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Surgical Treatment for Severe Primary Midbrain and Upper Pons Hemorrhages Using a Subtemporal Tentorial Approach

Jie Wu[1] Xiao Wu[2] Yong Zhang[3] Wei Du[1] Ke Wei[1] Guo Jie Yao[1]

[1] Department of Neurosurgery, General Hospital of Central Theater Command of Chinese People's Liberation Army, Wuhan, Hubei, China
[2] Department of Neurosurgery, The First Affiliated Hospital of Nanchang University, Nanchang, China
[3] Department of Neurosurgery, Beidaihe Rehabilitation and Recuperation Center of Chinese People's Liberation Army, Qinhuangdao, China

Address for correspondence Guo Jie Yao, MD, Department of Neurosurgery, General Hospital of Central Theater Command of Chinese People's Liberation Army, No. 627 Wuluo Road, Wuhan 430070, Hubei, China (e-mail: yaoguojie@hotmail.com).

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Abstract

Objectives It is unclear whether surgical hematoma evacuation should be performed in cases of primary brainstem hemorrhages (PBH). Here, we analyzed 15 cases with severe primary midbrain and upper pons hemorrhages to assess the associations between the subtemporal tentorial approach and patient functional outcomes and mortality.

Design A total of 15 patients diagnosed with severe primary midbrain and upper pons hemorrhages who had previously received the subtemporal tentorial approach at our facility from January 2018 and March 2019 were analyzed. All surviving cases received a follow-up at 6 months after surgery. The Glasgow Coma Scale and Glasgow Outcome Scale (GOS) scores were analyzed 1 and 6 months after surgery, respectively. Demographic data, lesion characteristics, and follow-up data were retrospectively collected.

Results All patients successfully underwent surgical evacuation for hematomas using the subtemporal tentorial approach. The overall survival rate for these cases was 66.7% (10/15). At the last follow-up, 26.7% of patients (4/15) exhibited healthy function (GOS score: 4), 20.0% (3/15) showed disability (GOS score: 3) and 20.0% (3/15) were in a vegetative state (GOS score: 2).

Conclusions Based on the results uncovered in this study, the subtemporal tentorial approach was found to be both safe and feasible and may be beneficial for the treatment of severe primary midbrain and upper pons hemorrhages, but a more comprehensive and comparative study is required to further confirm these results.

Keywords
- primary brainstem hemorrhage
- subtemporal tentorial approach
- outcomes

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Introduction

A cerebral hemorrhage is a common, deadly malady observed in neurology. The most devastating form of hemorrhage is the primary brainstem hemorrhage (PBH). PBHs rarely occur in patients suffering from hemorrhagic strokes, and account for only 5 to 10% of all intracranial hemorrhages.[1,2] The morbidity of PBH ranges from 2 to 4 cases in 100,000 individuals per year.[3] Hypertension is the most common cause of PBH, followed by cavernous and arteriovenous malformations.[4,5] The anatomical complexity and functional importance of the brainstem increases the risk of PBH during surgery. With the development of microsurgical and neuroimaging techniques, there has been an increase in treatment measures used for PBH, including stereotaxic aspiration and surgical evacuation. Some studies have reported that the surgical hematoma evacuation leads to a lower mortality rate and also exhibits acceptable functional outcomes.[6–9] However, investigators are still advocating for more conservative management measures. Surgical indication, outcomes, and approaches for PBH patients still need to be interrogated. Here, we conducted a retrospective study to assess the safety and efficiency of the subtemporal tentorial approach used to treat severe primary midbrain and upper pons hemorrhages.

Materials and Methods

Patients

A total of 15 patients diagnosed with severe primary midbrain and upper pons hemorrhages, who were treated using the subtemporal tentorial approach, were reviewed at our facility from January 2018 to March 2019. A list of characteristics for the patients used in this study is summarized in ►**Table 1**. Clinical inclusion criteria for patients in this study included a PBH volume >5 mL, stable vital signs, a Glasgow Coma Scale (GCS) score <8, a history of hypertension, an upper pons, midbrain or pons-midbrain hematoma, and consent for surgery. Exclusion criteria included dysfunction of coagulation, a hemorrhage due to aneurysm or vascular malformations, a hemorrhage caused by trauma or a tumor, serious comorbidities that prevented the patient from tolerating surgery, patients who exhibited a GCS score >8, or patients from whom consent for surgery was not obtained. All patients in this study received standard modern medical care after surgery.

