Materials and Methods:

The raw data of computed tomography angiography (CTA), magnetic resonance angiography (MRA), or digital subtraction angiography (DSA) of ACoA aneurysm patients were collected. After the digital models were created by software and the models were generated using 3D printing technology, ACoA aneurysm clipping via PA and EEA was simulated using the models.

3D slicer software (version 4.10, see www.slicer.org) was used to reconstruct digital models of ACoA aneurysms and adjacent structures, including the anterior skull base, internal carotid artery, ACoA artery complex, pituitary gland, optic nerve, optic chiasma, and other structures.

The virtual models were sent to a 3D printing company (Yungongchang, Shenzhen, China) that completed all the printing. Materials similar to real tissue were used to make the model: 0-degree silica gel for brain tissue; resin for the skull; soft resin for blood vessels; and 10-degree silica gel for the optic nerve, pituitary gland, and skin. To better distinguish tissues, the models used different colors: flesh color for brain tissue, light yellow for the skull, red for blood vessels, blue for the optic nerve, yellow for the pituitary gland, and yellow for skin.

To carefully evaluate the approaches, we used endoscopy instead of microscopy as the observation system. The simulation was mainly aimed to expose ACoA aneurysms and adjacent vessels and facilitate clipping after the craniotomy. ACoA aneurysms are surrounded by cisterns, but these were difficult to simulate in 3D printed models, therefore cistern exposure was not involved in this study. The pre-exposure portion of the craniotomy was not the main purpose of this study, and neither approach was simulated or compared. A Sylvian splitting simulation was not performed in the PA. Both an ipsilateral and contralateral PA were simulated. The approaches were performed with a 0-degree, 4-mm diameter, 18-mm-long rigid endoscope (Karl Storz Endoscopy, Tuttlingen, Germany) connected to a high-definition video monitor and a camera. For the EEA, the anterior sellar bone, tuberculum sellae, and planum sphenoidale were removed on the models. The bone opening was extended laterally to the optic canals. A Yasargil clip and single-shaft aneurysm clip applier were used to simulate clipping.

Aneurysms were classified into the following categories: small (<5 mm), medium (5–10 mm), and large (10–15 mm). For dome projection, we divided the aneurysm into superior, inferior, anterior, posterior, and lateral regions. Wide-necked aneurysms were defined as a dome/neck ratio < 2:1 or an absolute aneurysmal neck diameter >4 mm. Four measurement indicators were used. (1) The exposure length of the bilateral A1 and A2 was recorded (i.e., the longest lengths of the bilateral A1 and A2 were exposed when the ACoA was the center). (2) Surgical freedom (maximum horizontal and vertical angles) was assessed as previously described[1, 2]. With a long probe centered on the ACoA, the end of the probe was moved in the horizontal or vertical direction in the surgical window as much as retraction of the brain tissue and bony structures allowed. (3) The exposure rate of the aneurysm neck without instrumental assistance was calculated. (4) The simulation clipping success rate was determined.

Independent sample *t* tests were used to compare mean differences in continuous variables between the two groups. Chi-square tests were used to compare differences between discontinuous variables. $P < 0.05$ was considered statistically significant. The results were analyzed using statistical software (SPSS version 25, IBM Corp., Armonk, NY, USA).

References

1. Tayebi Meybodi A, Benet A, Rodriguez Rubio R, Yousef S, Lawton MT. Comprehensive Anatomic Assessment of the Pterional, Orbitopterional, and Orbitozygomatic Approaches for Basilar Apex Aneurysm Clipping. Oper Neurosurg (Hagerstown) 2018; 15: 538-550. doi: 10.1093/ons/opx265.
2. Zhu H, Vigo V, Ahluwalia A, Chae R, El-Sayed I, Abla AA, et al. Comparative Analysis of Pterional, Supraorbital, Extended Supraorbital, and Transtubercular-Transplanum Approaches for Exposing the Anterior Communicating Artery Complex: A Cadaveric Study. World Neurosurg 2020; 141: e576-e588. doi: 10.1016/j.wneu.2020.05.244.

Supplementary Table 1: Basic information of patients and characters of aneurysm.

