75 Middle Cerebral Artery Aneurysm: Proximal Middle Cerebral Artery Aneurysm Treated with Telescoping Flow Diverter Implantation and Loose Coiling After Preparatory Implantation of a Braided Stent as a Scaffold

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Abstract

A fusiform aneurysm in the M1 segment of the left-hand middle cerebral artery (MCA) had been incidentally discovered in a 50-year-old female. Diagnostic work-up, including a clinical examination, non-contrast-enhanced computed tomography (NCCT), CT angiography (CTA), and diagnostic angiography (DSA), performed at the refering hospital also revealed high-grade, proximal stenosis of the internal carotid artery (ICA) on the left-hand side. The patient was then referred to our institution for endovascular occlusion of the aneurysm. The case was discussed in the weekly neurovascular board meeting where it was decided to perform endovascular, extra-aneurysmatic flow diversion. This would include loose coil packing of the aneurysmal sac to promote thrombosis. Our intention was to keep the flow diverter's distal and proximal ends away from the MCA and ICA bifurcations in order to minimize the risk of thromboembolic complications potentially caused by covering the side branches, namely, the anterior cerebral artery (ACA) in the A1 and MCA in the M2 segment. Since nearly the entire M1 segment was affected by the fusiform dilatation, the distal and proximal landing zones for the flow diverter were rather short. Therefore, we decided to start by implanting a long, braided stent across the fusiform aneurysm, as this is more porous than a flow diverter. This would be followed by a second treatment session in which two flow diverters would be implanted and the aneurysmal sac loosely packed with coils once the initial stent had stabilized and endothelialization had occurred. Both procedures were carried out under general anesthesia with no clinical or technical complications. To enable good access in the first procedure, the stenosis in the ICA was treated beforehand by balloon dilation and implanting a self-expanding stent. The patient was discharged in a neurologically asymptomatic status after each treatment stage. Follow-up angiography performed 3 months after the second session revealed a complete occlusion of the fusiform aneurysm in the clinically unchanged asymptomatic patient, with no evidence of either intimal hyperplasia in the stented segment or that the side vessels had been negatively affected. The main topic of this chapter is the staged approach to the complex treatment of

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fusiform intracranial aneurysms starting with the implantation of a braided stent to act as scaffolding for hemodynamically active, low-porosity flow diverters.

Keywords

Middle cerebral artery, M1 · Fusiform aneurysm · Intracranial dissection · p48 flow diverter · LVIS Jr. Stent · Coil occlusion

Patient

A 50-year-old female patient, with an incidental finding of a fusiform MCA aneurysm in the left M1 segment. Her medical history was otherwise inconspicuous.

Diagnostic Imaging

Non-contrast-enhanced computed tomography (NCCT) performed at the referring hospital as a work-up for chronic headaches strongly suggested an aneurysm in the M1 segment of the left MCA. A CT angiography of the cervical and intracranial vasculature confirmed the diagnosis of a fusiform aneurysm in the M1 segment of the MCA and showed proximal high-grade stenosis of the ICA on the left-hand side. Diagnostic angiography of both ICAs and the left vertebral artery (VA), including a rotational 3D angiography, allowed the aneurysm morphology to be visualized in detail. Furthermore, the DSA showed minor stenosis of the proximal M1 segment adjacent to the proximal origin of the fusiform aneurysm as well as high-grade proximal ICA stenosis (Fig. 1).

Treatment Strategy

The patient was referred to our institution for endovascular treatment of said aneurysm. The case was discussed in our institutional neurovascular board meeting, resulting in a decision to pursue reconstructive endovascular treatment. We discussed the potential treatment strategies, including stent-assisted coiling, flow-diversion alone, and flow-diversion in combination with loose coiling. We decided on the latter approach since this appeared most the effective and predictable option for achieving a quick yet long-term occlusion of the aneurysm.

Our intention was to keep the flow diverter's distal and proximal ends away from the MCA and ICA bifurcations. This was in order to reduce the risk of the thromboembolic complications, which could be caused by covering the side branches, in this case, the anterior cerebral artery (ACA) in the A1 and MCA in the M2 segments. Since nearly the entire M1 segment was affected by the fusiform dilatation of the aneurysm, the distal and proximal landing zones for the flow diverter were rather short. Therefore, we decided to start by implanting a long, more porous braided stent across the fusiform aneurysm. We would then implant two flow diverters and loosely pack the aneurysm with coils in a later treatment session once the initial stent had had time to stabilize and endothelialize.

