

Original Article

Clinical analysis of the simultaneous clipping of bilateral middle cerebral artery aneurysms via the unilateral pterional approach

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Abstract: The aim of this study was to investigate the feasibility of the simultaneous clipping of bilateral middle cerebral artery aneurysms via the unilateral pterional approach in Asian patients. The study included 10 cases of bilateral middle cerebral artery aneurysms, including two males and eight females; the ratio of male to female patients was 1:4. The patients ranged in age from 44 to 67 years old. All 10 patients had onsets of subarachnoid hemorrhage; the Hunt-Hess grades after onset included seven cases of grade II and three cases of grade III. Computed tomographic arteriography (CTA) was performed, and the patients were diagnosed as having bilateral middle cerebral artery aneurysms. The surgery used a pterional approach, and the clipping of the bilateral middle cerebral artery aneurysm was performed from the side of the ruptured aneurysm. Postoperative patient assessments were conducted using Glasgow Outcome Scale (GOS) scores, and CTA was used for the reexaminations. All 10 cases of bilateral middle cerebral artery aneurysms were successfully clipped. All of the patients recovered well and were discharged. The GOS scores at the half-year follow-ups included nine cases of 5 points and one case of 4 points. The CTA checks at the half- to one-year follow-ups showed that the clippings of the aneurysms at the bifurcation of the bilateral middle cerebral arteries were complete and that there were no remnants at the necks of the aneurysms. At the two-year follow-up phone calls, the GOS scores of the case with the previous GOS score of 4 had increased to 5. The cases were retrospectively analyzed to investigate the degree of brain swelling, the length of the M1 segment, the size of the aneurysm, and the impact of the orientation of the aneurysm on the clipping of contralateral middle cerebral artery aneurysms. The results suggest that in appropriate cases, the simultaneous clipping of bilateral middle cerebral artery aneurysms via the unilateral pterional approach is feasible in Asian patients.

Keywords: Unilateral pterional approach, clipping, bilateral middle cerebral artery aneurysms

Introduction

The treatment of intracranial bilateral multiple aneurysms, especially bilateral middle cerebral artery multiple aneurysms, is a challenge for neurosurgeons. The selection of the best surgical method is still debated; in particular, there is no universal consensus on whether to choose the unilateral or bilateral craniotomy approach [1]. The bilateral approach first addresses the ruptured aneurysm side and then the unruptured aneurysm side in a single stage or multiple stages, while the unilateral approach first occludes the ruptured aneurysm at certain locations on the bilateral aneurysm via the unilateral approach and then addresses the unruptured aneurysm. Contralateral posterior communicating artery aneurysms, contralateral

anterior choroidal artery aneurysms, and contralateral carotid bifurcation aneurysms can all be successfully occluded with these operations [2, 3]. However, many intraoperative issues can affect the feasibility of the unilateral pterional approach in occluding a contralateral middle cerebral artery aneurysm in one stage and can increase the difficulty of the operation, such the brain swelling status, the length of the M1 segment, the size of the aneurysm, and the orientation of the aneurysm [4]. Although the previously mentioned studies discussed the feasibility of clipping of bilateral middle cerebral artery aneurysm via the unilateral pterional approach in detail, the cases were mainly from European countries and the United States. The brain anatomy of Asians is different than that of Europeans and Americans; Asians have a small-

er Sylvian fissure and intracranial space, and the brain tissue tension is higher in the presence of a subarachnoid hemorrhage, which makes the operation more difficult [5]. Thus, treatments that clip the bilateral middle cerebral artery aneurysm via the unilateral pterional approach may be different in Asian countries than in European and American countries. This study reports 10 cases of bilateral middle cerebral artery aneurysms in which single-phase simultaneous clipping via the unilateral pterional approach was used. The operations are described below.

Materials and methods

General information

This study includes 10 patients with bilateral middle cerebral artery aneurysms that were admitted to the neurosurgery department of the First Hospital of Jilin University between January 2011 and January 2014. The patients comprised two males and eight females; the ratio of male to female cases was 1:4. The patients ranged in age from 44 to 67 years old (average of 52.8). All 10 patients had onsets of subarachnoid hemorrhage (SAH); the Hunt-Hess (HH) grades after the onset included seven cases of grade II and three cases of grade III. Detailed information is shown in **Table 1**.

