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Endovascular Treatment of Large Proximal Basilar Artery Fenestrated Aneurysms: Overlapping Stent with Coil Embolization —A Case Report

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Abstract

This detailed case report presents and discusses the endovascular treatment of a large proximal basilar artery fenestrated aneurysm (PBAFA). Aneurysms occur rarely at the vertebrobasilar junction, with a moderate proportion of cases presenting fenestrations. Considering the high risk associated with posterior circulation aneurysms, including estimated rupture risk, periprocedural complications, or treatment difficulties in surgical procedures, endovascular treatment options are becoming increasingly favored, particularly considering the advancements in stent and flow diverter techniques. Our report focuses on a case of a 58-year-old male with a large unruptured PBAFA, treated using overlapping stent with coil embolization (OSCE) and triple catheter technique. This method was selected considering the size of the aneurysm, its complex vascular structure, and the risk of recurrence and complications. Our findings emphasize that a comprehensive understanding of vascular anatomy, hemodynamics, and the characteristics of endovascular treatment devices is essential for the treatment success. In addition, they demonstrate that the OSCE using low-profile visible intraluminal support devices combined with the triple catheter technique are an effective treatment option for large PBAFAs.

Keywords: overlapping stent with coil embolization, basilar artery fenestrated aneurysm, large unruptured intracranial aneurysm, triple catheter technique

Introduction

Vertebrobasilar junction (VBJ) aneurysm is extremely rare (0.5%), and it is said that 35%-70% of these cases are associated with fenestration,[1,2] which is referred to as proximal basilar artery fenestrated aneurysm (PBAFA). Fenestration is an anatomical variant, and the pathological relationship between fenestration and cerebral aneurysms is still not understood well.[3] However, the majority of observed cases involve small to moderate-sized aneurysms, with limited reports on the treatment of large or giant aneurysms.

Posterior circulation aneurysms pose a greater risk of mortality upon rupture and present a higher surgical challenge compared to anterior circulation aneurysms. Recently, with the rapid advancement of endovascular techniques and devices, endovascular treatment is often preferred for posterior circulation aneurysms. Despite advancements in endovascular treatment, large and giant aneurysms continue to pose significant challenges due to high recurrence rates and complications. Treatment options for PBAFA include simple coiling, stent-assisted coiling, parent vessel occlusion (PAO), and more recently, flow diverters (FD), with overall reported complete occlusion rate of 82.4% following the procedure.[4] Reports on large and giant PBAFA are rare, and no standardized treatment has been established. Overlapping stent with coil embolization (OSCE) has been shown to be effective in fusiform or wide-necked aneurysms, such as dissecting aneurysms,[5] blood blister-like aneurysms,[6] and complex intracranial

