

Endovascular Treatment of Falcine Sinus Dural Arteriovenous Fistula

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Case report

Keywords: falcine sinus, dural arteriovenous fistula, endovascular treatment

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ABSTRACT

Background: Dural arteriovenous fistula (DAVF) often occurs in the cavernous sinus, transverse sinus, sigmoid sinus, tentorium, etc. A DAVF in the falcine sinus is extremely rare in adults. DAVF treatment has progressed from microsurgery to endovascular treatment (EVT). At present, the treatment for DAVF in the falcine sinus is mainly EVT.

Cases presentation: We present 2 cases of DAVF in the falcine sinus. In case 1, the patient was a 38-year-old male, and in case 2, the patient was a 35-year-old female; both had sudden onset of cerebral hemorrhage. They underwent CT angiography (CTA) and/or digital subtraction angiography (DSA), which showed a DAVF in the falcine sinus. In case 1, the feeding artery was only the right middle meningeal artery (MMA), which drained to the superior sagittal sinus through the cortical vein. In contrast, in case 2, there were a variety of feeding arteries, including bilateral ophthalmic arteries, the internal maxillary artery and the right MMA, and the DAVF drained through both cortical veins and cerebral deep veins simultaneously. Both were cases of Cognard type IV DAVF. Using Onyx (Medtronic, Irvine, California, USA), both patients underwent complete EVT through the MMA, with a satisfactory therapeutic outcome.

Conclusion: We believe that it is highly feasible to use Onyx for DAVFs in the falcine sinus using an arterial approach through the MMA to perform EVT. Nevertheless, due to the limited number of cases, we still need to accumulate additional experience.

KEY WORDS: falcine sinus, dural arteriovenous fistula, endovascular treatment

BACKGROUND

Dural arteriovenous fistula (DAVF) often occurs in the cavernous sinus, transverse sinus, sigmoid sinus, tentorium, etc. [1-3]. The falcine sinus is located in the anterior cerebral falx and is extremely rare in adults [4]. Therefore, DAVF in the falcine sinus is also rare and has been reported in only a few cases [5-7]. DAVF treatment has progressed from microsurgery to endovascular treatment (EVT). At present, the treatment for DAVF in the falcine sinus is mainly EVT [6]. Because DAVF in the falcine sinus is rare, we present 2 such cases treated with EVT to accumulate experience.

CASES PRESENTATION

CASE 1

The patient was a previously healthy 38-year-old male who was hospitalized for coma an hour after the sudden onset of a headache. A physical examination showed light coma. The muscle strength of the right limb was grade 3, with a positive pathological reflex. Brain CT showed frontal lobe hemorrhage entering the ventricular system (Figure 1A); CTA showed a malformed blood vessel in front of the cerebral falx (Figure 1B), and DSA showed a DAVF in the falcine sinus, supplied by a single branch of the right MMA and draining to the superior sagittal sinus through the cortical vein on the medial side of the frontal lobe. The draining vein was dilated, and Cognard type IV DAVF was diagnosed (Figure 1C-F).

In terms of treatment, a Marathon microcatheter (Medtronic, Irvine, California, USA) was placed at the intersection of the MMA and the anterior falx artery (AFA) using a transarterial approach through the MMA (Figure 2A), and Onyx (Medtronic, Irvine, California, USA) was injected to penetrate the DAVF and beginning of the draining vein (Figure 2B). Subsequently, angiography of the right internal carotid artery and external carotid artery showed complete embolization of the DAVF (Figure 2C-D). After the operation, the patient received conservative treatment for 1 week and was then discharged. At the half-year follow-up, the patient was awake and could answer questions correctly, but the right limb remained paralyzed and the patient had lost the ability to live independently.

CASE 2

The patient was a previously healthy 35-year-old female who was hospitalized 2 hours after the onset of a sudden headache. A physical examination showed that she was lucid and had flexible limbs, neck stiffness, and a positive Kernig's sign. Brain CT showed intraventricular hemorrhage (Figure 3A). DSA showed a DAVF in the falcine sinus, which was fed by the anterior ethmoidal artery from the bilateral ophthalmic artery through the AFA. In addition, the bilateral internal maxillary artery (IMA) was anastomosed with the anterior ethmoidal artery through the vascular network originating from the end branch of the IMA and supplied blood through the AFA and the right MMA. The cortical veins and deep veins on the medial side of the frontal lobe were involved in drainage of the DAVF, and the draining veins were dilated; Cognard type IV DAVF was diagnosed (Figure 3B-F).