Treatment

***Procedure #1*: *15.11.2018*:** stent-PTA (percutaneous angioplasty) of the stenosis in the left proximal ICA followed by implanting a braided stent from the proximal M2 segment to the distal ICA across the fusiform aneurysm, in preparation for planned, further treatment

*Anesthesia***:** general anesthesia; 5,000 IU unfractionated heparin (Heparin Natrium, B. Braun) IV

*Premedication***:** 1× 600 mg clopidogrel (Plavix, Sanofi-Aventis) and 1× 500 mg ASA (Aspirin, Bayer Vital) PO 5 days prior to the procedure, followed by 1× 75 mg clopidogrel and 1× 100 mg ASA PO daily; Multiplate Test (Roche Diagnostics) (Area Under Curve, ARU): ASPI 25, ADP 26, TRAP 110, indicating dual platelet function inhibition

Access: right femoral artery 8F sheath

Guide catheter: 6F Neuron MAX 088 (Penumbra)

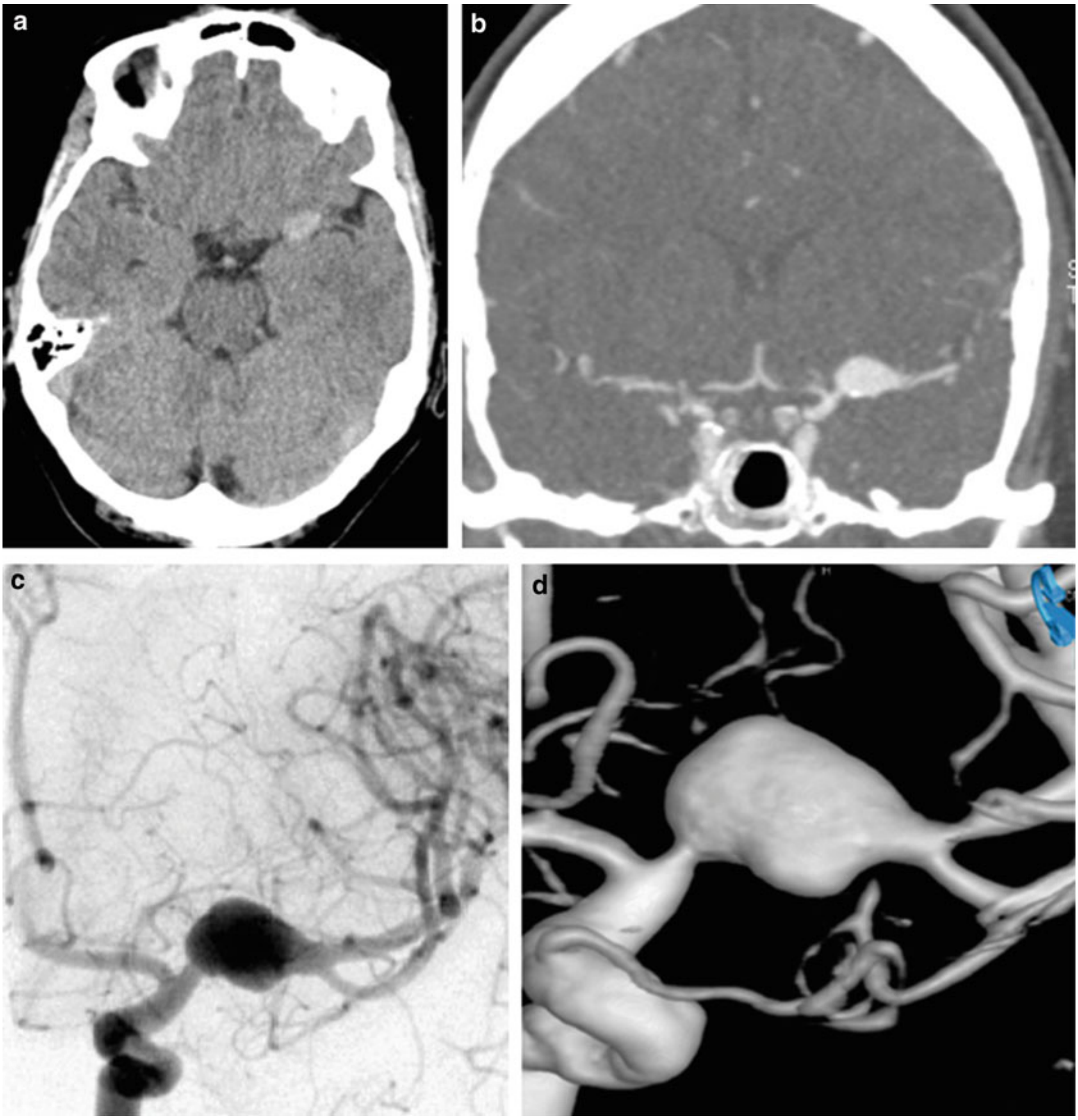

Fig. 1 Diagnostic imaging in a fusiform aneurysm of the left M1 segment. NCCT (axial view (**a**)) ruled out an SAH and revealed as an incidental finding a hyperdense oval lesion, strongly suspicious of an aneurysm of the left MCA. CTA (coronal view (**b**)) confirmed the diagnosis of a fusiform MCA/M1 aneurysm. DSA with contrast injection of the left ICA showed the fusiform aneurysm in posterior-anterior view (**c**). A 3D reconstruction of a rotational DSA showed a mid-grade stenosis of the right M1 segment just proximal to the aneurysm

Intermediate catheter: SOFIA plus 125 cm (MicroVention)

Microcatheter: Headway 17 (MicroVention)

Microguidewire: Traxcess 14 EX (MicroVention)

Implants: *proximal ICA*, Carotid Wallstent 7/40 mm (Boston Scientific); *MCA aneurysm*, LVIS Jr. 3.5/33 mm (MicroVention).

Additional devices: predilatation of the ICA stenosis, Sterling balloon 3/20 mm (Boston Scientific) and Sterling balloon 4/40 mm (Boston Scientific).

Course of treatment: a 6F Neuron MAX was placed in the common carotid artery on the left-hand side and used as a guiding catheter. DSA, including standard and oblique projections, allowed the high-grade carotid artery stenosis and the highly tortuous intracranial vasculature to be seen in detail before percutaneous angioplasty (PTA) was performed on the ICA stenosis and the stent implanted. The ICA stenosis was visualized at an angle at which none of the surrounding branches of the external carotid artery (ECA) were covering it. A Traxcess microguidewire was guided past the stenosis and placed with its distal end still in the extradural portion of the ICA. Then, 3 mm and 4 mm Sterling balloons were used to perform PTA on the stenosis before a Wallstent was implanted. Once the proximal ICA stenosis had been removed, a coaxial arrangement of a Neuron MAX and a SOFIA