Imaging examination

After being admitted to the hospital, all of the patients were given computed tomography (CT) and computed tomographic arteriography (CTA) examinations. The bleeding condition of the SAH and the presence of a hematoma in the Sylvian fissure were determined by CT. The formation of hydrocephalus was also assessed. After the CTA scan was completed, three-dimensional reconstructions were performed to examine the size and morphology of the bilateral middle cerebral artery aneurysm; in addition, the length of the M1 segment of the bilateral cerebral artery was measured, and the orientation of the aneurysm and its relationship with the surrounding blood vessels were carefully analyzed.

Assessment of the ruptured middle cerebral artery aneurysm

The following criteria were used to assess the ruptured aneurysm: ① CTA examination-the loca-

tion of the aggregation of SAH or the location of the hematoma is consistent with the location of the aneurysm; and ② CTA examination-the aneurysm has a large volume and an irregular shape, and it may also have complications of vasospasms and thinning of the parent artery [6].

Surgical treatment and follow-up

The operation uses the pterional approach, and the ruptured aneurysm side is selected to first dissect the ipsilateral Sylvian fissure. After the ipsilateral middle cerebral artery aneurysm is exposed, it is clipped, and the combined hematoma is cleared; the cerebrospinal fluid is then released. After the brain tissue collapses, the optic nerve gap is crossed to locate the contralateral carotid artery, which is dissected to the distal end along the middle cerebral artery. After the contralateral middle cerebral artery aneurysm is found, it is clipped.

Postoperative treatment

Conventional symptomatic treatment was performed. For the cases with severe SAH, continuous lumbar cistern drainage was performed to release the bloody cerebrospinal fluid for one week.

Follow-up

One half year after the operation, the Glasgow Outcome Scale (GOS) scoring system was used to grade the patients. One half year to one year after the operation, the patients returned to the hospital for a CTA check to determine whether there was an occurrence of the aneurysm and whether the parent artery was flowing freely. During this period, two phone call follow-ups were conducted.

Results

Imaging results

Of the 10 cases, four cases had a combined Sylvian fissure hematoma, and two cases had a combined acute hydrocephalus. Of the 10 ruptured aneurysms, seven were on the right side, and three were on the left side. The diameters of the ruptured aneurysms were 3.0-6.3 mm (average 4.87 mm), and the lengths of the M1 segments on the side of the ruptured aneurysms were 1.15-2.80 cm (average 1.91 cm).

Clipping of bilateral middle cerebral artery aneurysms

Table 1. Summary of clinical data

No.	Age	Sex	Onset	Preoperative HH	Operative side	Ipsilateral ruptured aneurysm		Contralateral unruptured aneurysm			Hydrocephalus	Combined hematoma	CTA follow-up	GOS
						Side and diameter	Length of ipsilateral M1 segment	Side and size	Length of contralateral M1 segment	Orientation				
1	60	Female	SAH	II	Right	R: 5.4 mm	1.81 cm	L: 3.1 mm	L: 1.63 cm	Forward upward outward	Yes	No	Complete clipping	5
2	48	Female	SAH	II	Right	R: 4.4 mm	1.15 cm	L: 2.3 mm	L: 1.31 cm	Forward downward inward	No	No	Complete clipping	5
3	52	Female	SAH	II	Right	R: 3.5 mm	1.90 cm	L: 2.0 mm	L: 1.39 cm	Forward upward inward	Yes	Yes	Complete clipping	5
4	44	Female	SAH	II	Right	R: 3.0 mm	1.36 cm	L: 3.5 mm	L: 1.5 cm	Forward downward outward	No	No	Complete clipping	5
5	52	Female	SAH	II	Left	L: 4.5 mm	2.03 cm	R: 3.3 mm	R: 0.81 cm	Forward downward inward	No	Yes	Complete clipping	5
6	44	Female	SAH	III	Right	R: 5.0 mm	2.09 cm	L: 4.3 mm	L: 1.37 cm	Forward downward	No	No	Complete clipping	5
7	55	Female	SAH	III	Left	L: 6.3 mm	1.51 cm	R: 2.5 mm	R: 1.22 cm	Forward downward outward	No	Yes	Complete clipping	5
8	67	Male	SAH	II	Right	R: 5.8 mm	1.91 cm	L: 3.0 mm	L: 1.58 cm	Forward upward outward	No	No	Complete clipping	5
9	58	Female	SAH	II	Left	L: 4.8 mm	2.50 cm	R: 3.5 mm	R: 1.25 cm	Forward downward inward	Yes	Yes	Complete clipping	5
10	48	Male	SAH	III	Right	R: 6.0 mm	2.80 cm	L: 4.5 mm	L: 1.45 cm	Forward downward	No	No	Complete clipping	5

