Endovascular treatment of ruptured aneurysms in anterior cerebral circulation with double microcatheter technique

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Research article

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Abstract

Purpose Single coiling may be the optimal strategy for ruptured aneurysms. But assisted techniques may be needed in some aneurysms. The authors report their experience of double microcatheter technique in the treatment of ruptured aneurysms in anterior cerebral circulation.

Methods Between 2012 and 2018, 82 patients with ruptured aneurysms in anterior cerebral circulation were treated with double microcatheter technique. The clinical records, angiographic results, procedure-related complications were reviewed. Clinical and angiographic follow-up was performed.

Results Completely occlusion, neck remnant and partial occlusion were achieved in 56.6%, 36.1% and 7.2% in the whole procedures, respectively. The overall rate of morbidity was 8.5% (7/82). The rate of permanent morbidity was 3.7% (3/82). Three patients (3.7%) died before discharge. There was no procedure-related mortality. The favorable outcomes were obtained in 75.6% (62/82) of the whole patients at discharge. High Hunt-Hess grade and suffering from craniotomy or EVD were risk factors for clinical outcomes at discharge. Sixty-eight patients received clinical follow-up at a mean interval of 15.75±12.71 months. Favorable outcomes were obtained in 61 (89.7%) patients. Angiographic follow-up was performed in 44 patients at an average of 13.16±13.12 months. The recurrence rate is 34.1%. Seven of them (15.9%) received retreatment.

Conclusion Double microcatheter technique is a safe and effective method for treatment of ruptured aneurysms in anterior cerebral aneurysms with low morbidity. Recurrence remains a problem. Patients should be followed up regularly.

Background

Since the publication of international subarachnoid aneurysm trial (ISAT) in 2002 [1], the endovascular approach became more and more popular in the treatment of intracranial aneurysms. Along with the improvement of devices and techniques, the prognosis of ruptured aneurysms has been improved significantly. But it is still a challenge for wide-necked and irregular aneurysms. The stent- or balloon-assisted coiling and flow diverter can be used in the treatment of wide-necked and irregular aneurysms [2–4]. However, the deployment of stent in ruptured aneurysms may increase the procedure-related complications, such as rebleeding and thrombosis [5–7]. Balloon-assisted coiling requires temporary blockage of blood flow and may incur increased risk of related complications [8,9]. Additionally, the delivery catheter of stent or balloon was difficult to navigate through the small or tortuous vessel. There was still limitation in the usage of stent- and balloon-assisted coiling.

Baxter et al. firstly reported the double microcatheter technique in 1998 [10]. The advantage of double microcatheter technique is that there was no need to take antiplatelet medications and no blockage of blood flow. It becomes an alternative method to treat wide-necked and irregular aneurysms. There were some reports about the double microcatheter technique recently [11–13]. But the report of double microcatheter technique for ruptured aneurysms in anterior cerebral circulation is rare. Here we report the safety and efficiency of double microcatheter technique in anterior circulation ruptured aneurysms.

Materials And Methods

Patients and aneurysms

We retrospectively collect the inpatient records of ruptured aneurysms in anterior cerebral circulation treated with double microcatheter technique between September 2012 and September 2018. The dissecting and fusiform aneurysms were excluded. A total of 82 patients were enrolled. Subarachnoid hemorrhage was confirmed by CT scanning. The clinical condition at admission was classified by Hunt-Hess grade. Most patients received CT angiography (CTA) and all of them were confirmed by digital subtraction angiography (DSA). Wide-necked aneurysms were defined as: neck diameter ≥ 4 mm or dome to neck ratio < 2. All procedures were performed within 48 hours after being admitted to hospital.

Of all the 82 patients, there were 17 male ones and 65 female ones. The mean age was 59.63 ± 10.22 years (ranging from 31 to 78 years). Hunt-Hess grade at admission was I in 13 patients, II in 23 patients, III in 29 patients, IV in 12 patients and V in 5 patients. Thirty-four of them were accompanied with hypertension and 9 with diabetes mellitus. Pre-procedure CT scanning showed that 11 patients were accompanied with hematoma, 8 with hydrocephalus and 4 with both.