intermediate catheter was advanced distally across the previously implanted stent. Three-dimensional angiography was used to view the aneurysm at an appropriate angle, allowing a clear view of the intended proximal and distal landing zones for the stent. The mid-grade stenosis of the M1 segment, which had been previously shown on imaging, did not require any PTA before the LVIS Jr. stent was implanted. After calibrating the measurements of the length of the fusiform aneurysm by the lengths of the intended distal and proximal landing zones for the stent, an LVIS Jr. stent of 3.5/33 mm was chosen for the procedure. A Headway 17 microcatheter was then navigated into the larger M2 segment of the MCA with the Traxcess EX microguidewire with no issues. The LVIS Jr. stent was placed across the aneurysm as intended with its distal end extending into the unaffected M2 branch for approximately 6 mm (distal landing zone). Its proximal end was in the most distal 7 mm of the ICA. A final angiographic run in working and standard projections showed regular flow within the stented segment and a mild stasis of contrast medium into the venous phase of the angiogram, indicating the subtle flow-diverting effect of the braided stent.

The absence of any inadvertent events (e.g., a dissection of the ICA or distal emboli within the dependent vasculature) was confirmed by the final angiographic run taken in two standard projections. The first stage of the planned procedure had been completed (Fig. 2).

Duration: 1st–12th DSA run: 47 min; fluoroscopy time: 25 min

Complications: none

Postmedication: 1× 100 mg ASA PO daily for life, 1× 75 mg clopidogrel PO daily for 12 months

Procedure #2**:** ***22.03.2019*****:** loose coiling of a fusiform M1 aneurysm after previous stent implantation, followed by the coaxial implantation of two flow diverters across the fusiform aneurysm and inside the previously implanted stent with preservation of the proximal and distal landing zones of the stent.

*Anesthesia***:** general anesthesia, 5,000 IU unfractionated heparin IV

*Medication***:** 1× 100 mg ASA PO daily, 1× 75 mg clopidogrel PO daily for the last 4 months; Multiplate Test (ARU): ASPI 31, ADP 25, TRAP 70, confirming dual platelet function inhibition

Access: right femoral artery 8F sheath

Guide catheter: 6F Neuron MAX 088 (Penumbra)

Intermediate catheter: Navien A+ 072 (Medtronic)

Microcatheter (flow diverter): VIA 21 (MicroVention)

Microcatheter (coils): Excelsior SL-10 (Stryker); *microguidewire:* pORTAL 14, pORTAL 14 EXT (phenox)

Implants: Coils: Target 360° STANDARD 5/15, Target 360° STANDARD 4/8, Target 360° STANDARD 4/10, (Stryker), Microplex 6–10/30 (MicroVention).