All 15 cases were classified into four groups that were based on hemorrhage location.[5,10] These groups included (1) "bilateral tegmental," which indicated that the hemorrhage was located in the bilateral tegmentum, (2) "massive," the most critical, where the hemorrhage bilaterally extends from the basis pontis to the tegmentum, (3) "small unilateral tegmental," where the hemorrhage only occupies the unilateral tegmentum, and (4) "basal–tegmental," where the hemorrhage is situated in the junction between the basis pontis and tegmentum.

Surgeries

Brainstem auditory evoked potential (BAEP) was monitored in all patients during microsurgical hematoma evacuation. The subtemporal tentorial approach was chosen based on hematoma location and where the hematoma reached the surface of the brainstem, so neurosurgeons could easily reach the hematoma without causing substantial damage to the brain. If the hematoma was accompanied with hydrocephalus, external ventricular drainage (EVD) was performed before a craniotomy. Otherwise, a lumbar drainage tube would be used

Table 1 Patient characteristics

Patient	Age (y)	Sex	GCS (admission)	Location	Type	Volume (mL)	Medical history
1	41	M	5	Pons-midbrain	Massive	13.4	HT
2	56	F	6	Pons-midbrain	Massive	6.6	HT
3	42	M	4	Pons	Basal tegmental	6.3	HT
4	53	M	6	Pons-midbrain	Massive	11.0	HT
5	57	M	4	Pons-midbrain	Massive	10.7	HT
6	46	M	5	Pons-midbrain	Massive	8.1	HT
7	44	M	6	Pons	Basal tegmental	5.2	HT
8	75	M	5	Pons-midbrain	Massive	12.2	HT
9	51	F	4	Pons	Massive	17.0	HT
10	33	M	5	Pons	Massive	9.3	HT
11	54	M	4	Pons	Bilateral tegmental	8.6	HT
12	39	M	4	Pons-midbrain	Massive	8.7	HT
13	46	F	5	Pons	Bilateral tegmental	4.7	HT
14	60	M	5	Pons	Bilateral tegmental	6.2	HT
15	46	M	5	Pons	Bilateral tegmental	7.6	HT

Abbreviations: F, female; GCS, Glasgow Coma Scale; HT, hypertension; M, male.

before surgery to release cerebrospinal fluid (CSF) with the goal of decreasing intracranial pressure during the operation.

All surgeries were performed with patients in the lateral position. An S-fashion incision originating from the zygoma was performed. A temporal bone flap measuring approximately 5 cm × 5 cm was formed using a milling cutter, with the lower edge parallel to the base of the middle fossa. A lumbar drainage tube or the EVD tube was opened slowly to release CSF after opening the dura. When the intracranial pressure dropped to a satisfactory level, the temporal lobe was gently elevated from the middle fossa floor using a brain retractor blade. Injury to the temporal lobe and inferior anastomotic vein was avoided. In 7 of 15 cases, this process was blocked by the inferior anastomotic vein or its branches. The adhesions between the vein and dura mater were loosened before retracting the temporal lobe. The tentorium and arachnoid covering the ambient cistern were both exposed, through the space between the temporal lobe and the base of the middle fossa. Then, the arachnoid was opened to obtain a larger operation space by releasing the CSF. After carefully dissecting the arachnoid and retracting the tentorial edge, the trochlear nerve, superior cerebellar artery, and the ventral lateral of pontine were made visible. To decrease the retraction of the temporal lobe and increase the exposure of the brainstem, a small tentorial incision and dural flap, immediately behind the entry point of the trochlear nerve in the dura, were performed. In 6 of 15 cases, the hemorrhage was visible from the lateral surface of the pons. When the hematoma was not viewed from the brainstem surface, a small incision was made based on preoperative computed tomography (CT) in a safe region of the lateral of pons to properly expose it. A microscopic aspirator was used to remove the hematoma present in the cavity. This process required a gentle operation and a combination of water to loosen the blot clots. Breaking the hematoma cavity and damaging normal brain stem tissue were carefully avoided (►**Fig. 1A–F**).