In terms of treatment, a Marathon microcatheter was placed at the intersection of the MMA and AFA using a transarterial approach through the MMA (Figure 4A), and Onyx was injected to penetrate the DAVF and beginning of the draining vein (Figure 4B). Subsequently, angiography of the right internal carotid artery and external carotid artery showed complete embolization of the DAVF (Figure 4C-F). After the operation, the patient received conservative treatment for 10 days and was then discharged. At the half-year follow-up, the patient had recovered well without sequelae.

DISCUSSION

DAVF can occur anywhere in the venous sinuses and dura mater of the brain [8]. However, it is relatively rare in the falcine sinus of the anterior cerebral falx because the falcine sinus is extremely rare in adults [4]. In addition, normally, the arterial supply to the anterior part of the cerebral falx is very small [9]. These arteries include the MMA, the AFA from the ophthalmic artery system, and the dural branches of the anterior cerebral arteries [10], which have high plasticity, as evidenced in moyamoya disease (MMD) (Figure 5).

When necessary, these arteries are quite thick and strong, and the MMA can be connected to the posterior part of the AFA [7]. If the falcine sinus is not completely degraded, there is the potential for DAVF formation. According to current mainstream opinion, if the falcine sinus forms a thrombus and then communicates with the proliferative and dilated dural artery, DAVF formation can occur [11].

In cases of DAVF, the arteries near DAVF can be recruited to add to the feeding blood supply; there may be many or only a few arteries involved [12]. For example, in case 1, only the dilated MMA was connected to the posterior part of the AFA as the blood supply. In contrast, in case 2, the blood supply was extensive. The bilateral ophthalmic arteries and the ends of the IMA were connected to the AFA through the anterior ethmoid artery, supplying blood to the DAVF, and the right MMA also supplied blood. The wide range of feeding arteries introduces large obstacles to DAVF treatment.

According to embryology, the anterior falcine sinus connects the superior and inferior sagittal sinuses, providing an alternative route for the cerebral venous drainage of the frontal lobes [4]. However, according to previous reports of DAVFs in the falcine sinus, the veins did not drain directly into the superior and inferior sagittal sinuses; instead, they drained through the cortical

drainage veins in the medial side of the frontal lobe, forming Cognard type IV DAVFs [4-7, 10, 12]. Although the falcine sinus may be open during DAVF formation, the falcine sinus does not communicate with the superior and inferior sagittal sinuses. Thus, DAVF formation can rely on cortical venous drainage only.

In case 1, only the cortical vein in the medial side of the frontal lobe was involved in drainage. In case 2, the deep vein system was also involved in drainage. Therefore, we can observe that venous drainage of the falcine sinus in cases of DAVF may be very extensive. Cognard type IV DAVFs in the falcine sinus are prone to rupture and hemorrhage.

Due to the location of the falcine sinus, interhemispheric hematomas form after rupture, which can break into the ventricle, as in both cases 1 and 2 reported in this paper. For DAVFs in the falcine sinus, similar to DAVFs located elsewhere, although various treatment options are available, EVT is still the most prevalent method. In addition, transarterial access is favored, unlike for DAVFs in the cavernous sinus, which allow the possibility of venous access for EVT [1].

For DAVF treatment by EVT, the MMA and the accessory meningeal artery are the gold standard vessels for EVT [13]. They also provide ideal routes to DAVFs in the falcine sinus. When choosing the MMA as the embolic route, the most important thing is to obtain the wedged position, which provides the ideal flow-arrest state for controlled delivery of embolic agents through the DAVF toward the venous side [14]. However, for DAVFs in the falcine sinus, it is very difficult for microcatheters to pass through the confluence of the MMA and the posterior part of AFA, which means that in our 2 cases, we were unable to achieve the ideal wedged position; we could use liquid embolic agents for EVT only at the location shown in Figures 2A and 3A.

Liquid embolic agents include n-butyl cyanoacrylate (NBCA, Histoacryl, Yocan Medical, Toronto, CA) and Onyx [15]. NBCA has a better ability to penetrate the shunt [16]. For example, Koyanagi et al. (2016) successfully treated a DAVF in the falcine sinus with the help of NBCA through the MMA [7]. We also consider Onyx to be feasible because we do not need to worry about Onyx reflux in the MMA; Onyx will keep moving forward, and it is not difficult to remove microcatheters from the external carotid artery system. Thus, Onyx was used for treatment, with beneficial therapeutic effects.

CONCLUSION

Therefore, we believe that it is highly feasible to use Onyx for DAVFs in the falcine sinus using an

arterial approach through the MMA to perform EVT. Nevertheless, due to the limited number of cases, we still need to accumulate additional experience.

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Abbreviations

DAVF: dural arteriovenous fistula; EVT: endovascular treatment; CTA: CT angiography; DSA: digital subtraction angiography; MMA: middle meningeal artery; AFA: anterior falx artery; IMA: internal maxillary artery; MMD: moyamoya disease.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Informed consents were obtained from the two patients included in the study.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

Funding

None.