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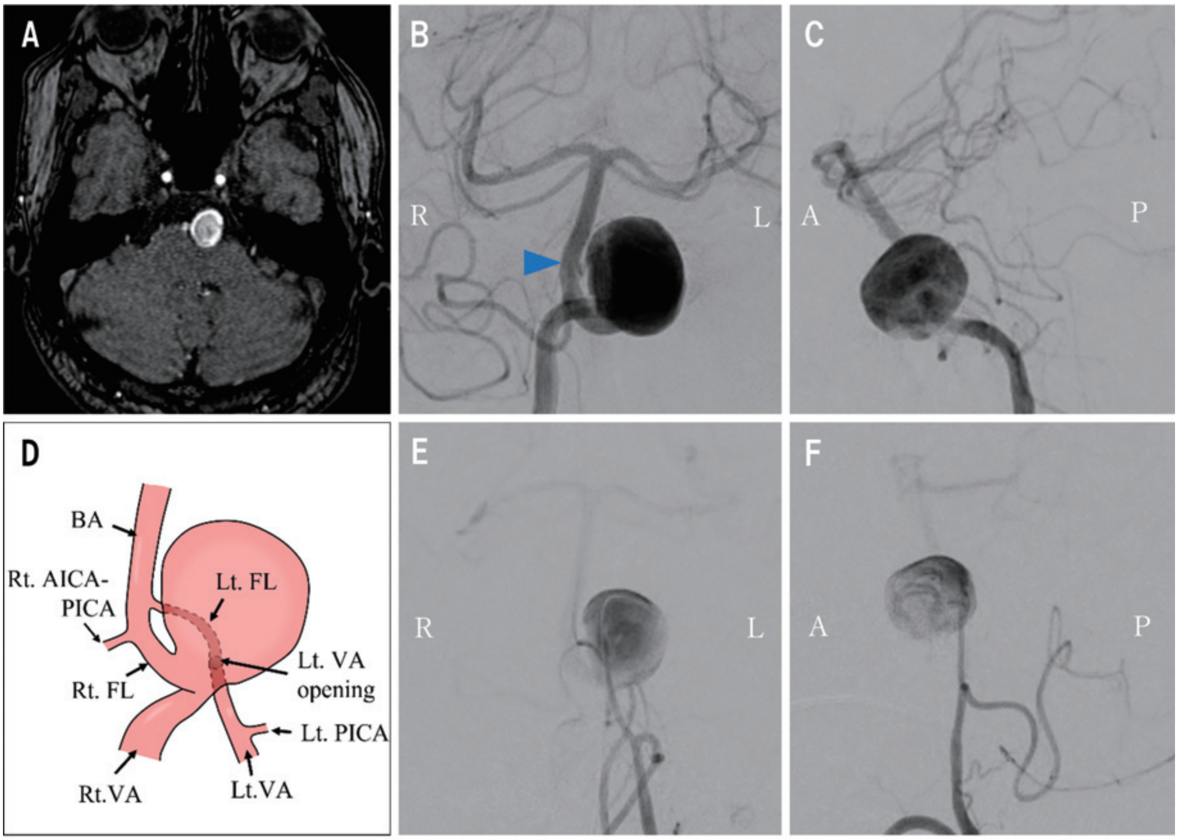

Fig. 1 Preoperative imaging studies.
A: Magnetic resonance angiography showing an aneurysm that mildly compresses the pons.
B: Right vertebral artery (VA) frontal angiogram. A blue arrowhead indicates the distal end of the fenestration.
C: Right VA lateral angiogram. Blood flow from the right VA goes directly toward the anterior wall of the aneurysm.
D: Illustration of the vascular anatomical structure of the aneurysm.
E, F: Left VA frontal angiogram. (E) Left VA lateral angiogram. (F) Blood flow from the left VA also goes directly into the aneurysm toward the posterior superior wall.
Note:
BA indicates basilar artery; VA, vertebral artery; FL, fenestrated limb; AICA, anterior inferior cerebellar artery; PICA, posterior inferior cerebellar artery; Rt, right; Lt, left
Orientation markers: A stands for anterior; P for posterior; R for right; L for left, indicating the angiogram orientation.

aneurysms.[7] In our study, we have treated a large PBAFA case using OSCE, achieving a favorable outcome, which is presented in this report.