CT was performed on all patients after the operation to assess the extent of hematoma clearance (►**Figs. 2** and **3**). The GCS score was assessed for 1 month. The quality of life of the patients was assessed 6 months postoperatively.

Results

Of the 15 patients included in this study, a total of 3 patients were female and 12 patients were male, with an average age ranging from 33 to 75 years old (49.8 ± 10.1). All patients had a history of hypertension and were comatose, with a GCS score ranging from 4 to 6.

Two of the 15 patients temporarily underwent EVD before craniotomy, for the hematomas were accompanied with hydrocephalus and the EVD tubes were successfully removed after surgery. In the rest of the patients, lumbar drainage tubes were used before surgery and all these tubes were instantly

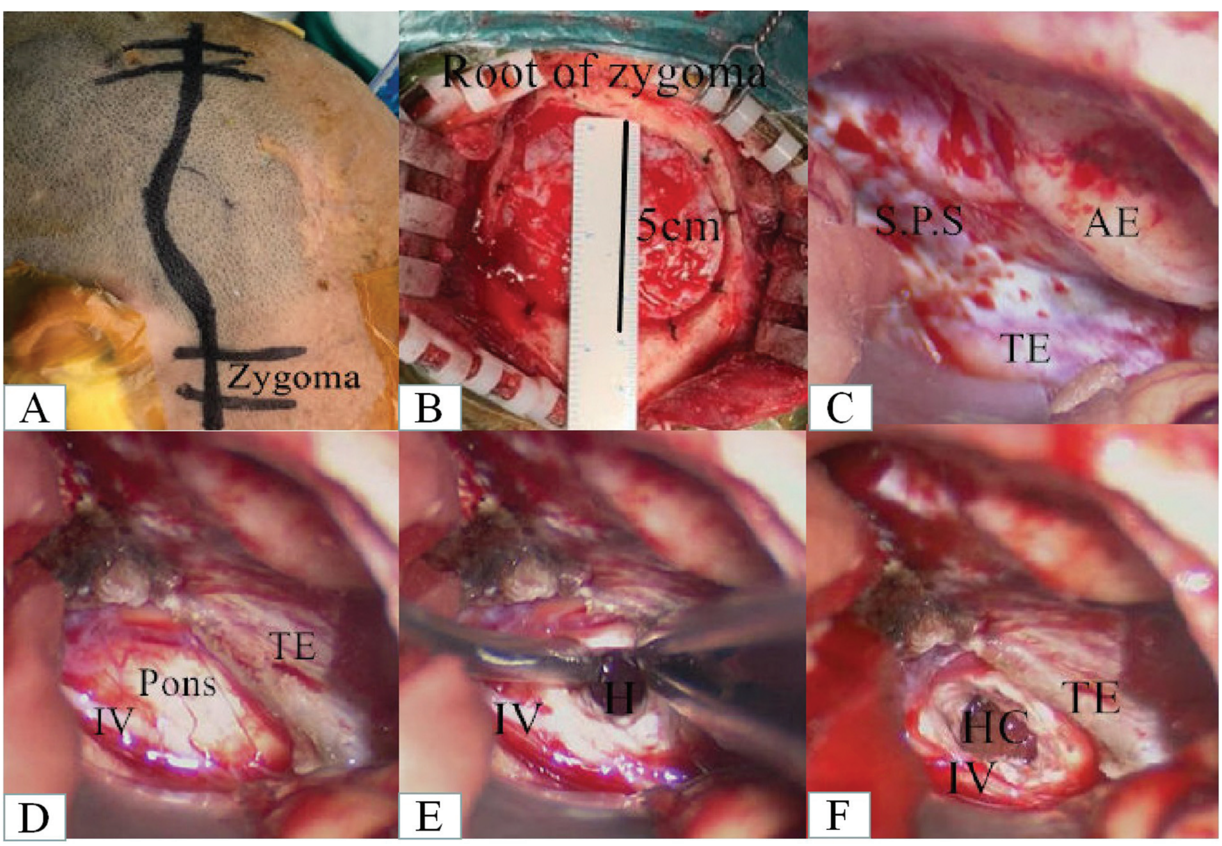

Fig. 1 The surgical procedure used to expose and remove the PBH through the subtemporal tentorial approach (**A–F**). AE, arcuate eminence; H, hematoma; HC, hematoma cavity; IV, trochlear nerve; PBH, primary brainstem hemorrhage; S.P.S, sup.pet.sinus; TE, tentorium.