SAH: Subarachnoid hemorrhage; HH: Hunt-Hess grade; R: Right side; L: Left side; GOS: Glasgow outcome scale.

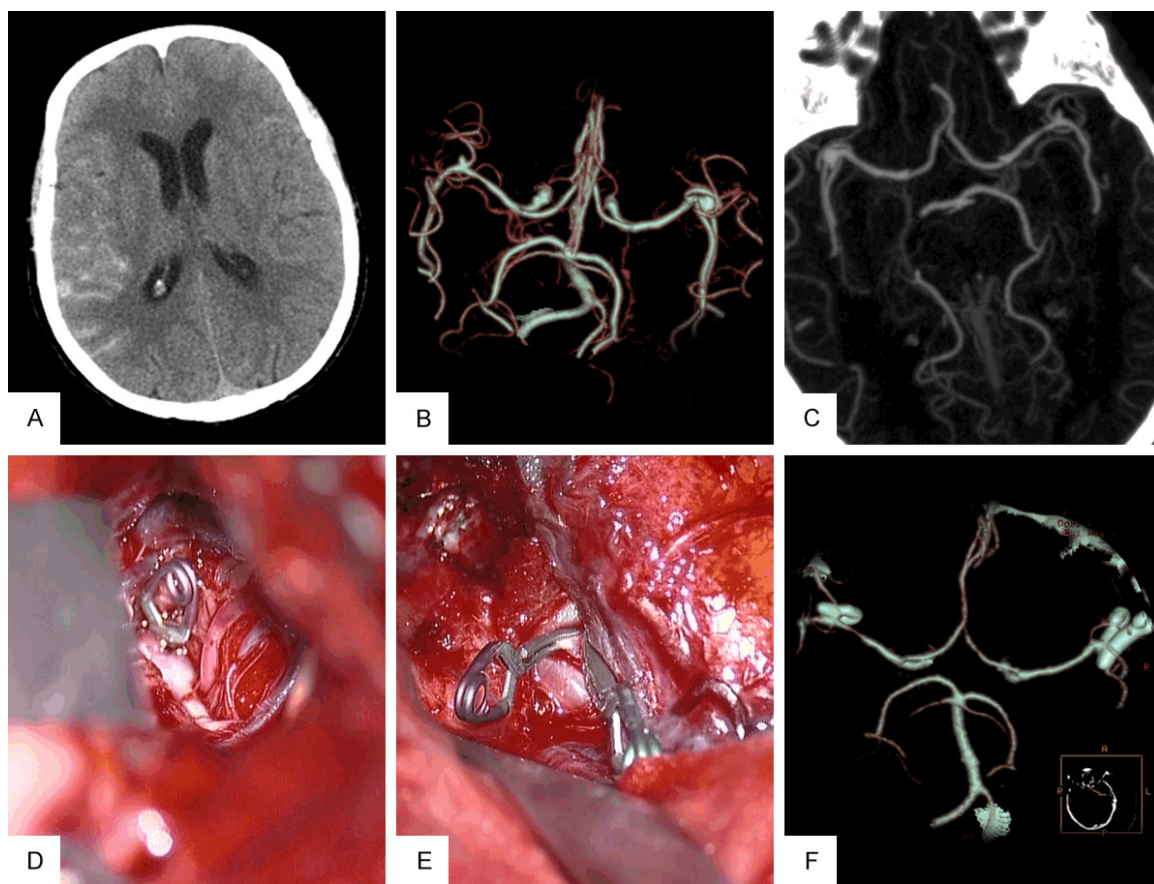


Figure 1. Imaging of case 1: A: CT showing the subarachnoid hemorrhage; the bleeding is concentrated in the sulci above the right Sylvian fissure, and the ventricle size is normal. B, C: CTA showing the bilateral middle cerebral artery aneurysm. The right aneurysm is larger, and the left aneurysm is smaller and points forward, upward and outward. D: Intraoperative image showing that the contralateral (left) middle cerebral artery aneurysm, which is opposite to the operation area, has been clipped. E: Intraoperative image showing that the ipsilateral (right) middle cerebral artery aneurysm, which is on the same side of the operation area, has been clipped. F: CTA reexamination showing that there was no relapse after the clipping of the bilateral middle cerebral artery aneurysm.