2 Flow diverters: p48 MW 3/18 mm, p48 MW 3/15 mm (phenox)

Additional devices: postdilatation of the proximal flow diverter, Ryujin Plus 2/20 mm (Terumo) (failed to reach target); SeQuent NEO 2.25/10 mm (B. Braun) (failed to reach target); Scepter C Balloon 4/10 mm (MicroVention)

Course of treatment: the second stage of the treatment involved placing the aforementioned guiding catheters in a coaxial fashion in the cervical segment of the left ICA, distal to the previously implanted Wallstent. An angiogram in standard projections showed the fusiform aneurysm unchanged from the initial procedure. There was no evidence of shrinkage or intra-aneurysmal

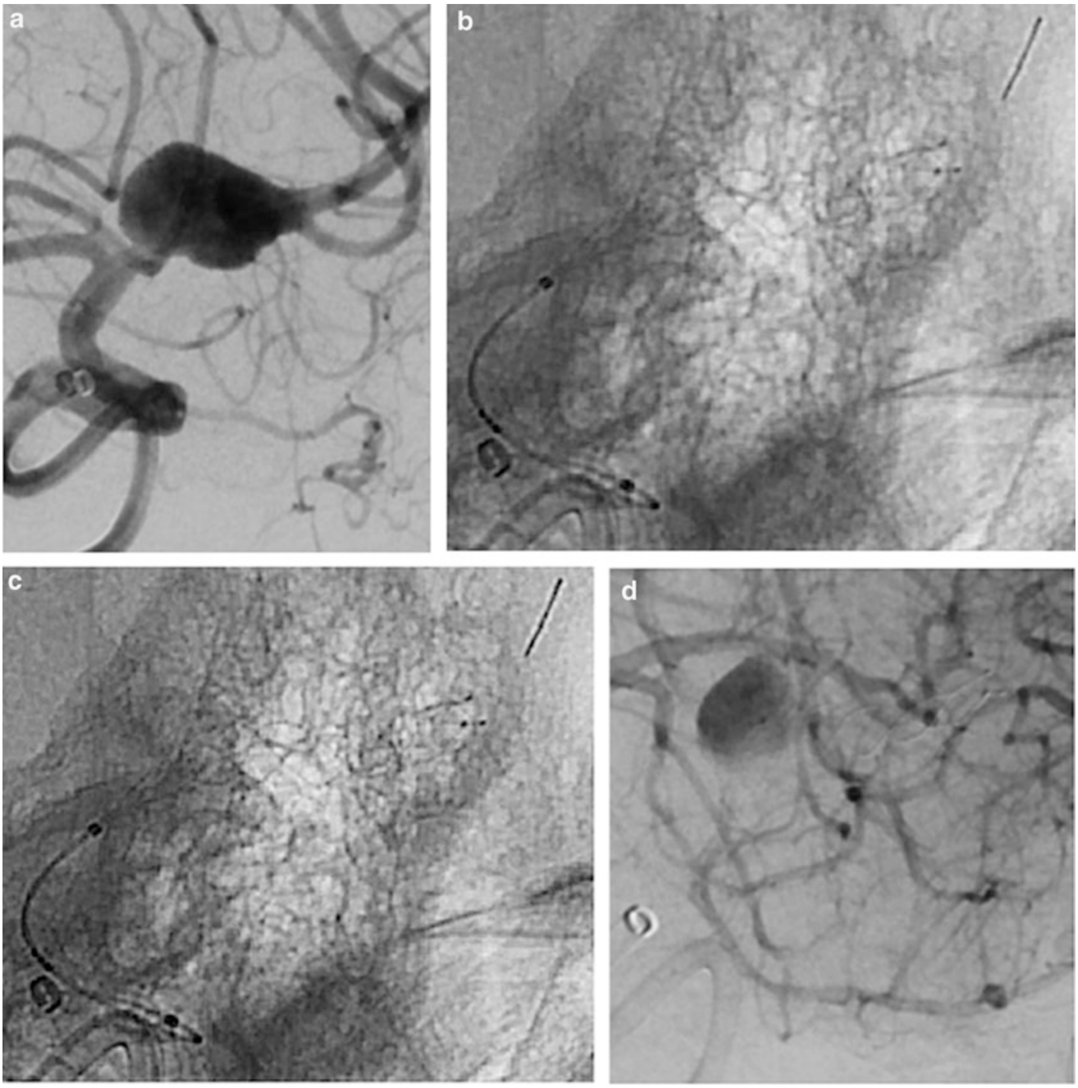

Fig. 2 The first step of the endovascular treatment of a fusiform M1 aneurysm. A Headway 17 microcatheter is placed in the left MCA M2 segment ready for the deployment of an LVIS Jr. stent (**a**), unsubtracted views after the implantation of the stent (working position (**b**) and lateral view (**c**)). Angiographic run after stent placement with regular flow within the stented segment and some contrast medium stasis within the fusiform aneurysm (working position (**d**))

thrombosis as may be expected from the remaining mild stenosis of the proximal M1 segment. The Navien-guiding catheter was positioned more distally in the ICA and, assisted by the pORTAL guidewire, the Excelsior SL-10 microcatheter was inserted through the struts of the LVIS Jr. stent into the upper part of the aneurysm without difficulty. The VIA 21 microcatheter was then navigated toward the proximal M2 segment following the course of the stent. Two low profile p48 MW flow diverters were deployed inside the LVIS Jr. stent, jailing the Excelsior SL-10 microcatheter. In order to achieve better apposition of the flow diverters, a balloon angioplasty was attempted. Two non-compliant coronary balloon catheters turned out to be too stiff, while a compliant remodeling balloon (Scepter) proved suitable. After a gentle balloon angioplasty, the saccular component of the aneurysm was loosely filled with four detachable coils. After withdrawing the Excelsior SL-10, the final DSA run confirmed the LVIS Jr. stent, the coils and the two flow diverters were all in their intended positions. No ischemic or hemorrhagic complications were encountered (Fig. 3).

Duration: 1st–12th DSA run: 131 min; fluoroscopy time: 49 min

Complications: none

Postmedication: 1× 100 mg ASA PO daily for life, 1× 75 mg clopidogrel PO daily for 12 months

Follow-Up Examination

An MRI at discharge after the second procedure revealed asymptomatic minor ischemic lesions in the left MCA territory. A follow-up angiography was carried out 3 months after the second treatment. It showed complete thrombosis within the fusiform aneurysm with minor stenosis remaining in the proximal M1 segment (Fig. 4). The next angiographic follow-up examination is scheduled for 9 months later according to our institutional standard. Dual antiplatelet medication continues to be taken.