Case Report

A 58-year-old man with a history of hypertension and diabetes mellitus was diagnosed with an abdominal aortic aneurysm. He was referred to our department after a preoperative assessment revealed a large, unruptured intracranial cerebral aneurysm at the VBJ. He exhibited no abnormal neurological findings. His magnetic resonance imaging (MRI) revealed a significant aneurysm at the VBJ, causing a mild mass effect at the pontomedullary junction (Fig. 1 A). There was no evidence of brainstem edema on the fluid-attenuated inversion recovery (FLAIR) sequence. Digital subtraction angiogram revealed bilateral vertebral arteries (VAs) with the right VA being the dominant side, a fenestration in the proximal basilar artery, and a large aneurysm originating from the proximal end of the fenestration. The aneurysm was saccular, with the neck of 7.9 mm, the height of 14.3 mm, and the width of 17.8 mm. Regarding the vascular structure in the area around the aneurysm, both the distal end of the right VA and the right fenestrated limb (FL) had a diameter of 3.2 mm. Furthermore, left anterior inferior cerebellar artery (AICA) and right posterior inferior cerebellar artery (PICA) were aplastic; the right AICA was an AICA-PICA variant, branching from the proximal basilar artery, and the distal end of the fenestration was found slightly distal to the right AICA-PICA bifurcation. The opening of the left VA was located slightly posterior to the aneurysm's neck where the right VA opened. The left FL ran posteriorly to the aneurysm (Fig. 1B-1F). Some perforating branches were visible in the mid-basilar artery, but no clear perforating branch was observed from near the aneurysm's neck to the fenestration. The angiogram revealed hemodynamic patterns where the right VA was tortuous at the aneurysm's neck, with blood flow from the right VA directly heading toward the aneurysm's anterior wall. Likewise, blood flow from the left VA was directed toward the posterior and upper aneurysm wall. After circulating inside the aneurysm, the blood then flowed out toward both FLs. Given the complexity and location of the vascular structure, along with the high recurrence risk, OSCE was selected as the treatment approach. The patient was prescribed dual antiplatelet therapy (75 mg of clopidogrel and 100 mg of aspirin per day) 14 days before the procedure. No platelet function tests were conducted.

Under general anesthesia, both femoral arteries were punctured, and activated clotting times were maintained at 250-300 s with systemic heparinization. A 6 Fr FUBUKI 90 cm ST (Asahi Intecc, Nagoya, Japan) was placed in the right VA, and a 5 Fr Guider softip 100 cm ST (Stryker, Kalamazoo, USA) was placed in the left VA. The working angles were set to isolate the aneurysm and neck and to provide a barrel view of the right FL. Without using an intermediate catheter, a Headway-17 (MicroVention, California, USA) microcatheter was navigated with a CHIKAI-14 micro guidewire (Asahi Intecc, Nagoya, Japan) through the right VA, beyond the aneurysm's neck, through the right limb of the fenestration, and into the right P2 segment of the posterior cerebral artery. An Excelsior SL-10 preshape J microcatheter (MC1) (Stryker Neurovascular, Fremont, CA, USA) was introduced from the right VA and looped approximately three-quarters of the way around within the aneurysm, positioning the tip at the posterior part of the aneurysm, guided by a CHIKAI-14 micro guidewire. Similarly, from the left VA, another Excelsior SL-10 preshape J microcatheter (MC2) was looped in the aneurysm. As a framing coil, a Target XL 360 Standard 20*50 (Stryker Neurovascular, Fremont, CA, USA) was partially released from the right SL-10. Subsequently, a 3.5 mm × 28 mm low-profile visible intraluminal support (LVIS) Jr. device (MicroVention-Terumo, Inc., Tustin, CA) was deployed from a Headway-17 microcatheter and positioned from the distal end of the fenestration to the right V4 segment (Fig. 2A and B).

After detaching the framing coil, the Headway-17(MC3) in the right VA was positioned into the aneurysm using a transcell approach with a CHIKAI-14. Following the framing coil, additional coils were inserted through MC1, while gradually pulling back to fill the aneurysm. Initially, this process resulted in incomplete embolization, leaving random gaps. Subsequently, coils were inserted into these dead spaces using MC2 and MC3, which had been looped in different directions by gradually pulling back the microcatheters. By using this triple catheter technique, the aneurysm was packed as tightly as possible with coils, achieving a volume embolization rate (VER) of 32%. While a portion of the aneurysm's neck remained, it was tightly packed, leaving no space to reposition the microcatheter via a transcell approach (Fig. 2C).

After placing Headway-17 in the BA with CHIKAI-14, a 3.5 mm × 23 mm LVIS Jr. device was overlaid inside the first one and deployed to cover the neck (Fig. 2D). The final angiogram confirmed the near-complete occlusion of the aneurysm by the coils and the preservation of both FLs. No contrast was seen within the aneurysm or along its wall, but a slight opacification of the right FL through the aneurysm was noted on the left VA angiogram (Fig. 2 E).