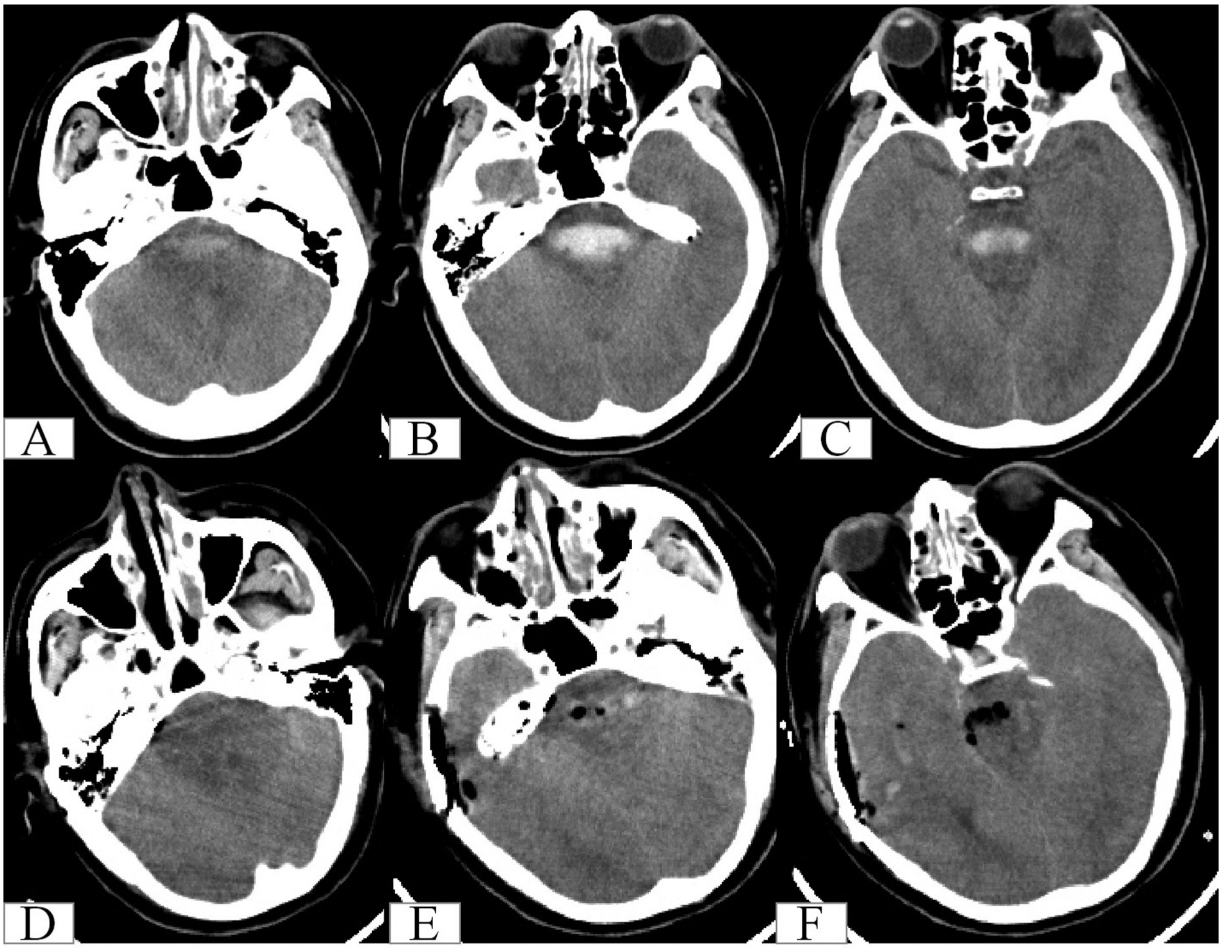

Fig. 2 Representative male, 42 years of age with a GCS score of 4 on admission. (**A–C**) A head CT demonstrated a "basal–tegmental" hemorrhage within the pons. The hematoma volume was ~6.3 mL. Most of the hematoma was evacuated through the right subtemporal tentorial 13 hours after the onset of the first symptom. (**D–F**) A postoperative CT showed that ~87.3% of the hematoma was removed. The GCS score was improved to 11 one month after surgery and the patient survived showing healthy functioning (GOS score 4). CT, computed tomography; GCS, Glasgow Coma Scale; GOS, Glasgow Outcome Scale.