Of the 10 unruptured aneurysms, the diameters of the aneurysms were 2.0-4.5 mm (average 3.2 mm), and the lengths of the M1 segments on the side of the unruptured aneurysms were 0.81-1.63 cm (average 1.35 cm). The orientations of the aneurysms varied; two cases were oriented forward, upward and outward, one case was oriented forward, upward and inward, two cases were oriented forward, downward and outward, three cases were oriented forward, downward and inward, and two cases were oriented forward and downward.

Surgical results

Pterional craniotomies from the side of the ruptured aneurysm were performed in all 10 cases. The ipsilateral middle cerebral artery aneurysm was first clipped. After part of the hematoma

was cleaned, the midline was crossed to reach the bifurcation part of the contralateral middle cerebral artery, and the contralateral unruptured aneurysm was clipped. All of the patients recovered well within two weeks and were discharged. In the four cases with the combined Sylvian fissure hematomas, CT reexaminations showed that the intracranial hematomas were absorbed; in the two cases with acute hydrocephalus, the ventricular size had returned to normal at the time of discharge.

Follow-up results

At the half-year follow-up, nine cases had GOS scores of 5, and one case had a score of 4. The CTA reexaminations at the half- to one-year follow-ups showed that the clippings of the aneurysms at the bifurcation part of the bilateral