Clinical Outcome

The patient was discharged 2 days after both endovascular procedures with no neurological symptoms and has remained asymptomatic during the ongoing follow-up (currently at 4 months).

Discussion

Fusiform aneurysms represent a subgroup of intracranial aneurysms since – as opposed to saccular aneurysms – the whole circumference of the vessel wall is affected. They account for approximately 3–13% of all intracranial aneurysms (Park et al. 2008). These aneurysms are associated with atherosclerotic disease or, typically in younger patients, occur as a result of a spontaneous or traumatic dissection of intracranial arteries. In the majority of cases, it is difficult to establish the underlying cause through imaging (Fischer et al. 2014; Stehbens 1983). Fusiform aneurysms might enlarge over time and cause compressive or ischemic symptoms, while subarachnoid hemorrhage occurs less frequently. As with saccular aneurysms, the basic treatment goal is to exclude the aneurysm from the cerebral circulation, which can be accomplished by reconstructive or deconstructive techniques. *Deconstructive* in this context means an occlusion of the affected artery whether through microsurgery or an endovascular procedure. We did not consider this option in our case as occluding the M1 segment in this asymptomatic patient would have required an extra-intracranial bypass, which might have carried a higher risk for (ischemic) complications than letting the aneurysm take its natural course. A surgical reconstruction of the M1 segment by wrapping or complex clipping techniques would likewise bear a disproportionate risk, so the decision taken by our neurovascular board was to reconstruct the affected artery by endovascular means. Several options were discussed ahead of treatment. The first would have been to cover the aneurysm with one or multiple porous stents with no additional coiling of the aneurysm. This meant assuming that the hemodynamic effect achieved would lead to complete thrombosis of the aneurysm. Since the metal coverage of porous stents is significantly lower than that of flow diverters, the argument for this approach was to preserve the efferent arteries in the vicinity of the aneurysm, namely, the A1 and M2 segments, since the risk of thromboembolic complications would decrease with a lower amount of metal placed above the origin of an artery. Successful treatment of intracranial aneurysms with porous stents used as flow diverters had been described before flow diverters became a routine tool; however, the efficiency of this technique remains unpredictable (Lieber et al. 1997; Pavlisa et al. 2010).