removed after surgery. In the follow-up, the surviving patients did not receive shunting procedures. The volume of PBH was calculated using $A^*B^*C/2$ according to the preoperative CT, where *A*, *B*, and *C* represented the maximum length diameter, width, and height of the hematoma, respectively.[11,12] The volume of PBH in the patients ranged from 5.2 to 17 mL (9.1 ± 3.3 mL). Evacuation rates for hematomas were obtained using CT scans instantly after the operation, where rates were observed as ≥90% for 6, 80–90% for 5, and ≤80% for 4 cases, with no significant changes in BAEP occurring during the intraoperative period (►**Table 2**). A total of three patients (20%) passed away during the perioperative period, where two passed away from postoperative brainstem failure and one from multiple organ failure. Improvement in GCS was observed in eight patients (53.3%) 1 month after surgery. The rest of the patients were followed up 6 months after surgery with their Glasgow Outcome Scale (GOS) scores as follows: 26.7% (4/15) showing healthy function (GOS score: 4), 20.0% (3/15) showing disability (GOS score: 3), 20.0% (3/15) showing a vegetative state (GOS score: 2), and 13.3% (2/15) who passed away (GOS score: 1) (►**Table 3**). In these surviving patients, two in vegetative states continued to recover in rehabilitation hospitals, and the rest surviving patients were taken care of by their families at home.

Discussion

This study revealed that improvements in consciousness and functional outcomes as well as a lower mortality rate were observed in primary midbrain and upper pons hemorrhage patients who underwent the surgical subtemporal tentorial approach.

PBH is a deadly disease with a mortality rate ranging from 80 to 100%, especially in cases where hematomas are larger than 5 mL.[13] Management of PBH is still not clearly defined by the American Heart Association or the European Stroke Organization guidelines.[14,15] This creates an issue for neurologists who seek an effective treatment to improve the outcomes of PBH. Even though some scholars argue that the conservative management is appropriate,[16,17] others have explored surgical treatment and argued that it is the most effective measure. For instance, one study[18] argued that surgical treatment of PBH was safe and effective. More specifically, others[7] have reported that five PBH cases who