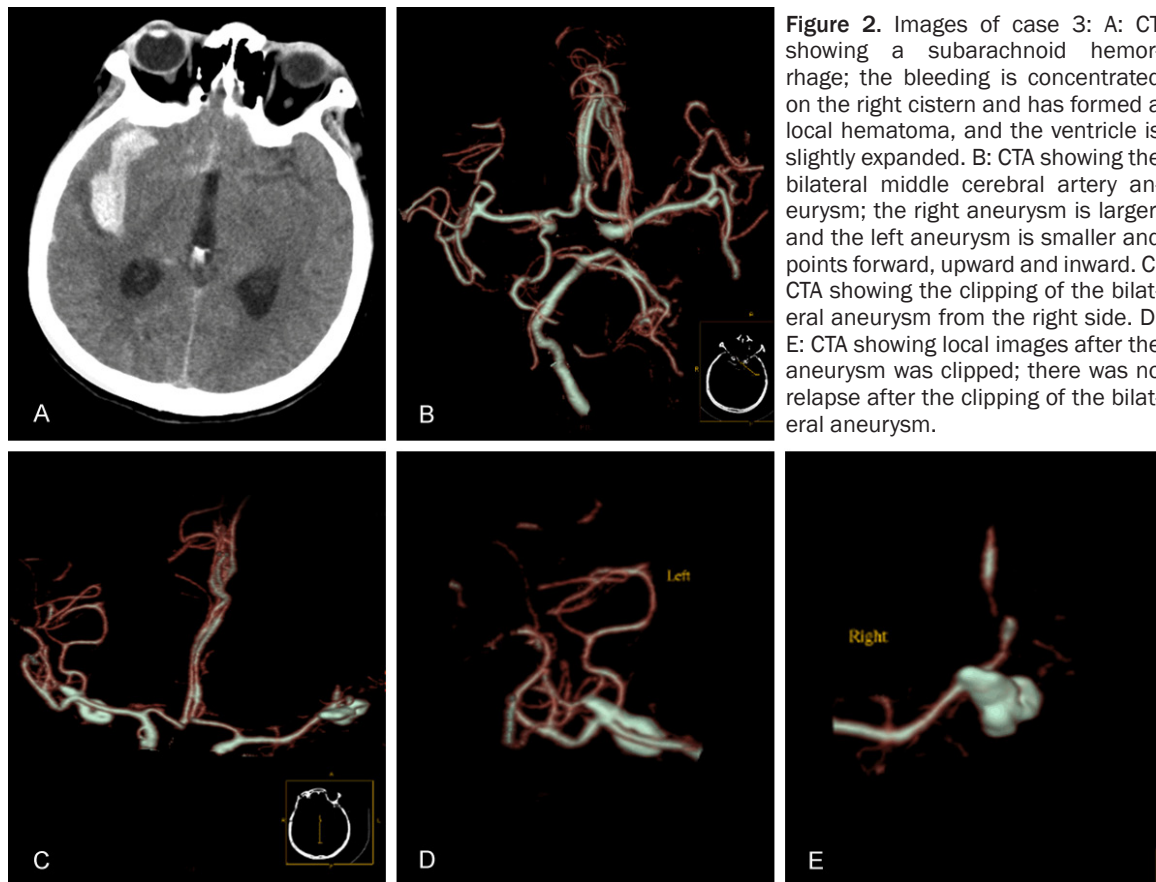


Figure 2. Images of case 3: A: CT showing a subarachnoid hemorrhage; the bleeding is concentrated on the right cistern and has formed a local hematoma, and the ventricle is slightly expanded. B: CTA showing the bilateral middle cerebral artery aneurysm; the right aneurysm is larger, and the left aneurysm is smaller and points forward, upward and inward. C: CTA showing the clipping of the bilateral aneurysm from the right side. D, E: CTA showing local images after the aneurysm was clipped; there was no relapse after the clipping of the bilateral aneurysm.

middle cerebral artery were complete; there were no remnants at the necks of the aneurysms. Phone call follow-ups were conducted for two years, and the previous GOS score of 4 had increased to 5. **Table 1** shows the detailed results, and **Figures 1-4** show representative cases.

Discussion

Bilateral middle cerebral artery aneurysms have been reported to account for 1% of all intracranial aneurysms, and they occur significantly more often in females than in males [7]. Of the 10 cases in this study, two were males, and eight were females; the ratio of 1:4 also shows that these aneurysms are more common in females. The treatment of bilateral middle cerebral artery aneurysms is still controversial, and the debate mainly focuses on whether the bilateral middle cerebral artery can be simultaneously clipped via the unilateral pterional approach. Several studies have been published in recent years. For example, in a 2015 study, Andrade et al. reported 38 cases of the

simultaneous clipping of bilateral middle cerebral artery aneurysms from one side [1]. In a 2012 study, Rodriguez et al. reported 11 cases of the simultaneous clipping of bilateral middle cerebral artery aneurysms from one side [4]. Although these studies suggested that this method is feasible, their conclusions were based on the selection of appropriate cases. This study summarizes and reports 10 cases of the simultaneous clipping of bilateral middle cerebral artery aneurysms using the unilateral pterional approach. Studies of Asian cases are rare. The anatomical characteristics of the SAH brain tissues of Asians are different from cases in European and American countries. The Sylvian fissure of Europeans and Americans is wider, and the tension in the presence of SAH is not as high as in Asians [5, 6]. Therefore, this report of 10 Asian cases is significant.

Currently, there is no clear treatment plan for intracranial multiple aneurysms or for bilateral aneurysms in particular. Because bilateral middle cerebral artery aneurysms are located far apart, there is controversy about whether they

