calculated as follows: (preoperative hematoma volume − postoperative residual hematoma volume) ÷ preoperative hematoma volume × 100%. We also calculated the incidence of postoperative complications, including rebleeding, intracranial infection and the leakage of cerebrospinal fluid. In addition, we calculated the 30- and 90-day survival rates. Patients were followed up for three months post-surgery and the GOS was used to evaluate patient prognosis (Table II); a GOS score greater than or equal to 4 indicated a good prognosis, while a GOS score <4 indicated a poor prognosis.

RESULTS

Postoperative Clinical Results

All patients underwent head CT re-examination within 24 hours of surgery. Hematoma clearance rates were > 90% in 11 cases and > 80%–90% in four cases, with a mean hematoma clearance rate of 90.52 ± 3.85%. There were no complications associated with intracranial rebleeding, intracranial infection, or cerebrospinal fluid leakage. The 30- and 90-day mortality rates were 26.7% (4/15) and 40% (6/15), respectively. All patients were followed up for three months after surgery. Of the 15 patients, six died and nine survived. The prognosis of the nine surviving patients was evaluated according to GOS. One case had recovered well and could live a normal life, two cases had mild disability, two cases had severe disability, and four cases survived in a vegetative state. The overall good prognosis rate was 20% (3/15).

Typical Cases of Brainstem Hemorrhage

Case 1

A 60-year-old male patient was admitted to our hospital due to a sudden disturbance of consciousness for five hours. Physical examination revealed that the patient was unconscious and in a state of tracheal intubation. Bilateral pupil size was 2 mm with absent light reflexes. Furthermore, the patient exhibited quadriplegia with bilateral Babinski sign positivity. Emergency head CT examination revealed pontine hemorrhage; the largest level of hematoma was predominantly

Table I: Basic Information Relating to the 15 Patients

Patient	Gender	Age (Years)	Preoperative GCS score	Preoperative bilateral pupil size (mm)	Hematoma location	Preoperative hematoma volume (ml)	Combined hydrocephalus (Yes/No)	Surgical approach	Hematoma clearance rate (%)	Postoperative GOS score
1	Female	57	3	5	Whole brainstem	12.3	N	Subtemporal	90.2	1
2	Male	39	3	2	Whole brainstem	12	N	Retrosigmoid	82.5	2
3	Male	52	3	5	Whole brainstem	15	Y	Frontal	84.7	1
4	Male	58	4	2	Mesencephalon-pontine	8	N	Retrosigmoid	91.3	2
5	Male	60	5	2	Pontine-medulla oblongata	14.8	N	Subtemporal	91.2	4
6	Male	54	5	1.5	Pontine	10.3	N	Subtemporal	85.4	3
7	Male	46	4	1	Pontine	8.4	N	Subtemporal	96.4	2
8	Male	68	3	3	Whole brainstem	13.8	N	Retrosigmoid	91.3	1
9	Male	48	3	2	Whole brainstem	14.5	N	Subtemporal	90.3	1
10	Male	40	3	Left 3 Right 5	Whole brainstem	12.7	N	Subtemporal	91.3	1
11	Male	47	5	Left 2 Right 1.5	Pontine	7.9	Y	Subtemporal	93.8	4
12	Female	44	4	Left 3 Right 3.5	Mesencephalon-pontine	11.6	N	Posterior median	88.8	2
13	Male	64	4	1.5	Pontine	9.7	N	Subtemporal	91.8	3
14	Male	64	3	2	Pontine	8	N	Subtemporal	93.8	3
15	Male	64	5	1.5	Mesencephalon-pontine	6	N	Posterior median	95	4

GCS: *Glasgow coma scale,* ***GOS:*** *Glasgow outcome scale,* ***N:*** *No,* ***Y:*** *Yes.*

Table II: Glasgow Outcome Scale (GOS) (3,16)

Score	Grade	Description
5	Good recovery	Able to return to normal life, despite mild defects
4	Moderate disability	Disabled but able to live independently and work under protection
3	Severe disability	Daily life cannot be independent and needs care
2	Vegetative state	Unable to interact with environment, unresponsive
1	Dead	Dead