Authors' contributions

JP conceived of the study and drafted the manuscript. ZY and JY participated in the supervision.

YZ, ZY, and JY conceived of the study and participated in its coordination, supervision, and revision of the manuscript. All authors read and approved the final manuscript.

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Not applicable.

FIGURE LEGENDS

Figure 1 Preoperative images from case 1

A: Brain CT scans showing that the hemorrhage in the longitudinal fissure extended backward into the left ventricular system. B: Brain CTA MIP showing that the DAVF was located in the anterior part of the cerebral falx at the midline (ellipse). C-D: Arterial-phase angiography showing no abnormalities in the left CCA (C) or right ICA (D). E-F: ECA angiography of the right anterior position (E) and lateral position (F) showing that the right MMA (red asterisk) supplied blood to the DAVF (ellipse in Figure E) in the falcine sinus through the posterior part of the AFA and drained to the sagittal sinus through the cortical vein on the medial side of the frontal lobe (blue asterisk), accompanied by tortuous and dilated draining veins. This was a Cognard type IV DAVF.

Abbreviations: CCA, common carotid artery; CTA, CT angiography; DAVF, dural arteriovenous fistula; ECA, external carotid artery; ICA, internal carotid artery; L, left; MMA, middle meningeal artery; MIP, maximum intensity projection; R, right.

Figure 2 The EVT process in case 1

A: Microcatheter angiography of the right MMA showing that the DAVF was fed by the AFA (red asterisk) and drained through the cortical vein (blue asterisk). The arrow denotes the position of the microcatheter. B: X-ray film showing Onyx casting in the DAVF via the MMA and regurgitation of Onyx in the MMA (red asterisk); the arrow denotes the position of the microcatheter. C-D: The right ECA (C) and right ICA (D) showing complete DAVF embolization.

Abbreviations: DAVF, dural arteriovenous fistula; ECA, external carotid artery; ICA, internal carotid artery; MMA, middle meningeal artery; R, right.

Figure 3 Preoperative images from case 2

A: Brain CT scans showing hemorrhage in the left ventricular system. B-C: Arterial-phase angiography of the right (C) and left ICA (D) showing a DAVF in the falcine sinus, which was fed by the anterior ethmoidal artery from the OphA through the AFA (asterisk). D: Arterial-phase angiography of the right ECA showing the right MMA passing through the posterior part of the AFA (one red asterisk) and the IMA supplying blood through the arterial network (two asterisks). E: Late-phase arterial angiography of the right ECA showing drainage of the DAVF. The blue

asterisk indicates drainage of the cortical vein on the medial side of the longitudinal fissure, and the arrow indicates where the DAVF drains through the veins at the base of the frontal lobe and connects backward to the basal vein of Rosenthal (BVR) and SS. The draining veins showed many dilatations; Cognard type IV DAVF was diagnosed. F: Left ECA angiography showing that the IMA also supplied blood to the DAVF (asterisk); the ellipse denotes the location of the DAVF in the falcine sinus.

Abbreviations: AFA, anterior falx artery; DAVF, dural arteriovenous fistula; ECA, external carotid artery; IMA, internal maxillary artery; L, left; OphA, ophthalmic artery; R, right.

Figure 4 The EVT process in case 2

A: Microcatheter angiography of the right MMA showing the blood supply of the AFA (red asterisk). The arrow indicates the beginning of the AFA, which was also the position of the head end of the microcatheter. The ellipse denotes the DAVF. B: X-ray film showing Onyx casting in the DAVF via the MMA. C-D: Right ECA (C) and right ICA (D) showing complete DAVF embolization. E-F: Left ECA (E) and left ICA (F) showing complete DAVF embolization.

Abbreviations: DAVF, dural arteriovenous fistula; ECA, external carotid artery; ICA, internal carotid artery; L, left; MMA, middle meningeal artery; R, right.

Figure 5 Potential arterial anastomosis inside the dura mater of the anterior part of the cerebral falx in a case of MMD

A-B: Right ECA angiography of the lateral position (A) and anterior position (B) showing that the MMA (red asterisk) coincides with the rear part of the AFA (white asterisk) at the midline (arrow). C: Left ICA angiography of the lateral position showing that the anterior ethmoidal artery from the OphA continues with the AFA (asterisks). D: Left ICA angiography of the anterior position showing the location of the AFA (ellipse).

Abbreviations: MMA, middle meningeal artery; OphA, ophthalmic artery; IMA, internal maxillary artery; L, left; R, right; MMD, moyamoya disease; ICA, internal carotid artery; ECA, external carotid artery; AFA, anterior falx artery.