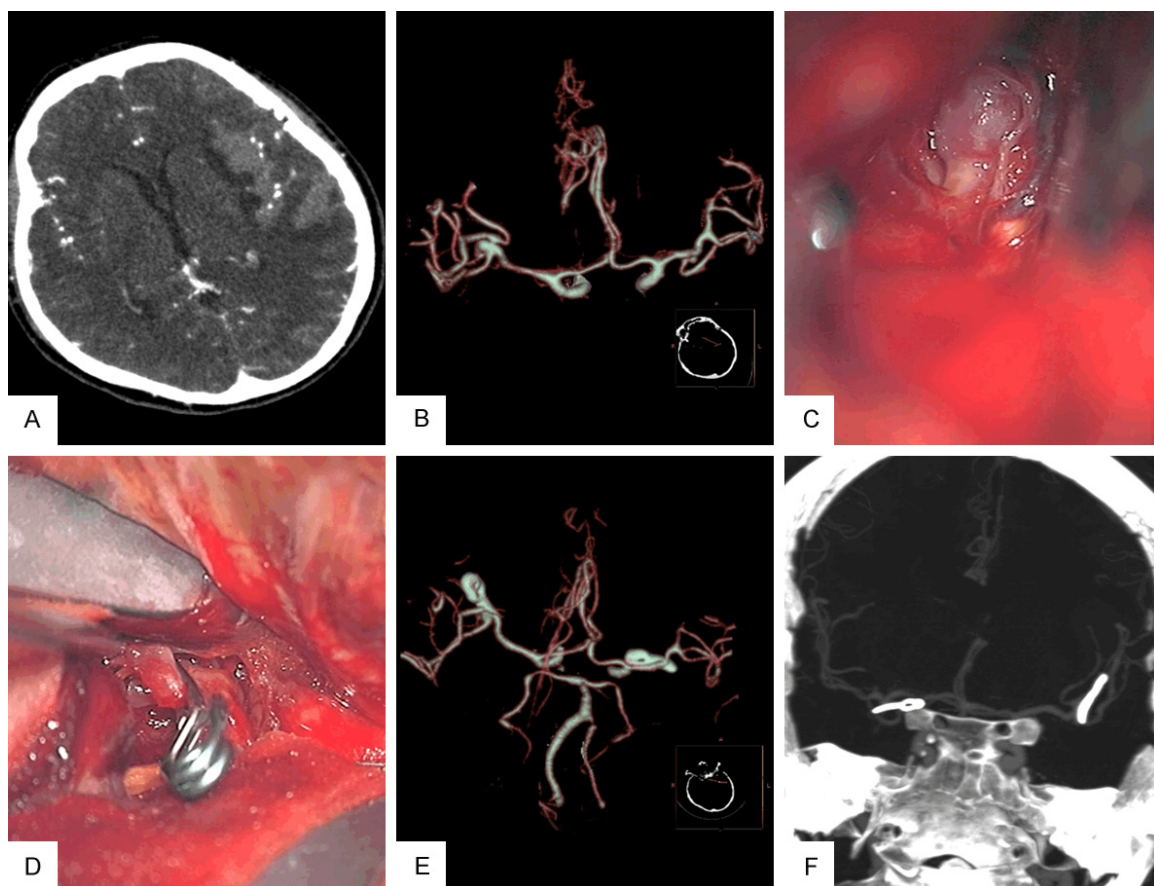


Figure 3. Images of case 5: A: Enhanced CT showing a subarachnoid hemorrhage; the bleeding is concentrated at the left Sylvian fissure and formed a local hematoma, and the ventricle size is normal. B: CTA showing the bilateral middle cerebral artery aneurysm. The left aneurysm is larger and is located at the bifurcation portion, while the right aneurysm is smaller and is located on the early branch; it points forward, downward and inward. C: Intraoperative image showing the contralateral (right) middle cerebral artery aneurysm. D: Intraoperative image showing the ipsilateral (left) middle cerebral artery aneurysm, which has been clipped. E, F: Postoperative CTA reviews showing that there was no relapse after the clipping of the bilateral aneurysm.

should be treated simultaneously. This study analyzed the treatment of 10 cases of bilateral middle cerebral artery aneurysms and suggests that in appropriate cases, the simultaneous clipping of bilateral middle cerebral artery aneurysms via the unilateral pterional approach should be used because it can reduce the patients' psychological burden of performing the operations at different phases and can reduce the risk that the aneurysms will rupture again while the patients are waiting for the surgery. This method can also greatly reduce the treatment cost for patients [8]. Studies have shown that if SAH patients have multiple unruptured aneurysms, the risk of rupture of an unruptured aneurysm after a single treatment of a ruptured aneurysm is higher than that of a similar-sized aneurysm without a

history of subarachnoid hemorrhage [9, 10]. This was also confirmed in the International Subarachnoid Aneurysm Trial (ISAT) study [11]. Moreover, postoperative active blood pressure-increasing treatment, which is a preventive measure for vasospasm, has a risk of causing re-bleeding of unruptured aneurysms [12, 13]. The 10 cases in this study used ipsilateral clipping of the bilateral aneurysms, the patients recovered well, and the costs were low. Therefore, this technique is feasible for appropriate cases.