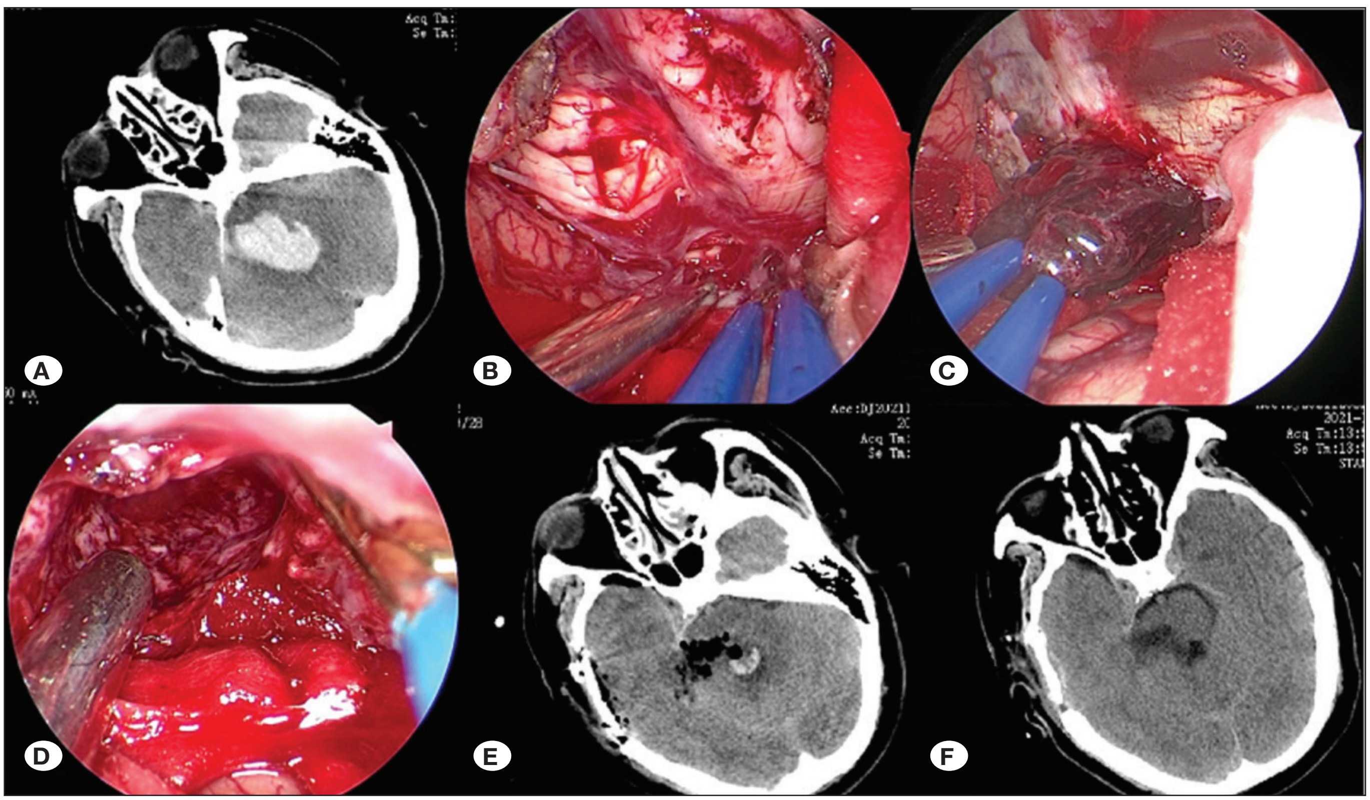

Figure 1: Preoperative head computed tomography (CT) showing that the largest level of the hematoma was located in the right pontine region **(A)**. The tentorium of the cerebellum was cut and the brainstem structure was exposed **(B)**. The hematoma was removed by neuroendoscopy **(C)**. Examination of the hematoma cavity showed no obvious active bleeding **(D)**. CT examination of the head within 24 hours revealed satisfactory brainstem hematoma clearance after surgery **(E)**. CT examination of the head one month after surgery **(F)**.

located in the right region of the pontine. The volume of the hematoma was calculated by 3D-slicer software before surgery (14.8 mL). Head computed tomography angiography (CTA) showed no significant abnormalities. The hematoma was subsequently removed by the right subtemporal approach and neuroendoscopic technology. Repeat head CT examination revealed that the hematoma had been completely removed during surgery. The patient was subsequently transferred to the rehabilitation department one month after surgery. After three months of follow-up, the GOS score of the patient was 4 points (Figure 1).