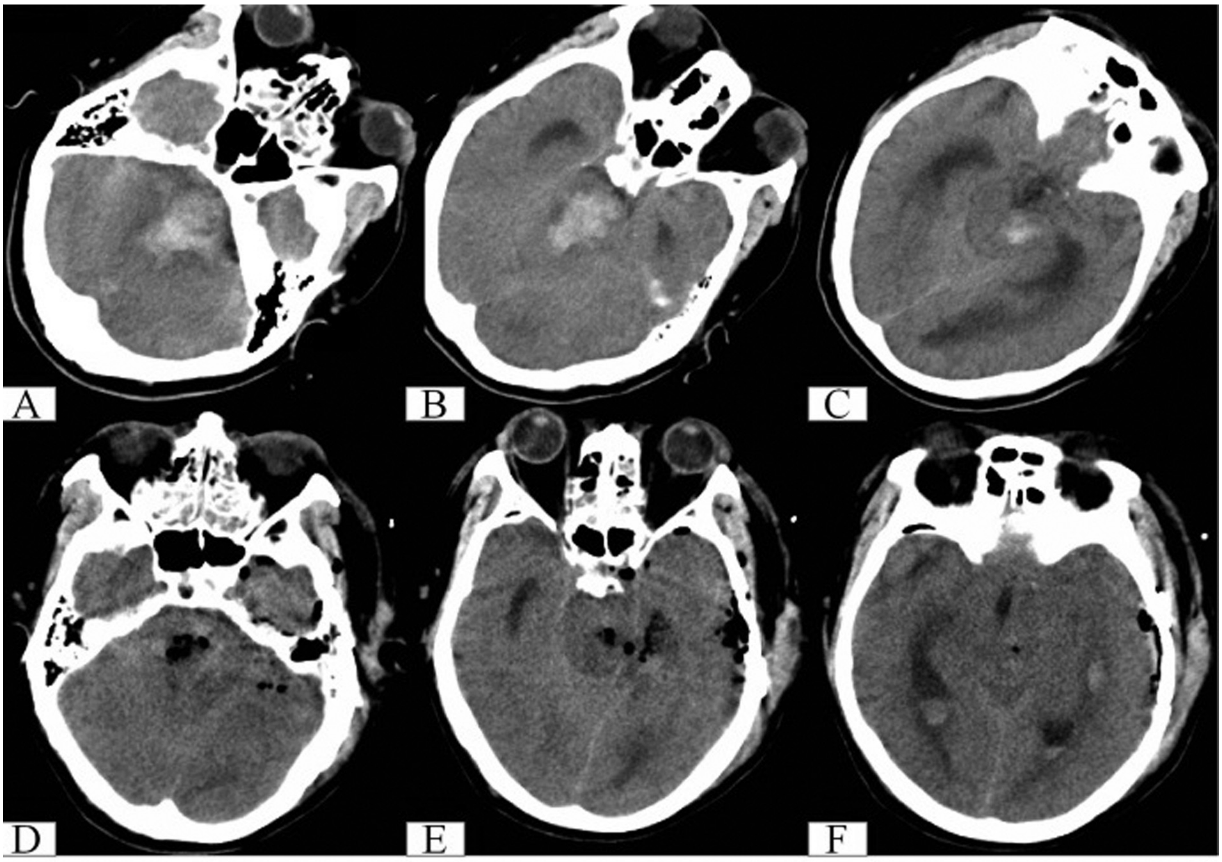

Fig. 3 Representative male, 53 years of age with a GCS score of 6 on admission. (**A–C**) A head CT demonstrated a "massive" pons hemorrhage extending into the midbrain combined with hydrocephalus. The hematoma volume was ~11.0 mL. Ventricular external drainage was initially performed before the craniotomy and most of the hematoma was removed through the left subtemporal tentorial 31 hours after onset of the first symptom. (**D–F**) A postoperative CT shows that ~95.5% of the hematoma was removed. Even though the hematoma was removed, the patient passed away due to brainstem function failure 10 days after surgery. CT, computed tomography; GCS, Glasgow Coma Scale.

Table 2 Surgery for primary brainstem hemorrhage

Patient	Interval to surgery (h)	Preop hematoma volume (mL)	Postop hematoma volume (mL)	Evacuation rate (%)	Position	Significant changes in BAEP intraoperative
1	13	13.4	1.8	86.6	Lateral	No
2	36	6.6	0.2	97.0	Lateral	No
3	13	6.3	0.8	87.3	Lateral	No
4	31	11.0	0.6	94.5	Lateral	No
5	3	10.7	1.8	83.1	Lateral	No
6	14	8.1	0.3	96.3	Lateral	No
7	6	5.2	1.7	67.3	Lateral	No
8	13	12.2	3.8	68.9	Lateral	No
9	8	17	1.7	90	Lateral	No
10	19	9.3	0.3	96.8	Lateral	No
11	24	8.6	2.0	76.7	Lateral	No
12	8	8.7	1.2	86.2	Lateral	No
13	15	5.7	1.3	77.2	Lateral	No
14	56	6.2	0.6	90.3	Lateral	No
15	10	7.6	0.8	89.5	Lateral	No

Abbreviation: BAEP, brainstem auditory evoked potential.

Table 3 Postoperative GCS score 1 month after surgery and GOS score 6 months after surgery

Patient	GCS (admission)	GCS (1 mo)	GOS score (6 mo)
1	5	Death	
2	6	8	1
3	4	11	4
4	6	Death	
5	4	4	2
6	5	8	3
7	6	12	4
8	5	Death	
9	4	4	2
10	5	5	3
11	4	13	4
12	4	4	1
13	5	7	2
14	5	12	4
15	5	8	3

Abbreviations: GCS, Glasgow Coma Scale; GOS, Glasgow Outcome Scale.

had successfully underwent surgical treatment showed improvements in consciousness and cranial nerve function, although these cases showed high GCS scores ranging from 13 to 15. However, relatively few patients who have received surgery for PBH have been thoroughly scrutinized and most studies have only been conducted through case reports.