Figures

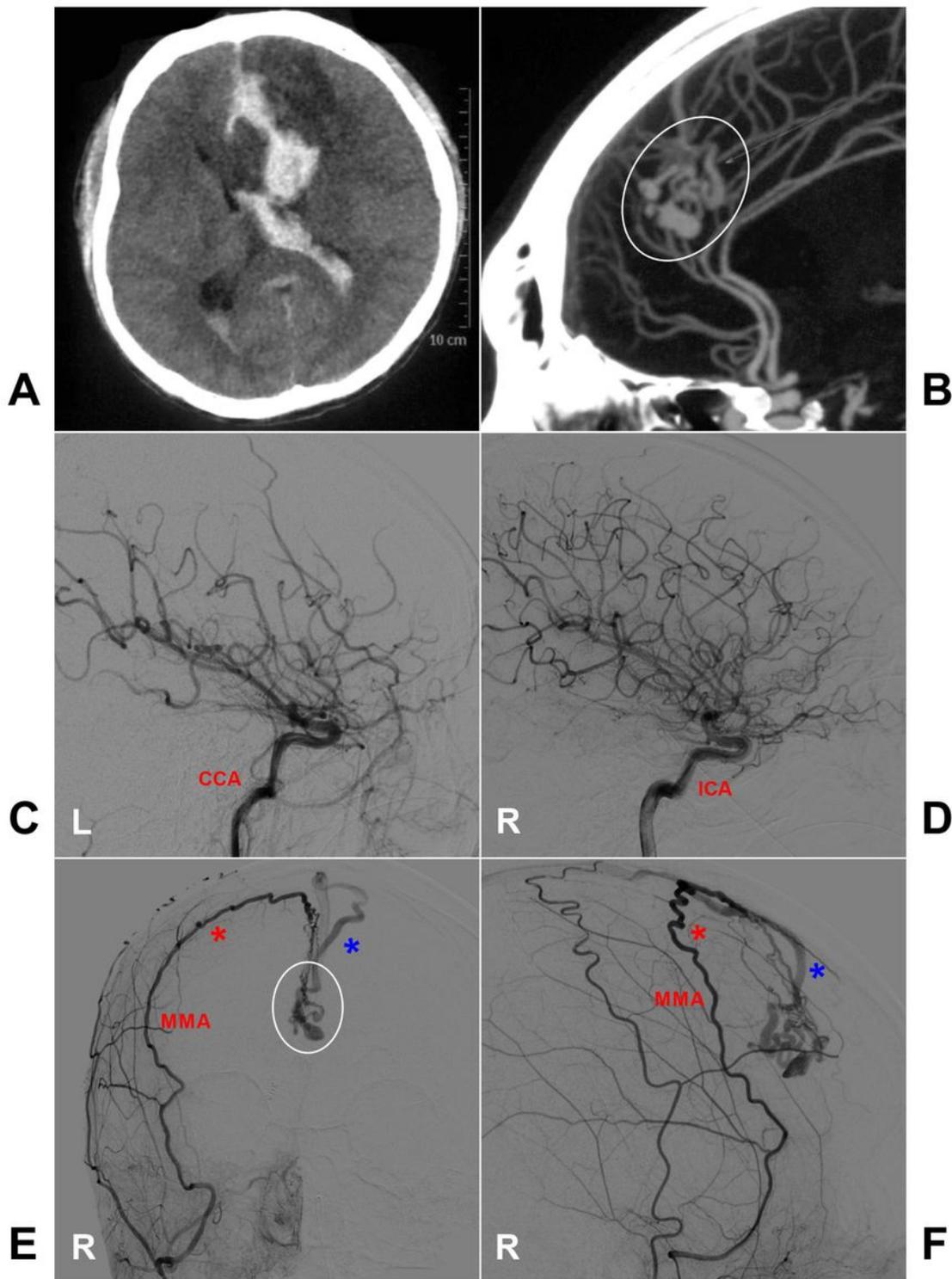


Figure 1

Preoperative images from case 1 A: Brain CT scans showing that the hemorrhage in the longitudinal fissure extended backward into the left ventricular system. B: Brain CTA MIP showing that the DAVF was located in the anterior part of the cerebral falx at the midline (ellipse). C-D: Arterial-phase angiography

showing no abnormalities in the left CCA (C) or right ICA (D). E-F: ECA angiography of the right anterior position (E) and lateral position (F) showing that the right MMA (red asterisk) supplied blood to the DAVF (ellipse in Figure E) in the falcine sinus through the posterior part of the AFA and drained to the sagittal sinus through the cortical vein on the medial side of the frontal lobe (blue asterisk), accompanied by tortuous and dilated draining veins. This was a Cognard type IV DAVF. Abbreviations: CCA, common carotid artery; CTA, CT angiography; DAVF, dural arteriovenous fistula; ECA, external carotid artery; ICA, internal carotid artery; L, left; MMA, middle meningeal artery; MIP, maximum intensity projection; R, right.