Items	***N* (%) or mean ± SD (mm)**
Age, years	59.7 ± 10.1
Male	59.0 ± 8.6
Female	60.8 ± 12.6
Size	
Small	15 (42.9) ;3.74 ± 1.14
Medium	16 (45.7);6.42 ± 1.25
big	4 (11.4);12.25 ± 0.96
Wide-neck	
Yes	32 (91.4)
No	3 (8.6)
Relative position of bilateral A2	
Sagittal plane	18 (51.4)
Horizontal plane	17 (48.6)
Dome projection	
Anterior	6 (17.1)
Posterior	2 (5.7)
Superior	7 (20.0)
Inferior	8 (22.9)
Lateral	12 (34.3)

SD: Standard deviation.

Supplementary Table2: Bilateral A1 and A2 exposures and surgical freedom of EEA and PA.

Variable	PA	EEA	Statistics	*P* value
Bilateral A1 and A2 exposures				
Ipsilateral A1	13.59 ± 2.05	5.57 ± 1.30	−19.549	<0.001
Contralateral A1	3.08 ± 1.50	5.09 ± 1.36	6.891	<0.001
Ipsilateral A2	7.98± 1.63	5.72 ± 1.50	−6.040	<0.001
Contralateral A2	7.40 ± 2.66	4.56 ± 2.09	−4.975	<0.001
Surgical freedom				
Horizontal direction	35.77 ± 1.66	13.23 ± 1.09	−67.093	<0.001
Vertical direction	15.37 ± 1.17	7.11 ± 1.28	−28.243	<0.001

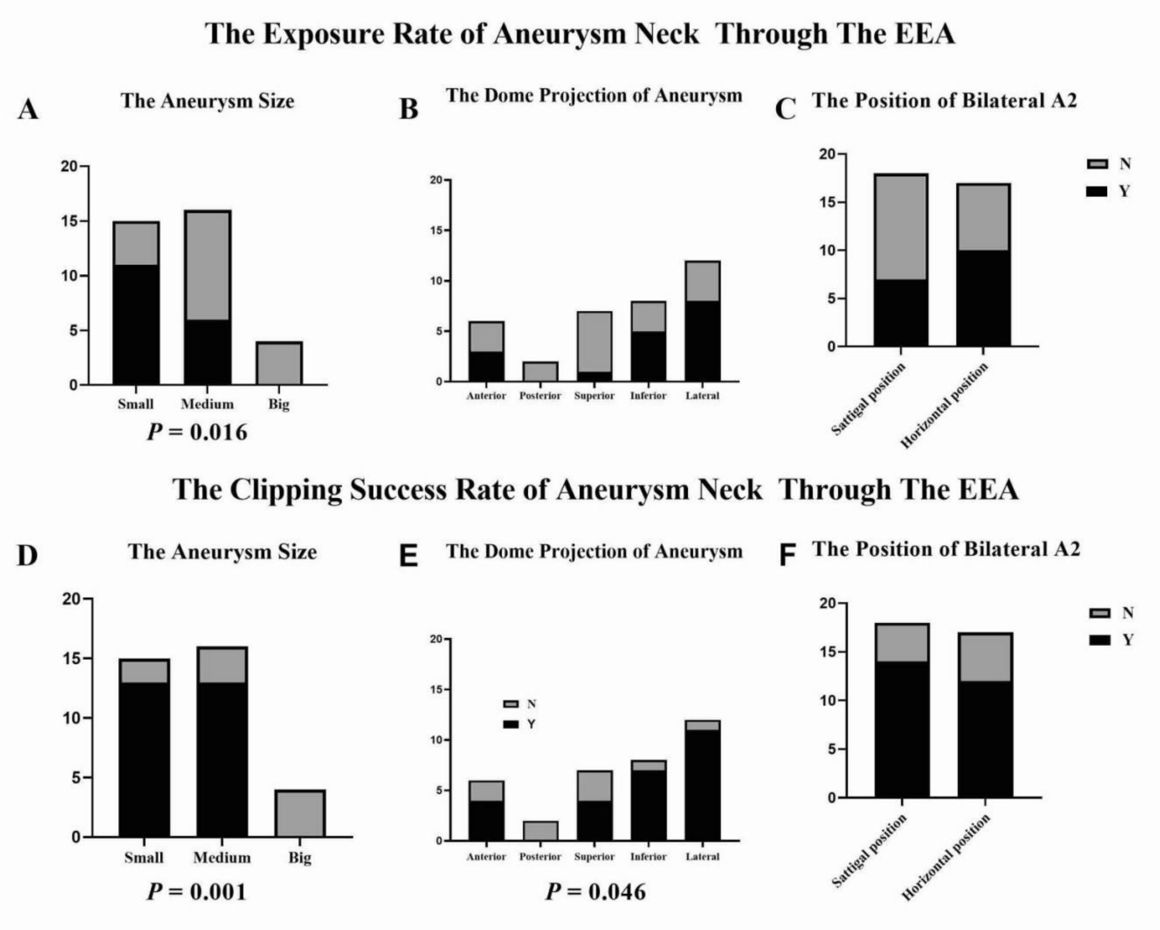
The data is expressed as mean ± SD (mm) or angle (°). EEA: Endoscopic endonasal approach; PA: pterional approach.