The second option would have been to treat this aneurysm using extra-aneurysmatic flow diversion alone. This appears to be the obvious strategy for fusiform aneurysms in general, however, might be challenging in longer lesions as the

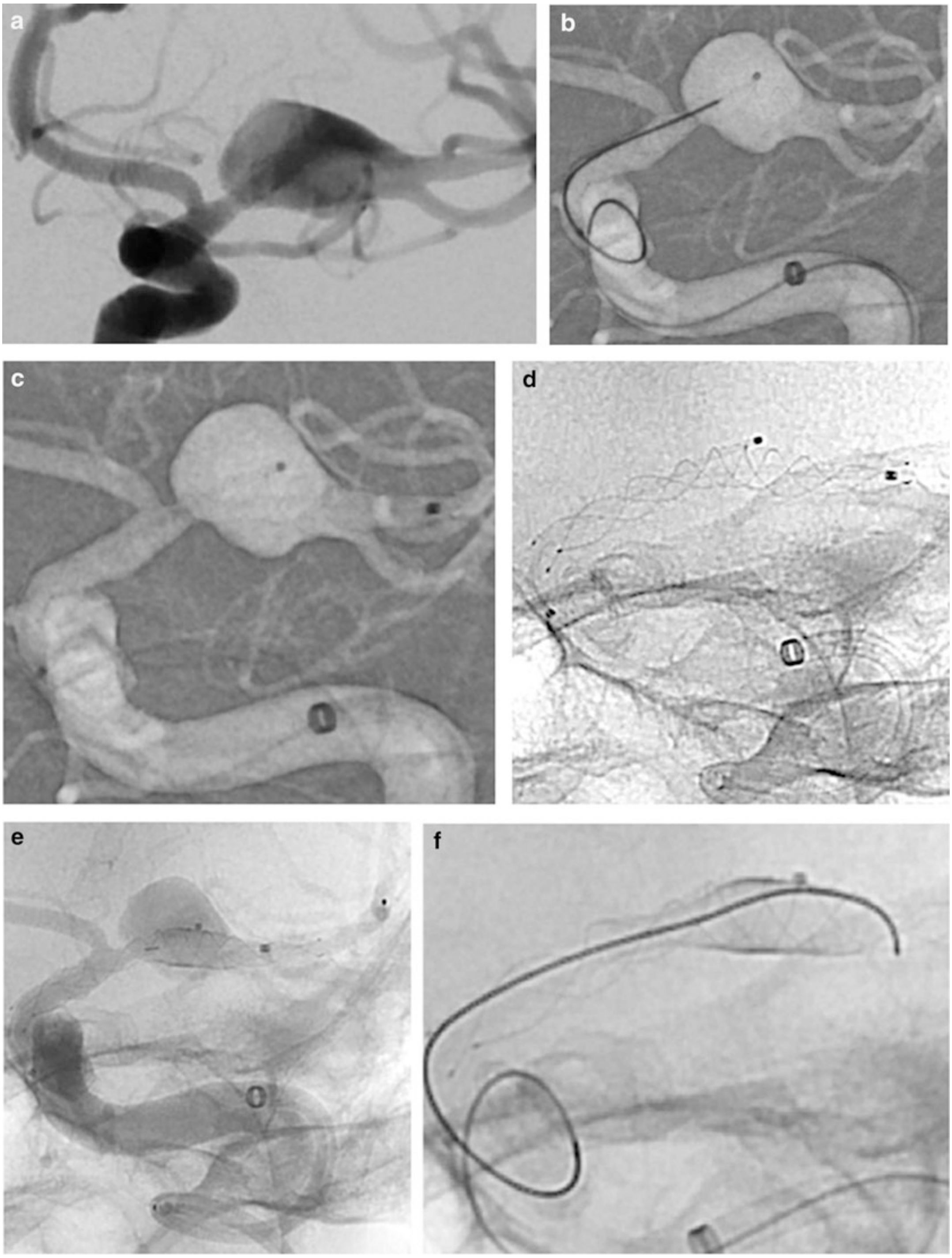

Fig. 3 (continued)