Bilateral posterior communicating artery aneurysms in one patient were treated with double microcatheter technique simultaneously. There were 83 aneurysms in 82 patients treated with double microcatheter technique. There were 26 anterior communicating artery aneurysms, 45 posterior communicating artery aneurysms, 8 middle cerebral artery aneurysms, 3 ophthalmic aneurysms, and 1 anterior choroidal artery aneurysm. Among of them, 65 (78.3%) were wide-necked aneurysms and 44 (53%) were accompanied with daughter sac or irregular configuration. The neck diameter ranged from 1.6 to 9 mm at an average of 3.69 ± 1.15 mm. The average of maximum diameter was 6.44 ± 2.67 mm (ranging from 2.9–13 mm). The dome/neck ratio ranged from 0.7 to 3.92 with an average of 1.78 ± 0.62. The average of aneurysm volume was 137.55 ± 173.08 mm^3 (ranging from 1.45 to 1025.09mm^3).

Endovascular procedure

All the procedures were performed under general anesthesia and systemic heparinization. A 6-F guiding catheter is placed into the internal carotid artery by the right femoral artery. The frontal, lateral and 3-D angiographies are performed in all patients in order to analyze the size, configuration of aneurysms. The microcatheter is navigated into the aneurysms under roadmap guidance after the selection of working projection. The two microcatheters will be shaped with different curve in order to get into different portion of aneurysms. The first microcatheter may migrate during the advancement of the second microcatheter. The tension of the first microcatheter need to be adjusted and the first coil might be fully or partially advanced into the aneurysm before the second microcatheter was advanced. The possibility of rebleeding is low because of the buffering of the first coil even if the first microcatheter migrates. For aneurysms with daughter sac, one microcatheter is usually navigated into daughter sac if there is no difficulty. And then another microcatheter was advanced after the first coil was fully or partially advanced. The second coil is advanced into the aneurysm. The two coils embrace each other to form a stable frame. One of the coils is detached and the other is left without detachment. The process is continued until the aneurysm is packed as densely as possible.

Clinical and angiographic assessment

The clinical outcomes at discharge and the last follow-up were scored using Glasgow Outcome Scale (GOS). Patients who obtained GOS 4–5 were defined as favorable outcome. Patients who obtained GOS 1–3 were defined as poor outcome. Aneurysm volume, coil volume and packing density were calculated using AngioCalc (www.angiocalc.com). At discharge, all patients were advised to be followed up by DSA at 3 months, 9 months and 21 months after the procedure. The immediate angiographic outcomes at the end of the procedure were classified as follow: complete obliteration, neck remnant and partial occlusion (contrast filling in aneurysm sac). Angiographic outcomes at follow-up were classified as follow: stable (no change in coil configuration, obliteration grade, or contrast filling), improved (progressive occlusion or involution of the neck remnant or contrast filling in aneurysm), and recanalized (aneurysm recurrence evident due to neck growth, coil compaction, coil extrusion by aneurysm degradation, or new sac formation) [14].

Statistic analysis

Statistic analysis was performed by SPSS software, version 19.0 (IBM Inc., Chicago, IL, USA). Univariate and multivariate logistic regression was used to analyze the risk factors for procedure-related morbidities and clinical outcomes at discharge. Multivariate proportional hazards regression (Cox) model were used to analyze the risk factors for clinical and angiographic outcomes at follow-up. P value < 0.05 was considered to be statistically significant.

Results

Perioperative complications

Among all the procedures, there was no intraprocedure rupture in this series of cases. There were 3 cases suffering from thrombosis or slow blood flow of parent artery during the procedures. After the usage of tirofiban by microcatheter, the thrombosis disappeared and the blood flow returned to normal, and there was no related neurologic deficit after the procedure. One patient suffered from rebleeding and ischemic event simultaneously after the procedure, and he received decompressive craniotomy. Three patients suffered from ischemic events after the procedure, and one of them recovered without neurologic deficit after the usage of antithrombotic medication. The overall rate of morbidity was 8.5% (7/82). But the rate of permanent morbidity was 3.7% (3/82). Because of the low morbidity rate, there was no significant correlation between patients or aneurysm characteristic and morbidity.