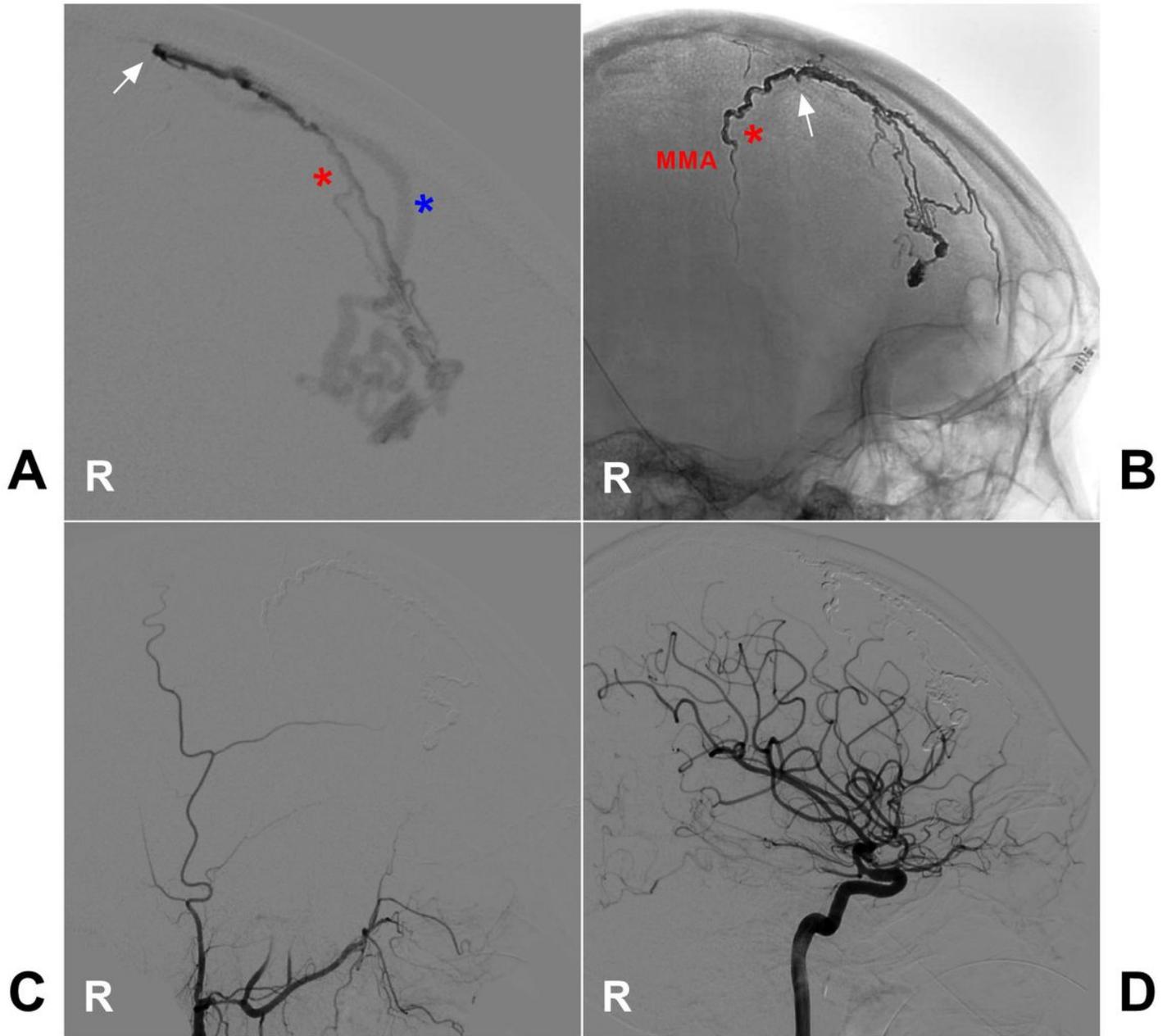


Figure 2

The EVT process in case 1 A: Microcatheter angiography of the right MMA showing that the DAVF was fed by the AFA (red asterisk) and drained through the cortical vein (blue asterisk). The arrow denotes the

position of the microcatheter. B: X-ray film showing Onyx casting in the DAVF via the MMA and regurgitation of Onyx in the MMA (red asterisk); the arrow denotes the position of the microcatheter. C-D: The right ECA (C) and right ICA (D) showing complete DAVF embolization. Abbreviations: DAVF, dural arteriovenous fistula; ECA, external carotid artery; ICA, internal carotid artery; MMA, middle meningeal artery; R, right.