Case 2

A 47-year-old male patient was admitted to our hospital due to a sudden consciousness disorder that lasted for three hours. Physical examination revealed that the patient was in a state of coma, with unequal pupil sizes on both sides, with a left pupil diameter of 2 mm and a right pupil diameter of 1.5 mm. The light reflex had disappeared, and the limbs were paralyzed with low muscle tone. There was a positive Babinski sign on both sides. Emergency head CT examination revealed a left pontine hemorrhage. The volume of the hematoma was calculated by 3D-slicer software before surgery (7.9 mL). Head CTA showed no significant abnormalities. The hematoma was removed by the left subtemporal approach and neuroendoscopic

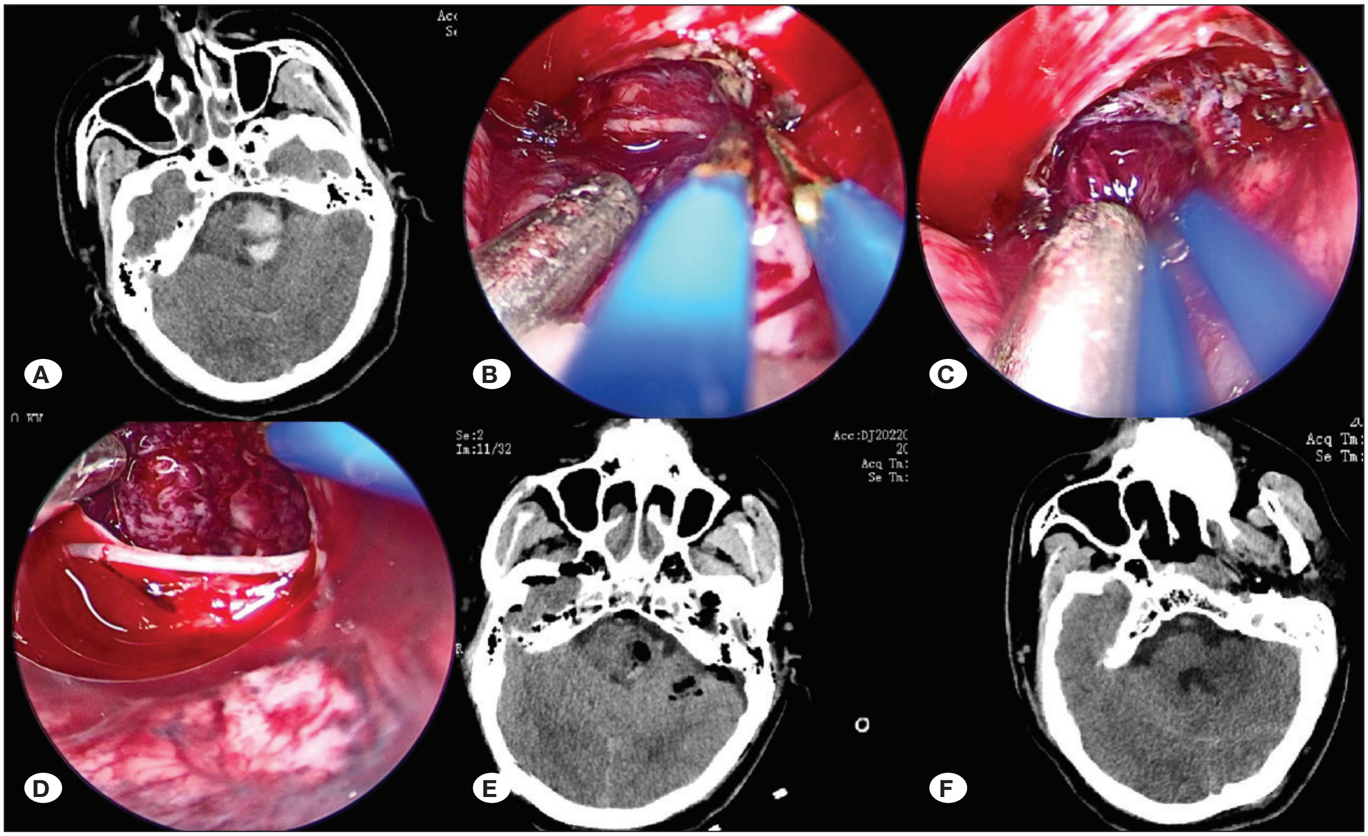

Figure 2: Preoperative head computed tomography (CT) showed that the largest level of the hematoma was located in the left pontine region **(A)**. The tentorium of the cerebellum was cut and the brainstem structure was exposed **(B)**. The hematoma was removed by neuroendoscopy **(C)**. Examination of the hematoma cavity showed no obvious active bleeding **(D)**. CT examination of the head within 24 hours revealed satisfactory hematoma clearance after surgery **(E)**. CT examination of the head one month after surgery **(F)**.

technology. Repeat head CT examination showed that the hematoma had been completely removed during surgery. the patient was transferred to the rehabilitation department one month after surgery. After three months of follow-up, the GOS score of the patient was 4 points (Figure 2).

Case 3

A 64-year-old male patient was admitted to our hospital due to a sudden disturbance of consciousness for two hours. Physical examination revealed that the patient was comatose with irregular breathing. Bilateral pupil size was 1.5 mm with absent light reflexes, and the patient displayed quadriplegia with bilateral Babinski sign positivity. Emergency