Additionally, external ventricular drainage (EVD) and craniotomy were performed simultaneously in 3 patients, EVD in 6 patients and craniotomy in 6 patients because of hydrocephalus, hematoma and severe vasospasm. Of the patients receiving EVD or craniotomy, 7 of them were anterior communicating artery aneurysm, 7 posterior communicating artery aneurysms and one middle cerebral artery aneurysm. Ventriculoperitoneal shunts were performed in 6 patients because of delayed hydrocephalus. One patient received implantation of vein filter because of deep venous thrombosis.

Clinical outcomes

In this series of patients, the clinical outcomes at discharge were as follow: GOS 1 in 3 patients, GOS 2 in 3 patients, GOS 3 in 14 patients, GOS 4 in 9 patients and GOS 5 in 53 patients. The mortality rate was 3.7% (3/82) at discharge. There was no procedure-related mortality. Of the three patients died before discharge, there were 2 patients with Hunt-Hess grade 5 and 1 patient with Hunt-Hess grade 4 at admission. The favorable outcomes were obtained in 75.6% (62/82) of the whole patients at discharge. Table 1 shows the risk factors of clinical outcomes at discharge using univariate and multivariate logistic regression. High Hunt-Hess grade and suffering from craniotomy or EVD were risk factors for poor clinical outcomes at discharge.

Table 1
Univariate and multivariate logistic analysis of risk factors for clinical outcomes at discharge

Factors	Univariate		Multivariate	
	OR (95%CI)	P value	OR (95%CI)	P value
Hunt-Hess grade	0.081–0.415	0.000	0.061–0.771	0.018
Craniotomy or EVD	0.003–0.096	0.000	0.000-0.218	0.004
Hematoma	0.025–0.311	0.000		
Hydrocephalus	0.027-0.400	0.001		
Wide neck	0.505–1.173	0.224		
Packing density	0.989–1.083	0.143		
Age	0.926–1.025	0.317		

EVD = external ventricular drainage

Apart from 3 patients dying before discharge and 11 patients lost to follow up, clinical follow-up was available in 68 patients at a mean interval of 15.75 ± 12.71 months (ranging from 3 months to 71 months). Seven patients obtained GOS 3, 6 GOS 4, and 55 GOS 5, respectively. None of them suffered from rebleeding. Favorable outcomes were obtained in 89.7% (61/68) of patients. The outcome of multivariate proportional hazards model is shown in Table 2. High Hunt-Hess grade was risk factor for clinical outcomes at follow-up.

Table 2
Multivariate proportional hazards model analysis for clinical outcomes at follow-up

Factors	Hazard ratio	(95%CI)	P value
Age	1.242	0.965–1.599	0.093
Hunt-Hess grade	40.582	2.232-737.766	0.012
Hypertension	0.079	0.004–1.686	0.104
Hematoma	0.100	0.002–4.462	0.235
Hydrocephalus	2.225	0.174–28.382	0.538
Craniotomy or EVD	3.659	0.123-108.774	0.454
EVD = external ventricular drainage			

Angiographic outcomes

The immediate angiographic outcomes showed that 47 aneurysms (56.6%) obtained completely occlusion, 30 aneurysms (36.1%) obtained neck remnant and 6 (7.2%) aneurysms obtained partial occlusion. There were two patients receiving daughter sac coiling. The coil volume ranged from 4.06 to 218.91 mm^3 (average 41.16 ± 44.79mm^3). The average of packing density was 35.59%±11.92%.

Angiographic follow-up was performed in 44 patients at an average of 13.16 ± 13.12 months (ranging from 3 to 71 months). Twenty-nine aneurysms showed stable or improved, and 15 aneurysms suffered from recurrence. The recurrence rate is 34.1%. Seven of them (15.9%) received retreatment.