Post-interventional MRI revealed no brainstem edema around the aneurysm on FLAIR and a small infarct in the right thalamus on diffusion-weighted imaging, but the patient exhibited no neurological symptoms. Dual antiplatelet medication continued for 12 months post-procedure, and the patient was advised to take aspirin indefinitely. The 12-month follow-up angiogram confirmed complete occlusion of the aneurysm and the cessation of blood flow from the left VA to the contralateral FL (Fig. 2F), although both FLs remained patent. No in-stent stenosis was observed. The patient was followed up for 3 years and has shown favorable progress.

Discussion

According to the most recent review on BAFAs, when dividing the basilar artery into proximal (from vertebrobasilar junction to AICA), middle (from AICA to superior cerebellar artery), and distal (from superior cerebellar artery and above) segments, 90% of BAFAs are located in the proximal basilar artery (PBA).[8] The predominant aneurysm type is saccular, and bilobed aneurysms are also observed.[4] These are reported as kissing aneurysms or dumbbell-shaped aneurysms.[1,9-14] Matsumoto et al.[14] highlighted that computational fluid dynamics analysis revealed one VA flowing into the ventral side of the aneurysm, and the other into the dorsal side. They also noted a histological absence of the media layer at the junctions of proximal and distal fenestrations,[15] arguing that anatomical defects in the vessel wall and wall shear stress might contribute to the formation of dumbbell-shaped aneurysms. The PBA is a unique intracranial location where two arteries converge, and in our case, blood from the two VAs flowed toward the anterior and posterior walls of the aneurysm, creating complex turbulent flows within. Such hemodynamics and vessel wall fragility, rarely seen in normal aneurysms, could play a role in the PBAFA development and enlargement. Furthermore, it has been reported that the media of ruptured intracranial aneurysms (IAs) is thinner than that of unruptured IAs,[16] suggesting that fenestration aneurysms, which might inherently lack media structure, could have a higher rupture risk. Therefore, high-quality treatment is required.