Supplementary Table3: Exposure of aneurysm neck and clipping of aneurysm in three different aspects, the EEA versus the ipsilateral PA, or the EEA versus the contralateral PA.

Variable	Exposure of aneurysm neck (Y/N)			Clipping (Y/N)		
	EEA (n = 35)	Ipsilateral pterion approach (n = 35)	Contralateral pterion approach (n = 35)	EEA (n = 35)	Ipsilateral pterion approach (n = 35)*	Contralateral pterion approach (n = 35)
Aneurysm size						
Small	11/4	10/5	11/4	13/2	15/0	15/0
Medium	6/10	11/5	8/8	13/3	16/0	14/2
Big	0/4	0/4	1/3	0/4	4/0*	2/2
Dome projection of aneurysm						
Anterior	3/3	2/4	3/3	4/2	6/0	6/0
Posterior	0/2	0/2	1/1	0/2	2/0	2/0
Superior	1/6	6/1*	5/2	4/3	7/0	7/0
Inferior	5/3	5/3	4/4	7/1	8/0	7/1
Lateral	8/4	8/4	7/5	11/1	12/0	9/3
Relative position of bilateral A2						
Sagittal plane	7/11	13/5*	10/8	14/4	18/0	15/3
Horizontal plane	10/7	8/9	10/7	12/5	17/0*	16/1

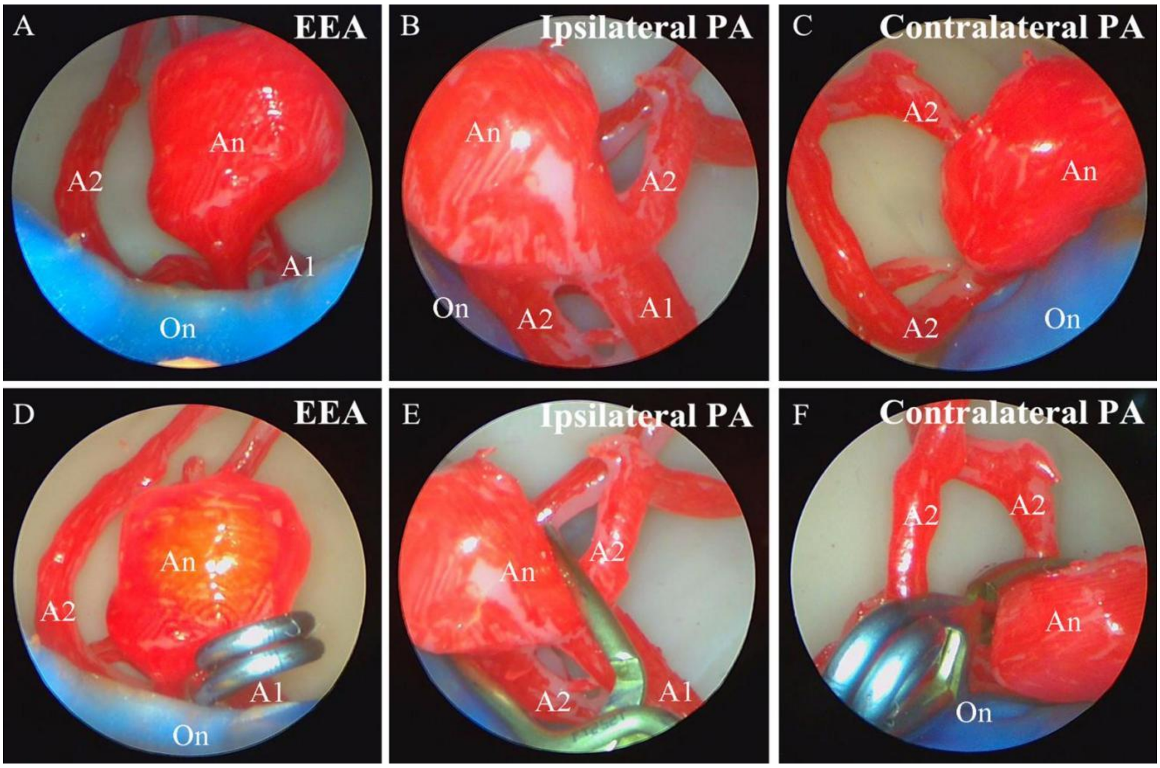
* Represents a statistical difference between the EEA and the ipsilateral PA ($P < 0.05$). EEA: endoscopic endonasal approach; N: The aneurysm neck cannot be exposed without instrumental assistance, or the clipping cannot be completed; PA: pterional approach; Y: The aneurysm neck can be exposed without instrumental assistance, or the clipping can be completed.