Discussion

Endovascular treatment has become the first choice for intracranial aneurysm. The treatment of wide-necked and irregular aneurysms in anterior cerebral circulation is still a challenge because of the coil instability and a high recurrence rate [15]. The improvement of devices and techniques extended the usage of endovascular coiling, such as stent- or balloon- assisted coiling, double microcatheter technique and flow diverter [2–4,12]. Those could be used in wide-necked or irregular aneurysms. But there are still some debates on the stent- or balloon-assisted coiling for ruptured aneurysms in acute stage.

Stent-assisted coiling was used to treat unruptured wide-necked aneurysms. The deployment of stent can protect coil from protruding into parent artery. Additionally, it can reduce the recurrence rate [16–17]. However, the deployment of stent in acute stage may incur more complications such as in-stent thrombosis [7,18,19]. Fan et al. reported that thrombosis occurred in 15.9% patients after stent-assisted coiling versus 3.8% after coiling alone for ruptured communicating artery aneurysms [18]. The usage of antiplatelet medications may increase the rate of rebleeding, especially in patients who require EVD, craniotomy or ventriculoperitoneal shunt [7,20,21]. Additionally, it is difficult to navigate the stent-delivery catheter in tortuous and small vessels. There are many reports of flow diversion treatment for intracranial aneurysms recently. But the occlusion of aneurysms may require weeks or months and the rebleeding is not excluded [22].

In 1997, Moret et al. firstly reported the balloon remodeling technique [23]. Balloon-assisted coiling is an alternative method for wide-necked or irregular aneurysms. It blocks the blood flow temporarily, which decreases the risk for rupture and protects the aneurysm neck. It may increase the packing density. There is no need to taking antiplatelet medications periprocedurally. However, delayed coil migration was reported insome cases [24]. It may also incur bleeding and thrombosis events [25,26]. Sluzewski et al. reported that the procedure-related complications were higher in balloon-assisted coiling (14.1%) compared with those in coiling alone (3%) [26]. Additionally, it is difficult to navigate into tortuous and small vessels. Therefore, balloon-assisted coiling was not supported by some authors [9,25].

In 1998, Baxter et al. firstly reported the double microcatheter technique [10]. Since then, there were some reported about double microcatheter technique [11–13] The advantages of double microcatheter technique are that there is no need to block the blood flow and take antiplatelet medications. The procedure is relatively simple compared with stent- or balloon-assisted coiling when it is used in wide-necked or irregular aneurysms. The two microcatheter had better to be shaped with different curve in order to get into different portion and form a stable frame. The advancement of the second microcatheter may incur the migration of the first microcatheter. Durst et al. reported three intraprocedural ruptures (3%) [12]. One of them occurred in an unruptured aneurysm because the microcatheter perforated the aneurysm dome. It is important to take care of the tension of the first microcatheter during the advancement of the second microcatheter. In our cases, the first coil was usually advanced fully or partially into the aneurysm without detachment before the advancement of the second microcatheter. The risk for rupture might decrease because the buffering of the first coil. No intraprocedural rupture occurred in our cases.

Double microcatheter technique can be used in a variety of aneurysms. Firstly, it can be used in wide-necked aneurysms. Two shaped microcatheters with different curve are navigated into different portion of aneurysms to form a stable frame. It was reported in several reports [11,12]. For wide-necked aneurysms with creep growth, we firstly used double parallel framing coils technique [Fig. 1]. Secondly, it can be used in aneurysms with daughter sac [Fig. 2]. One microcatheter can be navigated into the daughter sac if it is not difficult and another is navigated into aneurysm sac. The daughter sac is usually the bleeding point. It can decrease the risk for rebleeding if the daughter sac can be packed densely. Kim et al reported one case with fusiform aneurysm in the supraclinoid segment with a daughter sac [26]. The patient received selective coiling of daughter sac. Thirdly, it can be used in branch-incorporated aneurysms [Fig. 3]. One microcatheter was placed at the orifice of branch in order to protect it from being occluded. Another microcatheter was used to coil the aneurysm. Kim et al. reported this technique in 2018

[27]. Fourthly, it can be used in enlongated aneurysms. One microcatheter is navigated deeply into the aneurysm and another close to the neck [28]. Additionally, it can be used in parent artery occlusion for ruptured vertebral artery aneurysms by bilateral vertebral artery approach. But most vertebral artery aneurysms are dissecting ones. In this series of cases, the ruptured aneurysms in posterior cerebral circulation were excluded.