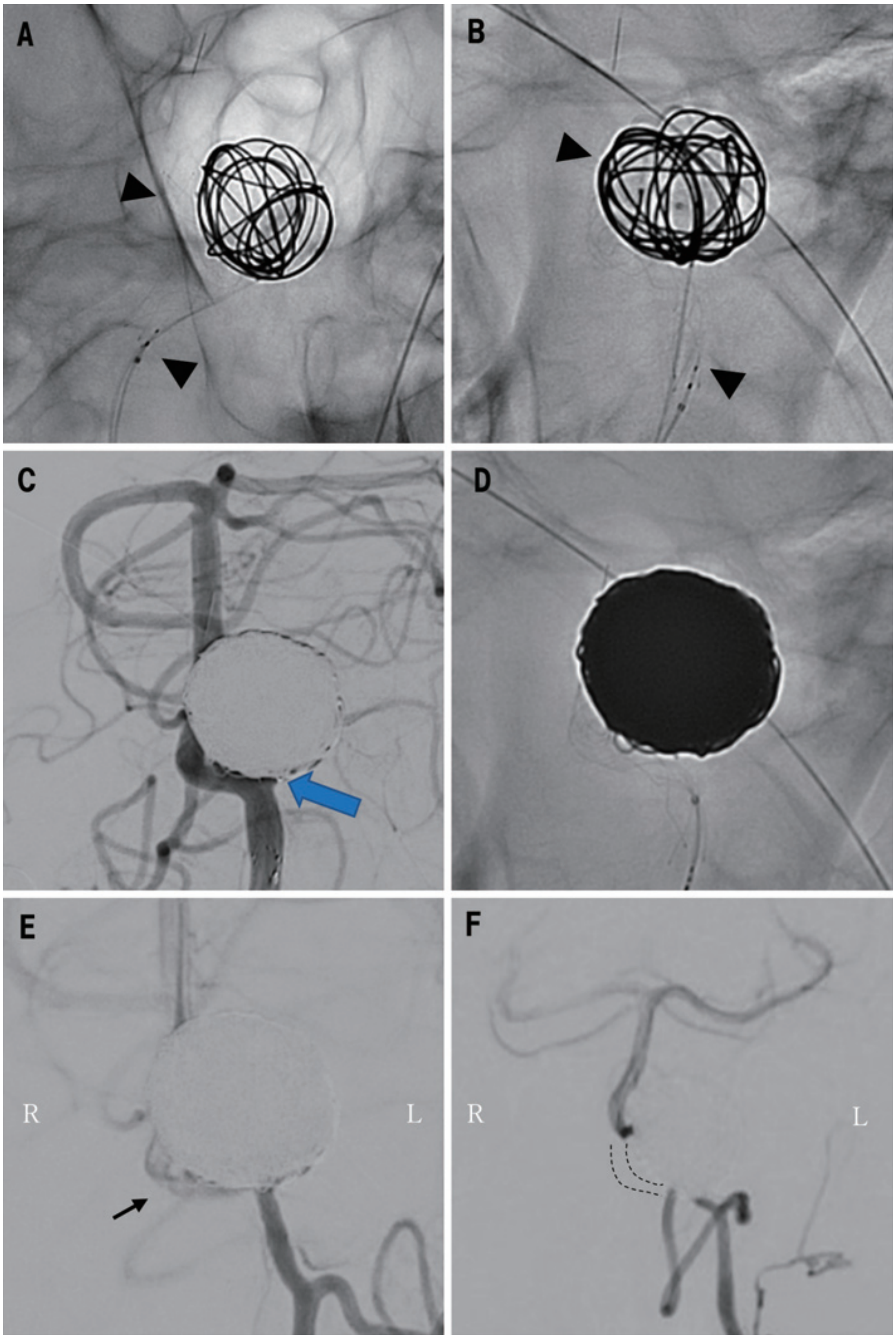

Fig. 2 Intraoperative and follow-up angiogram.
A, B: First low-profile visible intraluminal support (LVIS) Jr. deployment after framing coil placement. (A) barrel view, (B) neck-aneurysm view. Black arrowheads indicate the stent ends.
C: Post-coil embolization angiogram of the right vertebral artery (VA) in frontal view, showing a minor neck remnant indicated by a blue arrow.
D: Second LVIS Jr. deployment after coil embolization (neck-aneurysm view).
E: A frontal view of the final left VA angiogram, with a black arrow indicating blood flow from the left VA to the right fenestrated limb (FL) through the aneurysm neck.
F: One-year follow-up angiogram of the left VA (frontal view) showing cessation of blood flow from the left VA to the contralateral FL (the dotter lines). The aneurysm neck was resolved, achieving complete occlusion.
Note:
Orientation markers: A stands for anterior; P for posterior; R for right; L for left, indicating the angiogram orientation.

There are various size classifications for aneurysms. In some of the BAFA review,[4,8] the sizes were categorized as small (<7 mm), medium (7-14 mm), large (>14-24 mm), and giant (>24 mm). Table 1[1,13,17-29] presents the evolution of endovascular treatment for large and giant BAFAs. The aneurysms predominantly located in the PBA are mostly unruptured IAs. Treatments with stent-assisted coils (SAC) and FDs have shown good outcomes. In two cases treated with FD,[17,22] one side of the FL or VA was occluded. There were also cases where two SACs or FDs are employed in different vessels for the purpose of preserving fenestrations or VAs.