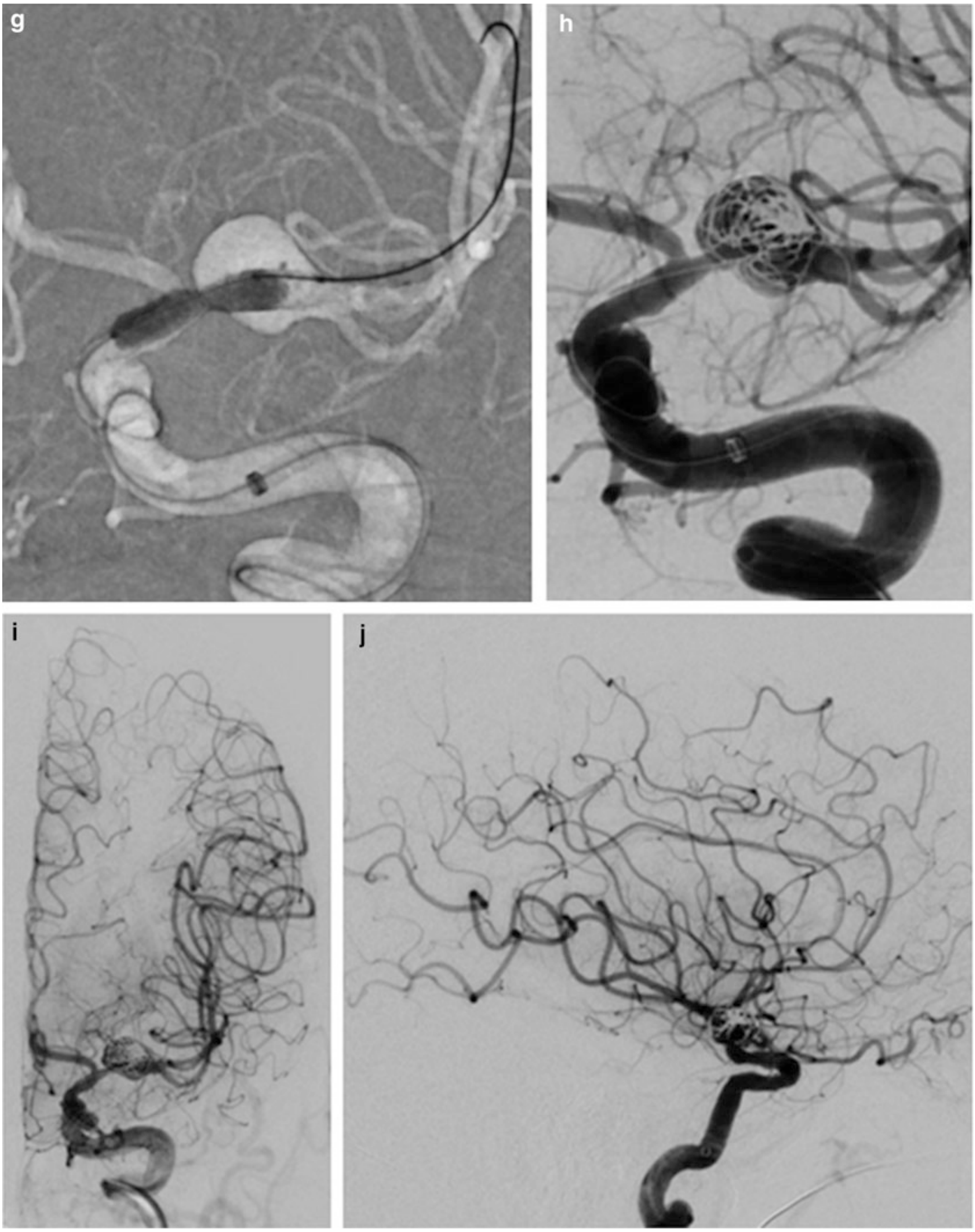

Fig. 3 Partial coil occlusion and flow diverter implantation to treat a fusiform MCA M1 aneurysm 4 months after the implantation of an LVIS Jr. stent. The aneurysm size and shape were as previously seen (**a**). An Excelsior SL-10 microcatheter was inserted into the saccular component of the M1 aneurysm (**b**). A VIA 21 microcatheter was then inserted along the LVIS Jr. stent into the superior M2 branch (**c**, **d**). The next stage was to deploy the first p48 flow diverter (3/18 mm) inside the fusiform aneurysm with its distal end in the transition zone of the fusiform artery and the regular M2 segment in order to preserve the efferent inferior M2 branch that had been previously covered by