The procedure of double microcatheter technique is simple. There are lower procedure-related complications in patients treated by double microcatheter technique than those treated by stent-assisted coiling [13]. The recurrence rate may be higher for patients treated with double microcatheter technique than those treated by stent-assisted coiling. The procedure-related complications are about 20% for patients receiving stent-assisted coiling with ruptured aneurysms [21,29]. The data for procedure-related complications in ruptured aneurysms treated by double microcatheter are rare. Yoon et al reported 56 patients treated by double microcatheter technique [11]. The procedure-related complications and permanent complications rate were 12.5% and 1.8%. The recurrence and retreatment occurred in 21 patients (56.8%) and 5 patients (13.5%). 64.3% of patients obtained favorable outcome at discharge. In our series of patients, the procedure-related complications and permanent complications rate were 8.5% and 3.7%. The recurrence and retreatment rates are 34.1% and 15.9%. The favorable outcomes were obtained in 75.6% (62/82) of the whole patients at discharge. We found that packing density was risk factor for recurrence. Hunt-Hess grade and suffering from EVD or craniotomy were risk factors for clinical outcome at discharge. Some authors thought that there was no significant difference in recurrence rate among patients treated by double microcatheter technique, stent- and balloon- assisted coiling [13,30]. More recurrence may be found with the extension of time. Retreatment may be chosen with lower morbidities. The physician must balance the complications and recurrence.

There are some limitations of this study. There is a selective bias because this is a retrospective and non-randomized study. The number of patients was limited. Some patients were lost to follow up because of poor outcome or change of contact information, especially angiographic follow-up.

Conclusion

In view of the present study, we conclude that double microcatheter technique is a safe and effective treatment modality for ruptured aneurysms in anterior cerebral circulation. Recurrence remains a problem. Patients should be followed up regularly. Randomized controlled trial with large sample is essential to analyze the efficiency of double microcatheter.

Abbreviations

CTA: CT angiography; DSA: Digital subtraction angiography; EVD: External ventricular drainage; GOS: Glasgow outcome scale; ISAT: International subarachnoid aneurysm trial

Declarations

Ethics approval and consent to participate

Not Applicable.

Consent for publication

All participants in the study have provided a signed informed consent for publication.

Availability of data and materials

Data and relevant materials are available upon request. However, access to the data is restricted to public and requires appropriate approvals from the authorized parties.

Conflict of interest

The authors declare that they have no competing interests.

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Authors' contributions

Authors have made significant contributions to the study design, data acquisition, analysis, and interpretation. They have read and approved the submitted version. ZL: Played a significant role in the planning and development of study material, data interpretation, manuscript revision. XZ, HW: Data acquisition, data analysis and interpretation, and a role in manuscript writing. JL, ZZ: Played a significant role in data analysis, interpretation and manuscript revision.