The feasibility of the simultaneous clipping of middle cerebral artery aneurysms via the unilateral pterional approach is determined by many factors. For example, the level of intraoperative brain tissue edema, the length of the M1 segment of the contralateral middle cere-

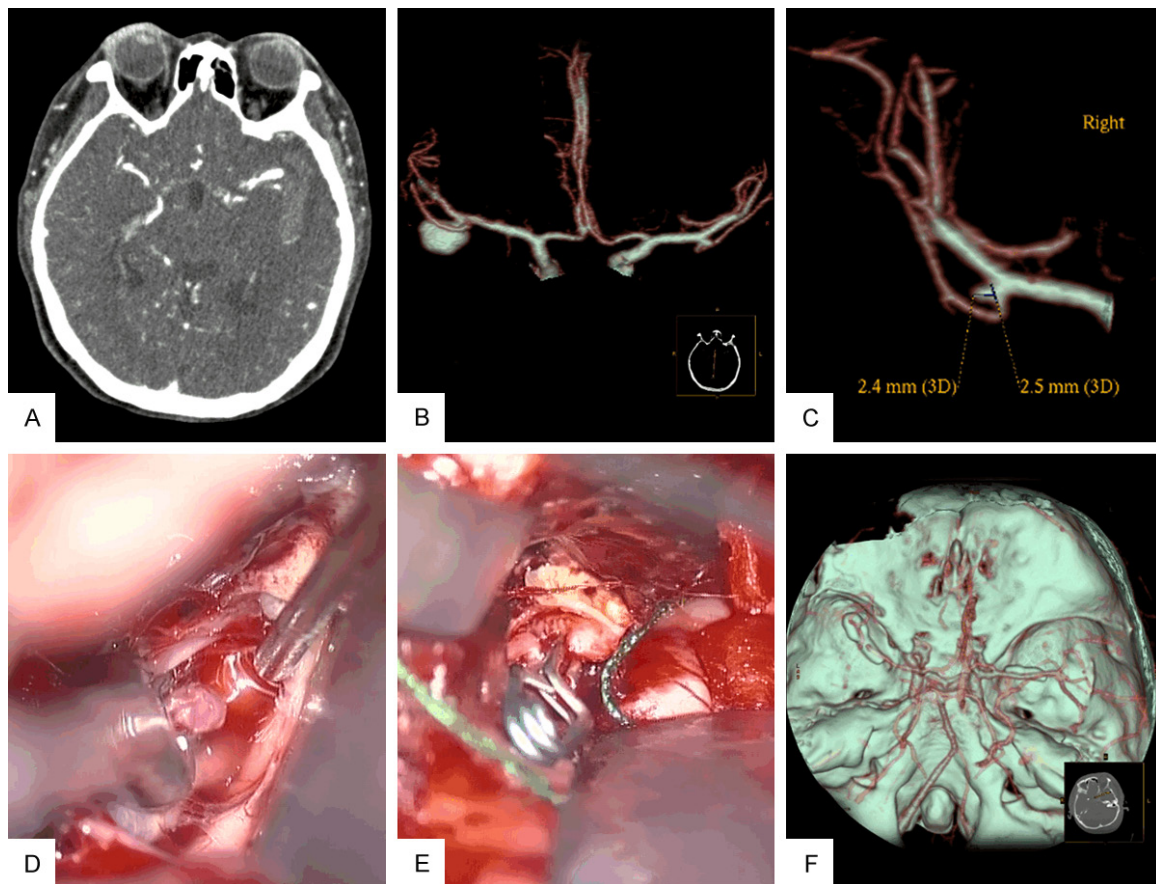


Figure 4. Images of case 7: A: Enhanced CT showing a subarachnoid hemorrhage; the bleeding is concentrated at the left Sylvian fissure and formed a local hematoma, and the ventricle size is normal. B, C: CTA showing the bilateral middle cerebral artery aneurysm at the bifurcation portion; the left aneurysm is larger, and right aneurysm is smaller and points forward, downward and outward. D: Intraoperative image showing the contralateral (right side) middle cerebral artery aneurysm. E: Intraoperative image showing the ipsilateral (left side) middle cerebral artery aneurysm, which has been clipped. F: Postoperative CTA review showing that there was no relapse after the clipping of the bilateral aneurysm.