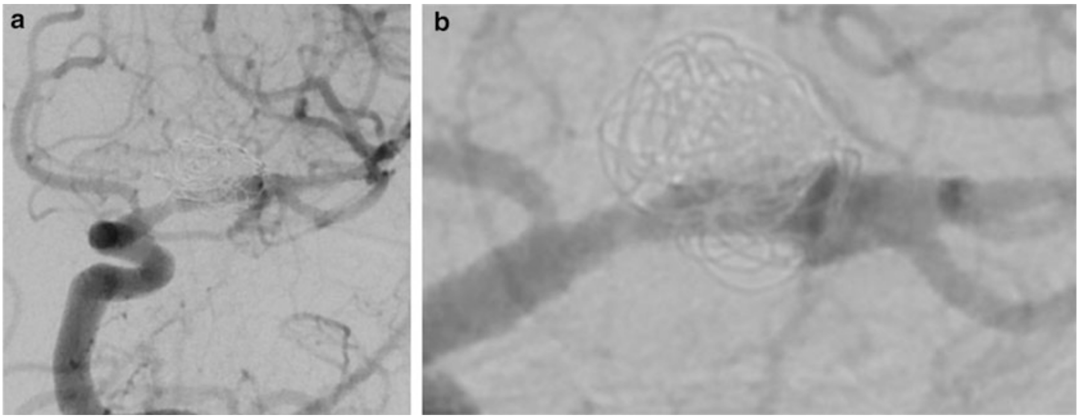

Fig. 4 Angiographic follow-up 3 months after the implantation of two p48 MW flow diverters inside an LVIS Jr. shows complete occlusion of the fusiform M1 aneurysm

stability of the device is reliant on the distal and proximal segments of the artery having remained unaffected by the aneurysm (*landing zones*) (Fischer et al. 2014). Furthermore, we had to consider the different diameters of the distal (M2) and proximal landing zones (terminal ICA) as an argument against implanting one long flow diverter. The fusiform dilatation of the M1 segments would also have caused a significant foreshortening of any flow diverter, which in combination with the aforementioned aspects would have increased the complexity of this strategy.

The third potential method would have been stent-assisted coiling. Arguments against this approach were the increased risk of side branch occlusion, possibly leading to basal ganglia ischemia due to the necessity of densely packing the fusiform aneurysm, as well as the likelihood of occlusion using this technique not being successful on the first attempt.

The strategy applied in our case addressed the drawbacks of the above options. Implanting a long, braided stent to act as a scaffold for the later flow diverters and coils made stability less of an issue while also making it possible to preserve the efferent arteries. The additional coiling of the aneurysm helped to initiate and accelerate the intra-aneurysmal thrombosis. Furthermore, the coils also contributed to the stability of the implanted stent and flow diverters (Alturki et al. 2018; Thielen et al. 2017).

The brand and size of flow diverters and stents used were decided by the operator. This technique could be performed with stents or flow diverters from other brands as long as the required sizes are available. Determining the size of flow diverter required in this procedure was done by measuring the intended landing zones and weighing up the

Fig. 3 (continued) the LVIS Jr. stent (**e**). A second p48 MW flow diverter (3/15 mm) was then placed into the first one, with the proximal end landing directly distal to the M1 stenosis (**f**). We decided to perform a dilatation of said stenosis with the additional goal of better positioning the proximal end of the second flow diverter to the vessel wall. A pORTAL guidewire was advanced into the distal section of the MCA, and the VIA 21 microcatheter was withdrawn after the pORTAL wire was extended using the pORTAL EX wire. Several attempts to advance Ryujin and SeQuent balloon catheters failed, probably due to the tortuosity of the vasculature and the two stent layers within the stenosis. Eventually, a Scepter C balloon was successfully advanced into the stenosis, and low-pressure manual inflation was performed (**g**). This maneuver resulted in a moderate resolution of the M1 stenosis, allowing four coils to be loosely placed inside the aneurysm via the previously placed microcatheter (**h**). Finally, the microcatheter was withdrawn, and the procedure drawn to a close with no angiographic suggestion of any negative side effects (**i**, **j**) reduced flow diversion inherent in oversized devices against the poor wall apposition resulting from undersized devices (Fischer et al. 2014).

Good arguments could be made for dilating the proximal M1 stenosis before implanting the stent. We had planned to not dilate the stenosis, however, did not expect the second flow diverter to end directly at the stenosis. Therefore, we changed our initial plan and performed post-dilatation as described. As well as reducing the stenosis, this might also have helped the flow diverter to better adapt to the vessel wall.

Therapeutic Alternatives

Bypass Surgery
Conservative Management
Microsurgical Wrapping
Parent Vessel Occlusion
Stent-Assisted Coiling
Telescoping Stenting

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