The location and size of a hematoma dictate the surgical strategy that is used. For lesions located in the upper pontine and midbrain, potential surgical approaches include the orbitozygomatic, retrolabyrinthine, supracerebellar infratentorial, subtemporal tentorial, suboccipital telovelar, and suboccipital retrosigmoid approaches. The subtemporal approach was initially used to perform a rhizotomy on the trigeminal nerve.[19] Now, it is widely used by neurosurgeons to treat lesions located around the brainstem. Areas of exposure provided by the subtemporal tentorial approach include the entire lateral midbrain surface, the pontomesencephalic junction, and the lateral upper pons.[20] Advantages to this approach include maximum exposure to the brainstem, a shorter path to hematomas, and less complications. However, there were some common intraoperative complications when performing this approach, including temporal lobe contusion, venous infarction of the vein of Labbé, and the trochlear nerve injury.[21–24] In our case series, one branch of the vein of Labbé was disconnected in two patients, because they hindered the surgery approach but could not be dissected from dura matter. Luckily, there were no hemorrhage, venous infarction, and edema following this disconnection and retraction of the temporal lobe during this approach. More importantly, it has given us some enlightenment that preoperative vein evaluation is required to decrease the risk of venous injury of the vein of Labbé. The other intraoperative complications were not occurred in our case series. Inappropriate temporal lobe elevation during the operation may also lead to temporal lobe contusion. In this study, measures that were followed reduced the need for temporal lobe retraction. These measures included the use of mannitol, preoperative placement of lumbar drainage, and incision of the tentorium. In addition, the head higher than foot and zygomatic arch positions at the highest point were able to separate the temporal lobe and middle cranial fossa due to gravity, which also helped reduce retraction of the temporal lobe. According to the location of the hematoma (8 cases in pons and 7 cases in pons-midbrain), patients underwent surgeries using the subtemporal-tentorium approach. Approximately, 73.3% of patients obtained a satisfying evacuation rate (>80%) and showed no temporal lobe contusions during the perioperative period. Changes in BAEP during intraoperative monitoring may reflect damage or reversible dysfunction to the ear, cochlear nerve, or brainstem auditory pathways up to the midbrain.[25] There were no significant changes in BAEP observed during operations that indicated no or limited damage to the brainstem. Thus, for patients with PBH in the upper pons or midbrain, the subtemporal tentorial approach was safe and appropriate. Other studies[8,9] have reported surgical evacuation of upper pons hemorrhages through the anterior subtemporal approach. Different from other craniotomy methods, our method formed a temporal bone flap that was smaller. In addition, we performed lumbar drainage before surgery to decrease the need for retraction of the temporal lobe for patients without hydrocephalus and monitored BAEP during the intraoperative period to increase chances of a successful operation.

The overall survival rate was 66.7% 6 months after surgery. However, other studies investigating conservative treatment measures reported that the survival rate was 44%.[2] A retrospective analysis of 281 patients diagnosed with PBH showed that the survival rate was 42.3%.[26] There is no doubt that previous reports have brought valuable knowledge to the research community but it is important to note that in our study we observed a higher survival rate. Furthermore, the GOS scores observed in our study were higher than what has been previously reported.[27]

As with any study, our research also has its limitations including the fact that this was a retrospective study performed at a single institution. In addition, selected cases were severe, showing GCS scores ranging from 4 to 6 on admission, which may not be applicable for all PBH cases. In addition, it is important to note that the number of patients included in this study was limited and that additional studies with a larger sample size must be interrogated. Lastly, we hoped to evaluate the use of different approaches to make a more accurate comparison regarding which approach is most optimal.

Conclusion

Based on our study, it can be concluded that the subtemporal tentorial approach for severe primary midbrain and upper pons hemorrhage patients is feasible, safe, and may be beneficial for the treatment of severe primary midbrain and upper pons hemorrhages. However, a more comprehensive and comparative study is required to further confirm these results.

Conflict of Interest
None declared.

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