Supplementary Figures:

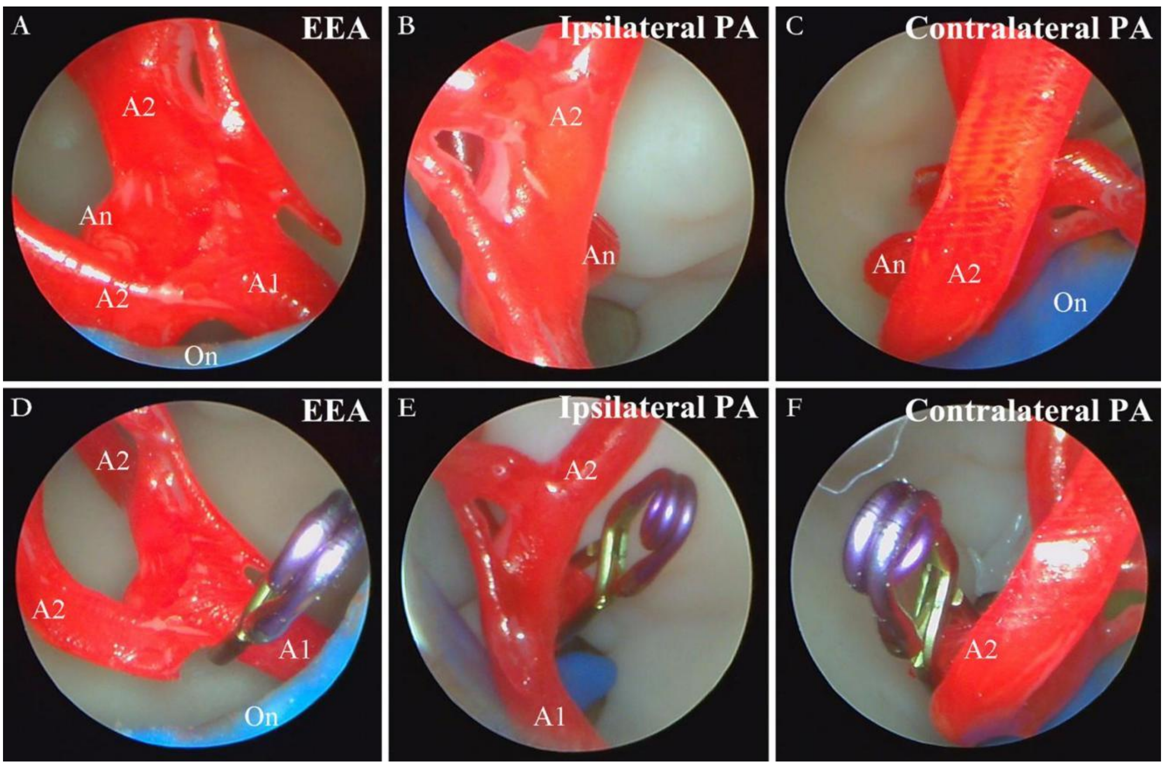


Supplementary Figure 1: Analysis of the EEA in ACoA aneurysm clipping. The aneurysm neck exposure rate and clipping success rate were calculated. The exposure rate for aneurysm neck with different (A)aneurysm size, (B)dome profection and (C) position of bilateral A2 are compared. The clipping success rate are with different (D)aneurysm size, (E)dome profection and (F) position of bilateral A2 are compared. There was significant differences in exposure rate for aneurysms with different sizes (A). Aneurysm size (D) and dome projection (E) also significantly affected the success rate.