head CT examination revealed a hematoma located in the dorsal pontine. The volume of the hematoma was calculated by 3D-slicer software before surgery (6 mL). Head CTA revealed no significant abnormalities. The hematoma was removed by the membranous medullary velum approach and neuroendoscopic technology. Repeat head CT examination revealed that the hematoma had been completely removed during surgery. The patient was transferred to the rehabilitation department one month after surgery. After three months of follow-up, the GOS score of the patient was 5 points (Figure 3). The patient's surgical video can be found in Video 1.

DISCUSSION

HBSH is the deadliest form of cerebral hemorrhage, accounting for 6 to 10% of all cases of hypertensive cerebral hemorrhage (4). HBSH most commonly occurs in the pontine region. Due to its special anatomical location, corrective surgery is difficult, the surgical risk is significant, and the patient prognosis is poor (1,12). Previously, the surgical treatment of HBSH was considered to be of limited value, and conservative medical treatment was mainly adopted. American Heart Association/American Stroke Association(AHA/ASA) guidelines clearly prohibit surgical intervention for brainstem hematoma, although the effect of conservative treatment remains extremely poor (4). Over recent years, surgeons have adopted various surgical methods to treat HBSH in order to reduce patient mortality and improve their survival rate and quality-of-life. The symptoms of some HBSH patients were improved after surgical treatment, and the prognosis of surgery was better than that of conservative treatment; furthermore, clinical experience led to greater surgical effect (2,5,18).

Many surgical methods have been applied for HBSH, including craniotomy hematoma removal, stereotactic hematoma puncture, and drainage. Each of these methods has its own advantages and disadvantages (2,9). Neuroendoscopy is one of