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Figures

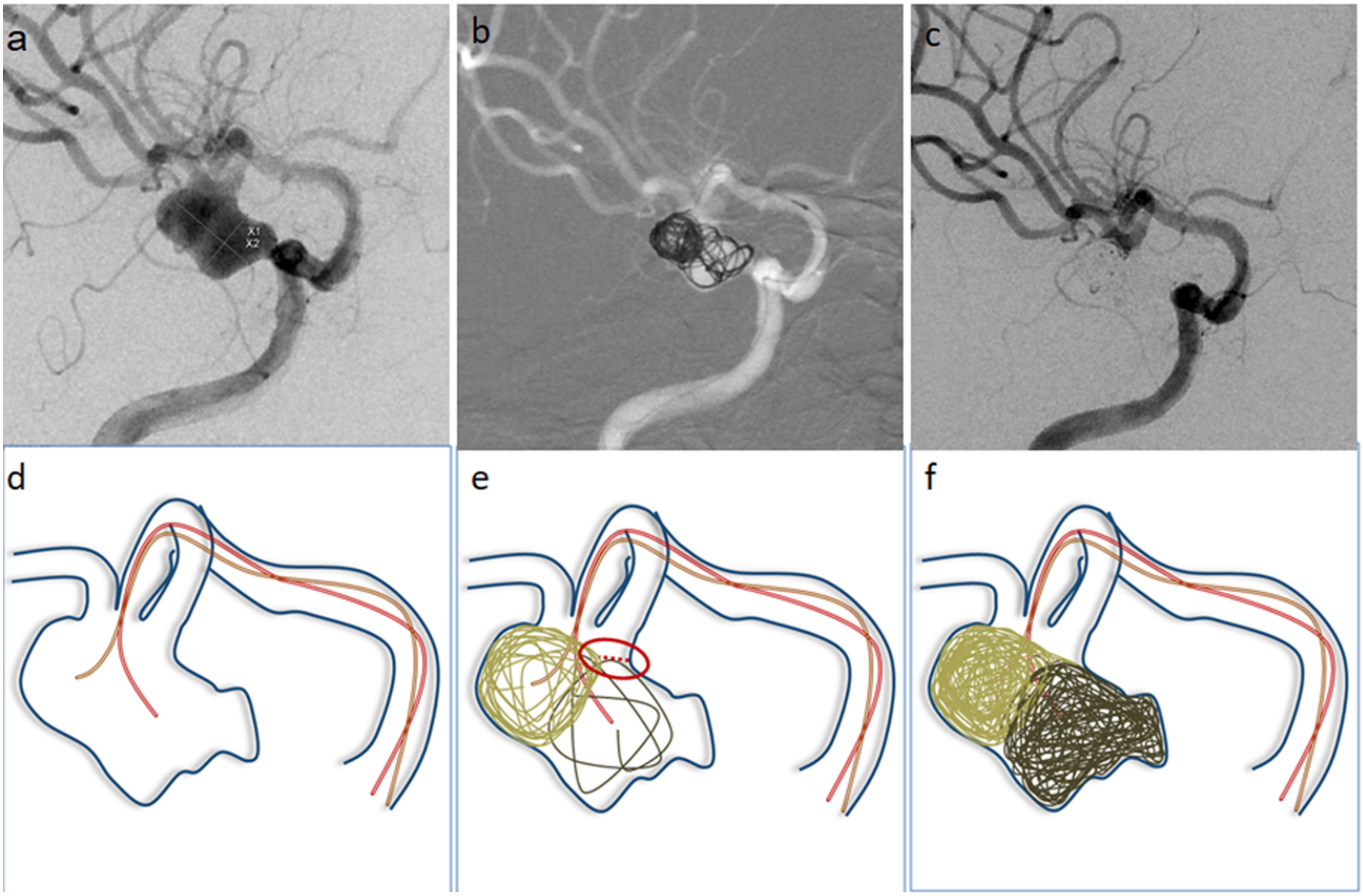

Figure 1

A: The angiographic imaging showed middle cerebral artery aneurysm; D: Illustration: Two microcatheters with different curve were navigated into different portion of the aneurysm. B,E: The first two coils were advanced into aneurysms through two microcatheters to form a stable frame. They supported and embraced each other. C,F: The aneurysm was embolized with neck remodeling.