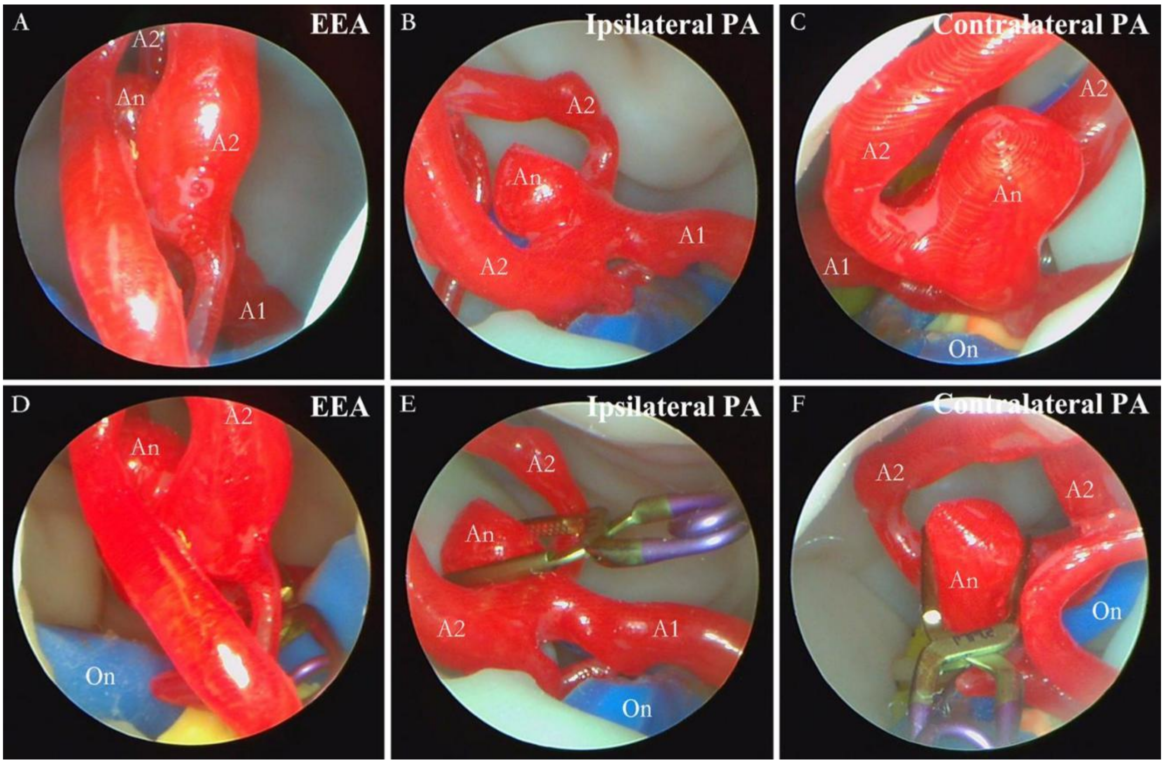
ACoA: Anterior communicating artery; EEA: endoscopic endonasal approach; N: The aneurysm neck cannot be exposed without instrumental assistance, or clipping cannot be completed; Y: The aneurysm neck can be exposed without instrumental assistance, or clipping can be completed.