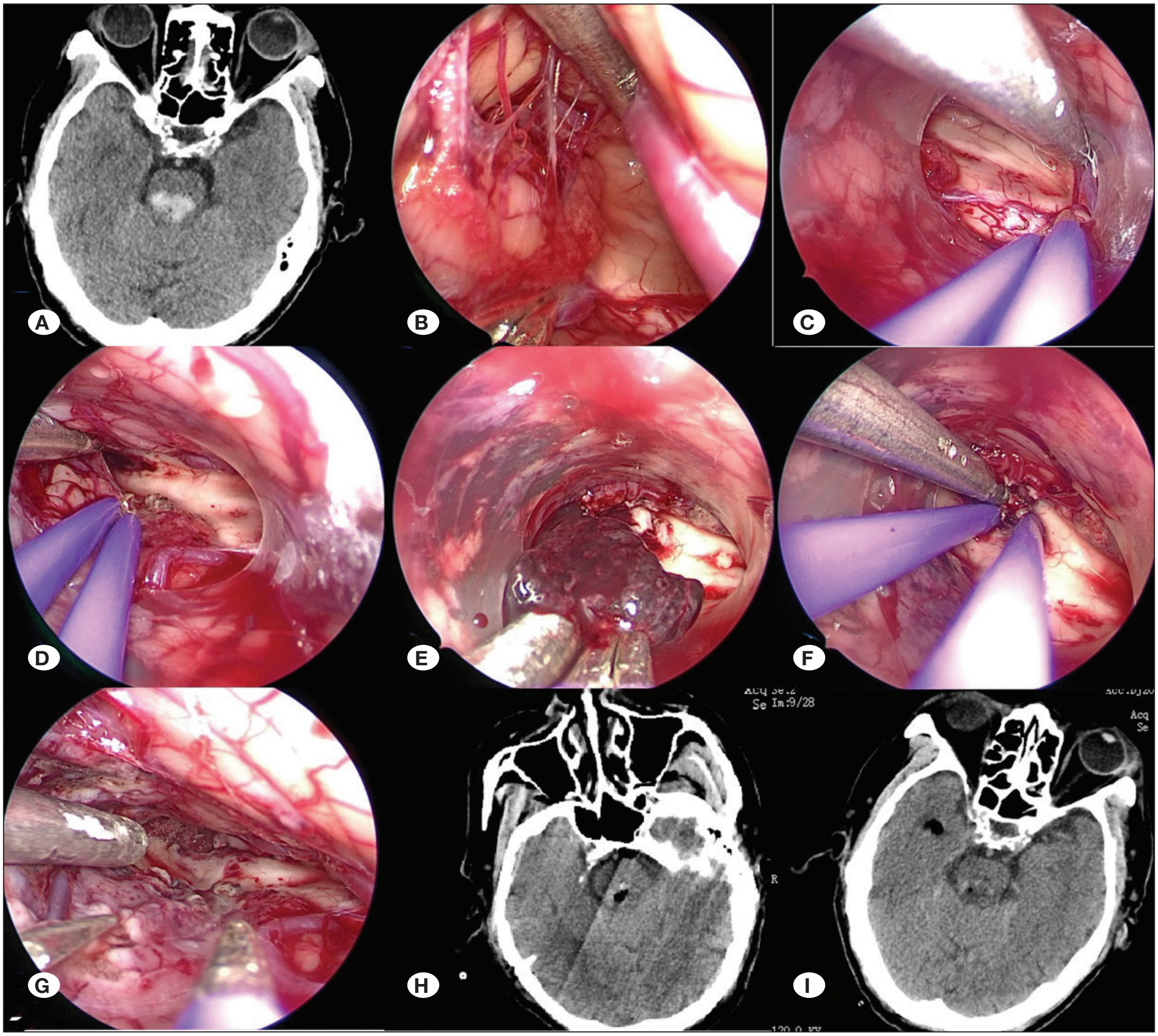

Figure 3: Preoperative CT examination of the head showed that the hematoma was located in the dorsal pontine region **(A)**. The membrane medullary velum structure was opened **(B)**. A micro-sheath (Endoport) was then implanted to explore the bottom of the fourth ventricle **(C)**. Hematoma rupture was observed at the upper end of the fourth ventricle **(D)**. The hematoma was removed by neuroendoscopy **(E)**. Complete hemostasis **(F)**. There was no obvious active bleeding **(G)**. CT examination of the head within 24 hours revealed satisfactory brainstem hematoma clearance after surgery **(H)**. CT examination of the head three days after surgery **(I)**.