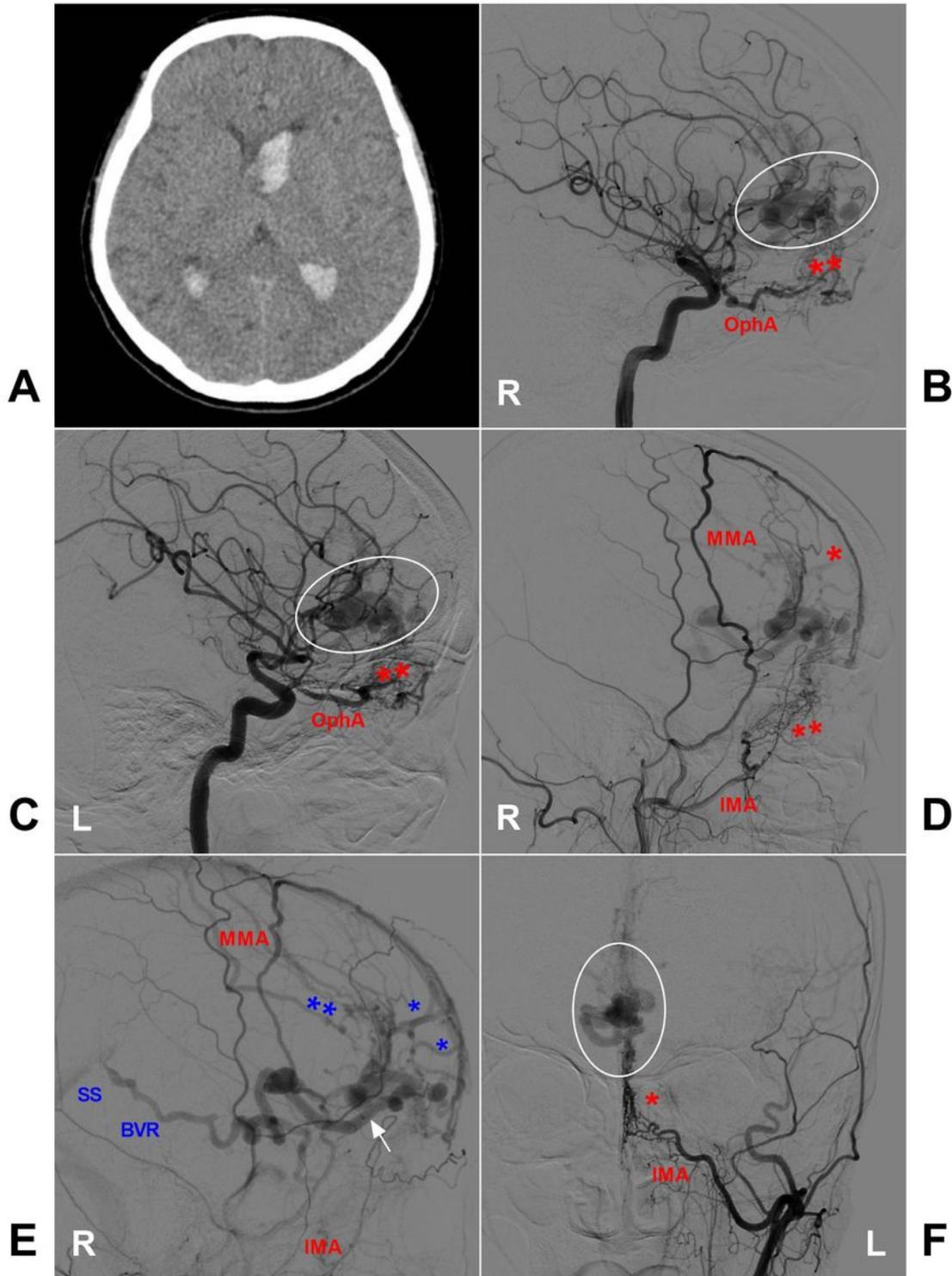


Figure 3

Preoperative images from case 2 A: Brain CT scans showing hemorrhage in the left ventricular system. B-C: Arterial-phase angiography of the right (C) and left ICA (D) showing a DAVF in the falcine sinus, which was fed by the anterior ethmoidal artery from the OphA through the AFA (asterisk). D: Arterial-phase angiography of the right ECA showing the right MMA passing through the posterior part of the AFA (one red asterisk) and the IMA supplying blood through the arterial network (two asterisks). E: Late-phase arterial angiography of the right ECA showing drainage of the DAVF. The blue asterisk indicates drainage of the cortical vein on the medial side of the longitudinal fissure, and the arrow indicates where the DAVF drains through the veins at the base of the frontal lobe and connects backward to the basal vein of Rosenthal (BVR) and SS. The draining veins showed many dilatations; Cognard type IV DAVF was diagnosed. F: Left ECA angiography showing that the IMA also supplied blood to the DAVF (asterisk); the ellipse denotes the location of the DAVF in the falcine sinus. Abbreviations: AFA, anterior falx artery; DAVF, dural arteriovenous fistula; ECA, external carotid artery; IMA, internal maxillary artery; L, left; OphA, ophthalmic artery; R, right.