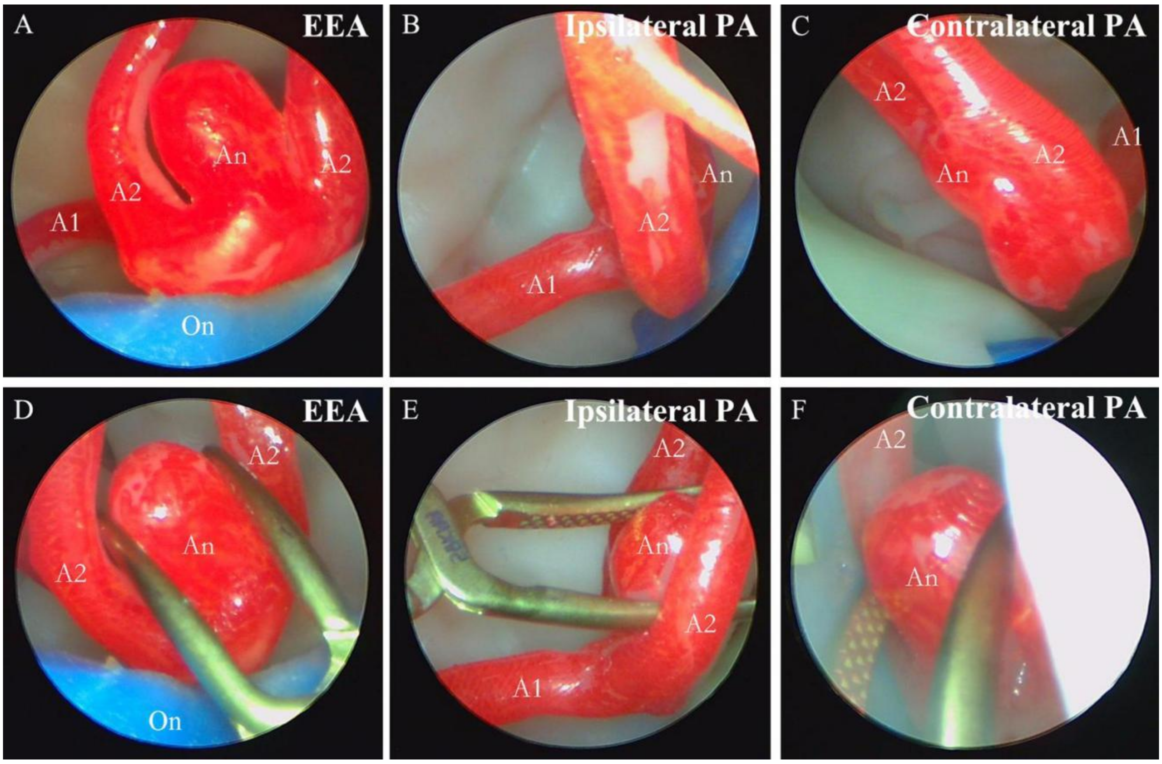
Supplementary Figure 2: Large aneurysm (>10 mm), projected anteriorly with the horizontal bilateral A2 position. A and D show that the aneurysm neck was not visible with the EEA, so the ipsilateral A1 was clipped to simulate proximal control. B, C, E, and F show aneurysm neck exposure and the final clipping with the PA (ipsilateral or contralateral). An: aneurysm; A1: the A1 segment of anterior cerebral artery; A2: the A2 segment of anterior cerebral artery; EEA: endoscopic endonasal approach; PA: pterional approach; On, optic nerve.



Supplementary Figure 3: Aneurysms projected posteriorly, with the horizontal position of bilateral A2. A and D show that the aneurysm was difficult to visualize with the EEA, therefore the ipsilateral A1 was clipped to simulate proximal control. B and C show that the aneurysm was visualized with the PA (ipsilateral or contralateral), and clipping was completed (E and F).An: aneurysm; A1: the A1 segment of anterior cerebral artery; A2: the A2 segment of anterior cerebral artery; EEA: endoscopic endonasal approach; PA: pterional approach; On, optic nerve.



Supplementary Figure 4: Aneurysm projected superiorly, with bilateral A2 in the sagittal position. A and D show that one A2 artery blocks aneurysms with the EEA, making it difficult to simulate clipping, and the clip is placed on the ipsilateral A1 to simulate proximal control. B and C show that the neck is easy to visualize with the PA (both ipsilateral and contralateral), and the aneurysm can be clipped (E and F).An: aneurysm; A1: the A1 segment of anterior cerebral artery; A2: the A2 segment of anterior cerebral artery; EEA: endoscopic endonasal approach; PA: pterional approach; On, optic nerve.



Supplementary Figure 5: Aneurysm projected superiorly, with bilateral A2 in the horizontal position. A and D show that the neck is exposed with the EEA, and the clipping is completed. B and C show that one A2 obstructs exposure of the aneurysm neck with the PA (ipsilateral or contralateral). However, due to the high degree of surgical freedom of the PA, clipping can still be completed (E and F).An: aneurysm; A1: the A1 segment of anterior cerebral artery; A2: the A2 segment of anterior cerebral artery; EEA: endoscopic endonasal approach; PA: pterional approach; On, optic nerve.