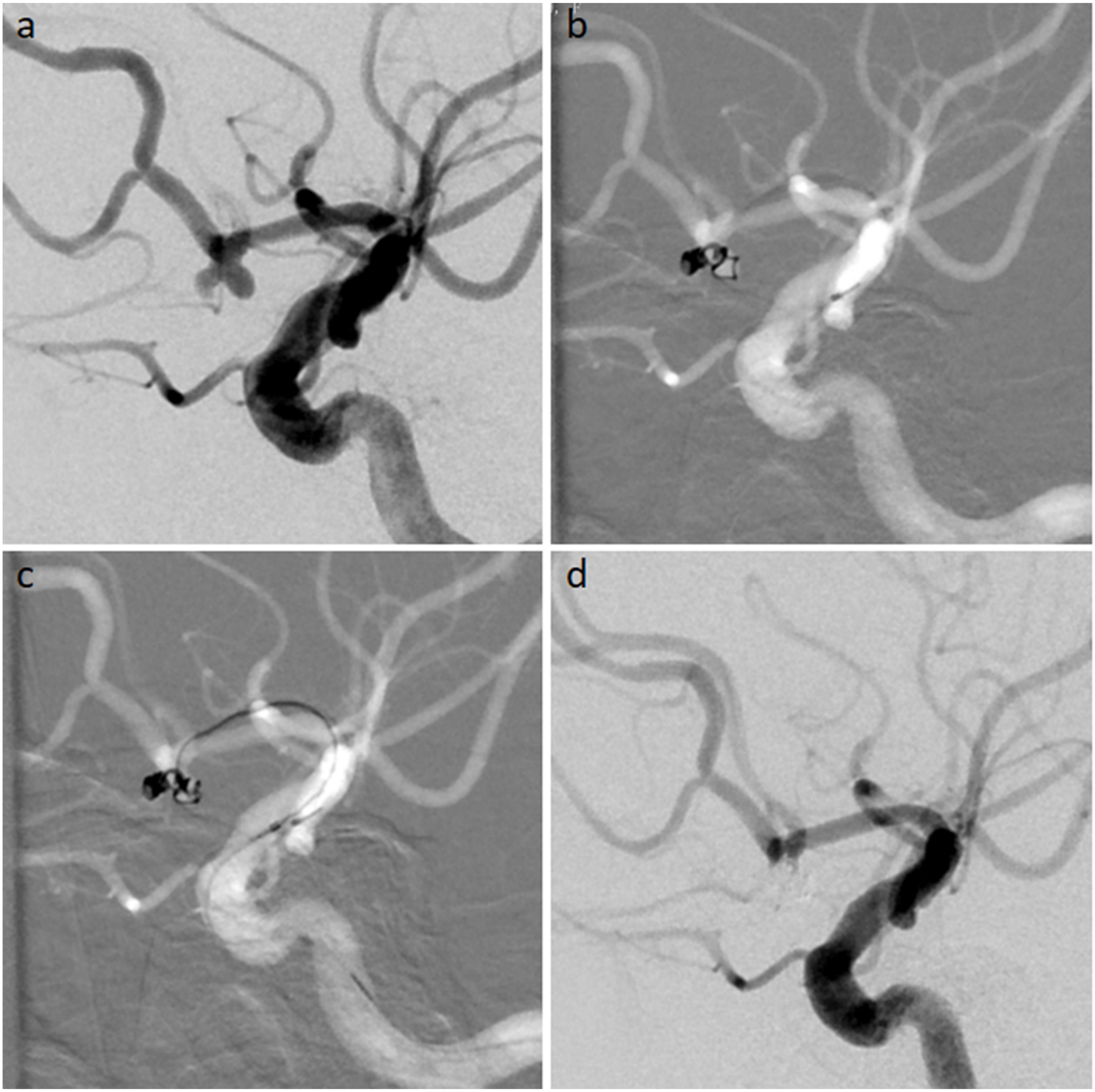

Figure 2

A:The angiographic imaging showed anterior communicating artery aneurysm with a daughter sac. B: The first microcatheter was navigated into the left sac of the aneurysm. The first coil was fully advanced into the aneurysm. Part of the first coil and the microcatheter got into the right sac in the end. C: Another microctheter was navigated into the aneurysm. D: The aneurysm was completely occluded.