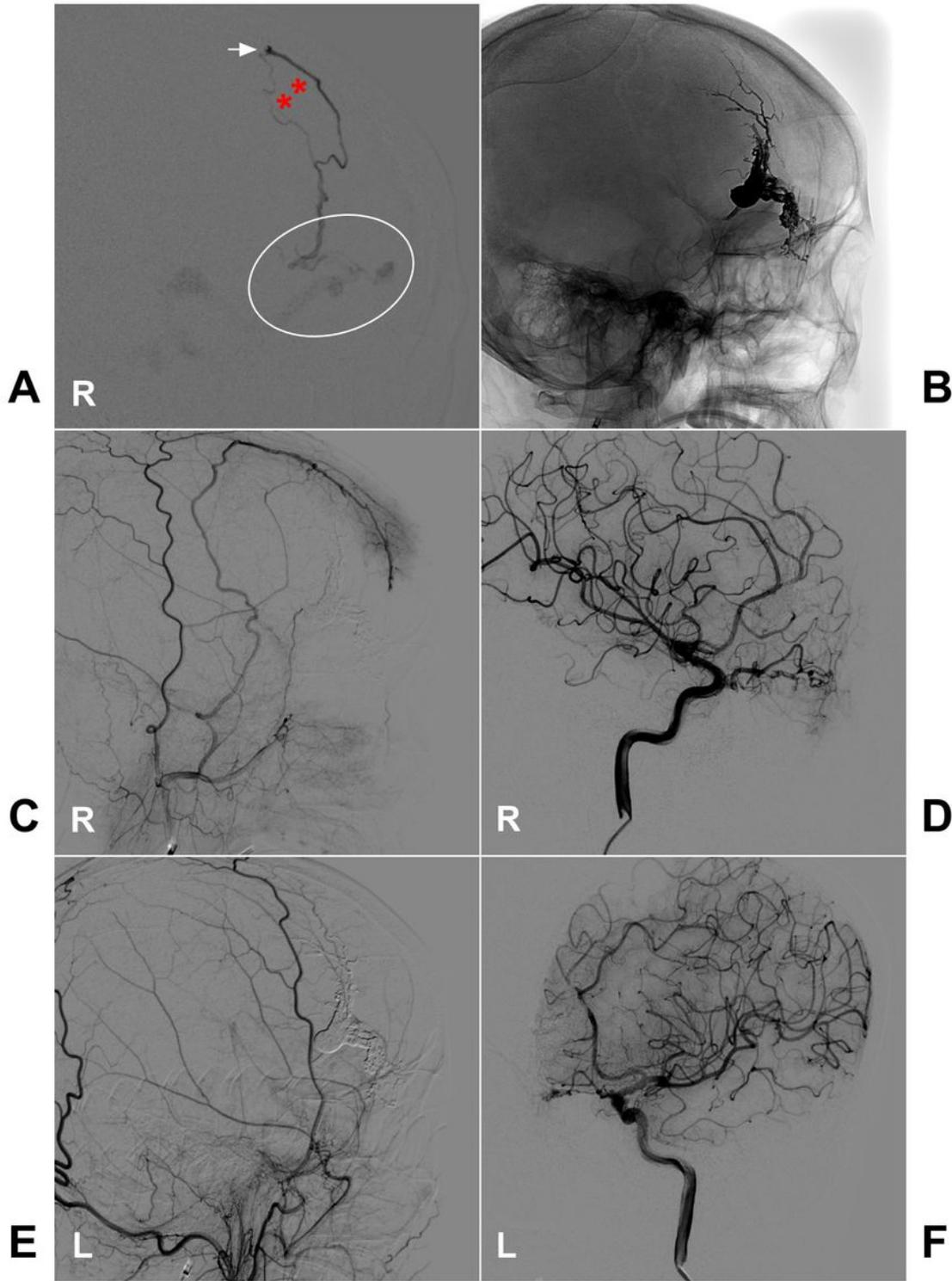


Figure 4

The EVT process in case 2 A: Microcatheter angiography of the right MMA showing the blood supply of the AFA (red asterisk). The arrow indicates the beginning of the AFA, which was also the position of the head end of the microcatheter. The ellipse denotes the DAVF. B: X-ray film showing Onyx casting in the DAVF via the MMA. C-D: Right ECA (C) and right ICA (D) showing complete DAVF embolization. E-F: Left ECA (E) and left ICA (F) showing complete DAVF embolization. Abbreviations: DAVF, dural arteriovenous