the surgical methods for brainstem hemorrhage, but has been rarely used. Oertel et al. used neuroendoscopy to resect 19 patients with brainstem cavernous malformations, and reported good clinical effects and no postoperative complications related to neuroendoscopy (13). Takimoto et al. were the first to remove a brainstem hematoma by neuroendoscopy, making neuroendoscopic technology as a viable alternative for the surgical treatment of brainstem lesions (15). In another study, Zhou et al. used neuroendoscopy technology to treat brain stem and fourth ventricle lesions via the posterior sigmoid sinus approach, including three cases of pontine arm cavernous hemangioma and two cases of brain stem and fourth ventricle tumors. The enhanced maneuverability of neuroendoscopy during surgery effectively compensated for the limitations of a microscope, made the operation more minimally invasive, and achieved good surgical results (19). Liu et al. reported a successful case of neuroendoscopy for brainstem hemorrhage in a man with severe HBSH. One month after surgery, his GCS score improved from 3 to 11, and his symptoms improved significantly (10). Huang et al. used neuroendoscopy to treat 14 patients with primary brainstem hemorrhage; nine of these patients achieved satisfactory functional recovery. This technique caused minimal levels of damage to important brainstem structures, and achieved satisfactory clinical results (5). However, the safety and efficacy of this procedure has yet to be demonstrate in a large study cohort.

Over recent years, we have used neuroendoscopic technology to treat 15 cases of HBSH, and achieved good clinical results. Neuroendoscopy has several advantages for the treatment of brainstem hemorrhage. First, there is no need to overpull the brain tissue during the operation, there is minimal damage to the brain tissue, and only mild edema occurs in the brain tissue following surgery, especially in the brainstem. Secondly, neuroendoscopy can visualize important nerves and blood vessels in the brainstem and surrounding areas, thus reducing iatrogenic injury. Third neuroendoscopy can be used in a narrow space in multiple directions and angles, thus improving the hematoma clearance rate. In addition, when using this method, it is easy to identify small bleeding points during surgery. This means that it is possible to stop bleeding in good time and ensure hemostasis with only a low probability of postoperative rebleeding. Finally, neuroendoscopy results in a shorter surgical duration, less intraoperative bleeding, and fewer postoperative complications.

There are several key points to emphasize from our research. First, when a hematoma breaks through the cortex of the brainstem, the hematoma can be gradually removed along the break. When the hematoma does not break through the surface of the brainstem, the site of the hematoma can be determined under the guidance of neural navigation, and the non-vascular area on the surface of the brain stem can be selected, while avoiding the location of important nerve nuclei for corticostomy. Secondly, removal of the hematoma should be carried out in the hematoma cavity as far as possible and not exceeding the edge of the hematoma cavity. To avoid damage to normal brain tissue, the suction force should not be too excessive. Third, when there is active bleeding, low-power bipolar electrocoagulation can be used for accurate hemostasis, and the surgical area can be repeatedly rinsed with normal saline to reduce thermal damage. Areas of active bleeding can be covered by a hemostasis gauze or cotton sheet without the need for bipolar electrocoagulation. Finally, the midbrain aqueduct should be opened during surgery to establish an unobstructed cerebrospinal fluid circulation pathway to prevent postoperative hydrocephalus.

There are some limitations to this study that need to be considered. First, we only included a small number of patients. Second, this was a retrospective study performed in a single-center with a short follow-up time. Multi-center, large-sample, case-randomized and controlled studies are still needed to further confirm the clinical efficacy of this technique.

CONCLUSION

Neuroendoscopy-assisted treatment of HBSH is safe and effective, offering a high hematoma clearance rate, fewer postoperative complications, and favorable surgical outcomes. However, this study has some limitations. The sample size of patients in this group is small, it is a single-center retrospective study, and the follow-up period is relatively short. To further validate the clinical efficacy of this technique, multi-center, large-sample, case-randomized controlled studies are needed, which should be covered in future studies.

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Declarations

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Availability of data and materials: The datasets generated and/or analyzed during the current study are available from the corresponding author by reasonable request.

Disclosure: The authors declare no competing interests.

AUTHORSHIP CONTRIBUTION

Study conception and design: ZLY, QC
Data collection: ZLY
Analysis and interpretation of results: ZLY, LZ
Draft manuscript preparation: ZLY
Critical revision of the article: LZ, QC
Other (study supervision, fundings, materials, etc...): QC
All authors (ZLY, LZ, QC) reviewed the results and approved the final version of the manuscript.

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