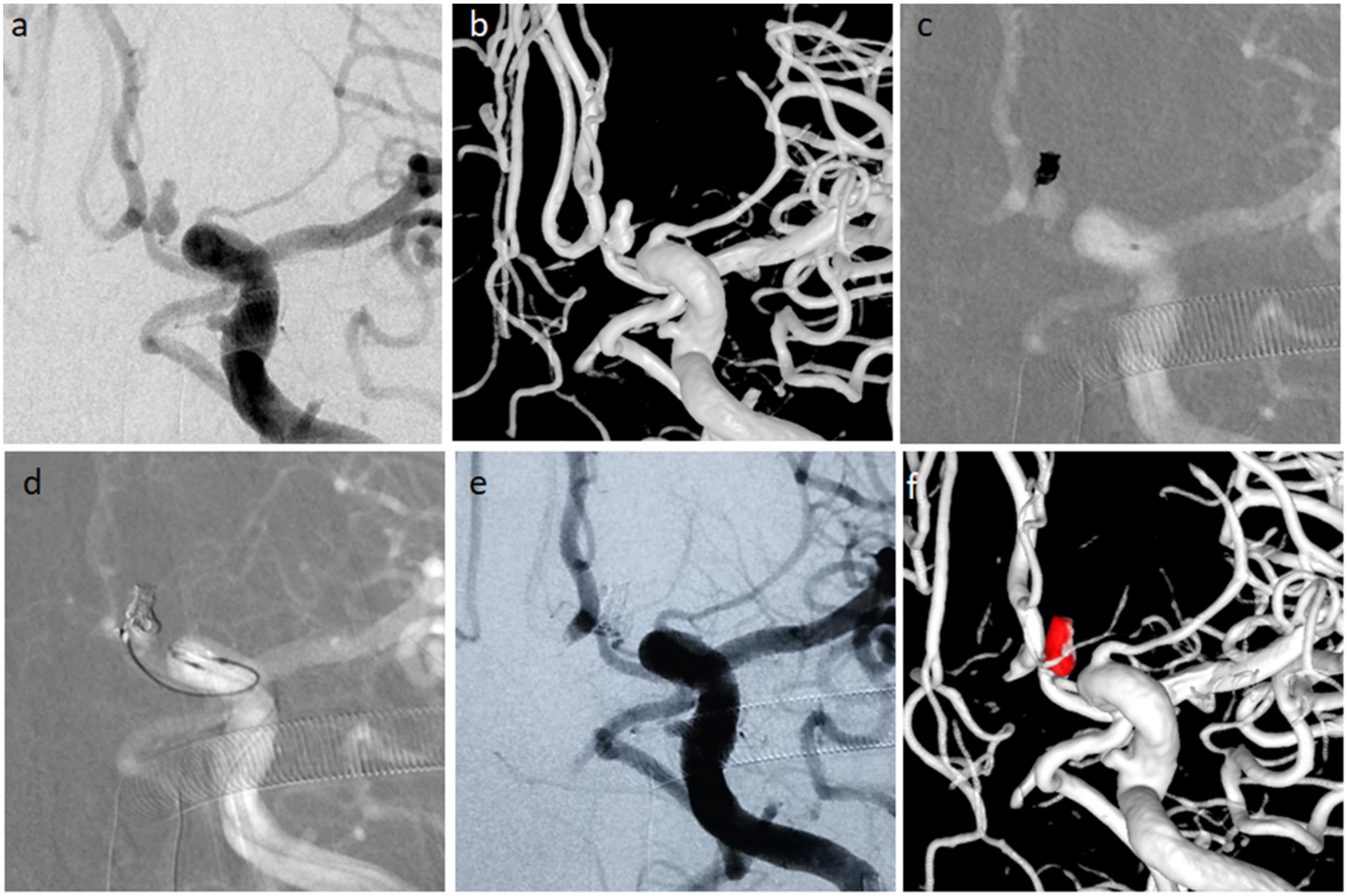

Figure 3

A,B: The angiographic and 3-D imaging showed anterior communicating artery complex aneurysm. Heubner artery originated from the neck. C: The first coil was navigated into the aneurysm and the first coil was fully advanced into the aneurysm. D: The second microcatheter was navigated into the aneurysm in order to protect Heubner artery from being occluded. E:The aneurysm was completely occluded and Heubner artery was patent.