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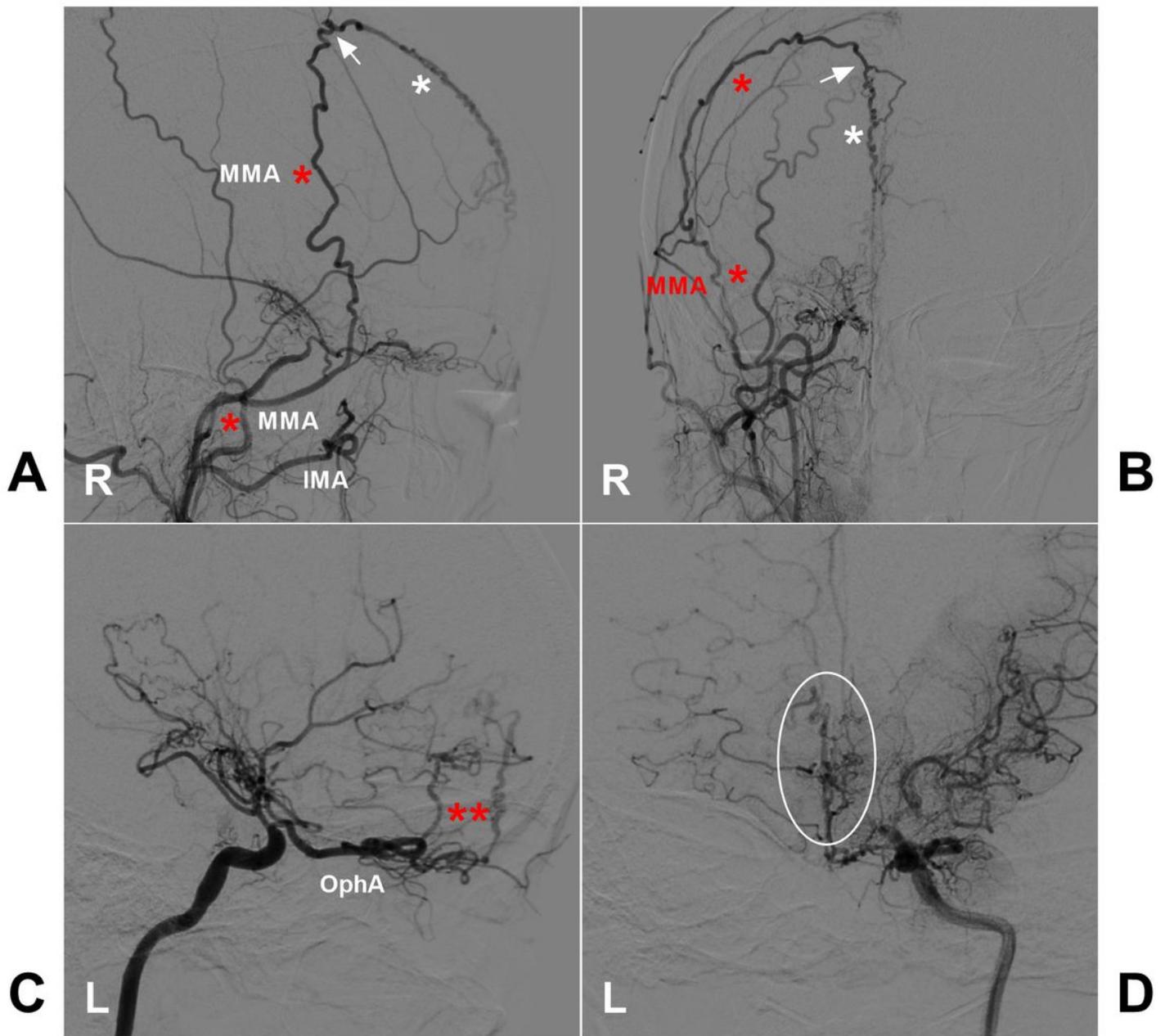


Figure 5

Potential arterial anastomosis inside the dura mater of the anterior part of the cerebral falx in a case of MMD A-B: Right ECA angiography of the lateral position (A) and anterior position (B) showing that the MMA (red asterisk) coincides with the rear part of the AFA (white asterisk) at the midline (arrow). C: Left ICA angiography of the lateral position showing that the anterior ethmoidal artery from the OphA continues with the AFA (asterisks). D: Left ICA angiography of the anterior position showing the location of the AFA (ellipse). Abbreviations: MMA, middle meningeal artery; OphA, ophthalmic artery; IMA, internal

maxillary artery; L, left; R, right; MMD, moyamoya disease; ICA, internal carotid artery; ECA, external carotid artery; AFA, anterior falx artery.