bral artery, the size of the contralateral aneurysm, and the orientation of the artery all affect the feasibility of the operation and can increase the difficulty of the operation [4]. The results of this study support these conclusions. Of these factors, the most important is the degree of brain edema [8]. This study found that the use of unilateral pterional craniotomy to clip bilateral middle cerebral artery aneurysms is not suitable for patients with severe brain tissue swelling, especially during acute subarachnoid hemorrhage or for patients with HH grades of III and above. When brain tissue experiences severe swelling, it is highly fragile during traction. This is especially important in the cases in this study and may be because Asians have smaller intracranial volumes and the natural gap is too tight. In addition, this clipping meth-

od is not suitable for operations on large or very large contralateral aneurysms because the operation field that reaches the bifurcation part of the contralateral middle cerebral artery is narrow; thus, when the contralateral middle cerebral artery aneurysm is very large, it is difficult to clearly expose it and perform simultaneous combinatorial clipping using multiple aneurysm clips. For example, in the cases that were reported by De Sousa et al. in 2015, the diameters of the clipped aneurysms were less than 10 mm, and they mainly used one aneurysm clip [14]. In the 10 cases in this study, the clipping of the contralateral middle cerebral artery aneurysm only used an average of one aneurysm clip, and they were mainly miniature aneurysm clips; the sizes of the contralateral aneurysms were 2.0-4.5 mm (average of 3.2

mm). The smaller sizes of the aneurysms may be the difference between European and American patients and Asian patients.

In addition to brain tissue swelling, the length of the M1 segment of the contralateral middle cerebral artery is an important factor that will affect the simultaneous clipping of the bilateral aneurysm via the unilateral pterional approach. The narrow and long operation channel has a conical shape. A longer M1 segment increases the difficulty of clipping the aneurysm and has stricter requirements for the operation devices. In addition, operating on a distal structure in a narrow space is a challenge for the surgeon. Due to the limited operation space and the microsurgical instruments, conventional surgical operations cannot be performed, and the aneurysm cannot be exposed completely. For example, in a 1997 study, Oshiro et al. suggested that when the M1 segment is less than or equal to 14 mm long, the bifurcation portion of the contralateral middle cerebral artery can be exposed [15]. In a 1993 study, Lynch et al. failed to correct a contralateral middle cerebral artery aneurysm mainly because the contralateral M1 segment was too long and was difficult to expose it [16]. In the 10 cases in this study, the contralateral M1 segments were 0.81-1.63 cm long (average 1.35 cm), which is similar to that in Lynch's study. It should be noted that the aneurysms that are located on the early branches of the middle cerebral artery are much easier to address; for example, in case 5 in this study, the contralateral M1 segment was 0.81 cm long, and the operation was much easier. Therefore, the length of the M1 segment of the contralateral middle cerebral artery is also an important parameter.

The difficulty of the surgery is also dependent on the orientation of the aneurysm. If the parent artery or the surrounding arteries block the aneurysm, the operation will be more difficult. When clipping a distant aneurysm such as a contralateral middle cerebral artery aneurysm and therefore searching for the aneurysm along the main stem of the contralateral middle cerebral artery towards the distal bifurcation part, the aneurysm can be easily found when it is pointing forward or downward. In contrast, if the body of the aneurysm points backward, which is parallel to the M1 segment's main stem, it can be difficult to dissect, expose and clip it, especially when the neck of the aneu-

rysm is wide [17, 18]. In particular, when the body of the aneurysm points toward the insula, the clipping of the aneurysm from the contralateral approach will be blocked by the M1 segment; the aneurysm thus cannot be completely exposed in the operation field, and the operation may damage the perforator vessels. In these cases, the operation has some limitations, and the appropriate technique should be selected carefully [19, 20]. In this study, we chose cases in which the contralateral middle cerebral artery aneurysm was oriented either forward or downward, which made the clipping more convenient. The results of this study suggest that if appropriate cases are selected, the method of clipping bilateral middle cerebral artery aneurysm via the unilateral pterional approach in a single stage is feasible. The level of preoperative brain tissue swelling, the length of the M1 segment, and the orientation of the aneurysm are the major influencing factors.

Disclosure of conflict of interest

None.

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