Given the high risk of recanalization following coil embolization for wide-necked and large aneurysms,[30] choosing SAC, which has a lower recurrence rate than coiling alone, appears to be rational.[31] Given the lack of sufficient randomized controlled trials, decisions about the choice and number of stents in treatment should be based on a thorough understanding of the underlying treatment theories and a careful consideration of each device's advantages and disadvantages. The morphological classification of BAFA by Trivelato et al.[32] is based on the neck diameter of the aneurysm (Narrow: 1, Wide: 2) and the position of the neck relative to the FLs (both FLs: A, one FL: B). Most large BAFAs have a wide neck and involve both FLs, so they are likely classified as Type 2A. Based on this classification, Styczen et al.[33] created a flowchart for the selection of endovascular treatment for BAFA. In brief, for narrow-neck aneurysms, simple coil embolization is preferred, while for wide-neck aneurysms, the treatment is determined based on the relationship with the FLs and the presence of perforating branches. For Type 2A aneurysms, the treatment options include (1) Woven Endo Bridge (WEB), (2) SAC, (3) coiling ± balloon remodeling technique, and (4) FD (in the absence of perforating branches), with SAC and FD being considered reasonable treatments for this case (Fig. 3). The primary advantage of FD is avoiding physical intraoperative perforations as it enables treatment without placing a device inside the aneurysm. However, FD induces aneurysm occlusion by promoting intrasaccular blood stasis and subsequent thrombosis, which could potentially lower the treatment success rate for bifurcation aneurysms, similar to the observed poor occlusion rates in fetal-type IC-Pc aneurysms.[34] In PBAFAs, where blood flow usually enters from a pair of VAs and exits through two FLs, solo FD treatment is challenging, necessitating FD accompanied by coil embolization or dual FDs to obstruct the aneurysm's blood flow. If the aneurysm is a giant aneurysm with significant brainstem compression, the most reliable treatment considered is the highly challenging trapping accompanied by bypass. While FD can be a treatment option, it lacks immediate effect, poses a risk of aneurysm growth due to incomplete occlusion and a risk of rupture post-treatment due to increased intra-aneurysmal pressure following FD placement.[35] Therefore, its reliability is low. Furthermore, in Japan, the coil embolization within the aneurysm is not covered by insurance when a FD is implanted. In our case, the selection of SAC enabled the application of the triple catheter technique following stent placement. By utilizing the transcell approach for microcatheter placement within the aneurysm, in addition to the jail technique and a microcatheter from the contralateral VA, we were able to achieve a high VER. This approach eliminated the blood flow entering the aneurysm body from the left VA, and technically and structurally, the small diameter of the left VA and left FL, the small neck diameter, and the large size of the aneurysm. It resulted in the use of coils with small curvatures, allowing us to preserve the left VA and left FL. A report that observed proximal bilateral pontine infarctions consistent with basilar artery fenestration[36] suggests the possibility of perforating branches at FLs. The frequency of perforating artery infarction due to distal vertebral artery occlusion is unknown, but Natarajan et al. experienced brainstem infarction in the perforating territory in a case treated with pipeline and parent artery occlusion for a fusiform vertebrobasilar aneurysm.[37] The sacrifice of one VA in the treatment of large vertebrobasilar aneurysms with SAC or FD is a reported complication risk,[38] suggesting that preserving the left VA and left FL reduces the risk of complications. Especially in case of unruptured IAs, the decision to sacrifice these vessels should be made cautiously.

The flow diversion effect is believed to be enhanced in OSCE, and it increases the metal coverage ratio (MCR) and pore density compared to standard SAC.[39,40] Aneurysm flow can be shear-driven (seen in side-wall aneurysms, where the blood flow direction is parallel to the aneurysm neck and parent artery) and inertia-driven flow (seen in terminal aneurysms, where blood flows into the aneurysm due to inertia). In our case, we observed the inertia-driven flow pattern, which is less likely to achieve effective flow diversion compared to shear-driven flow.[41] This increases the likelihood of residual blood flow into the aneurysm. While there are methods to adjust a single LVIS Jr device to increase the MCR,[42] there is a higher risk of the stent's proximal end dislodging into the aneurysm considering the high shortening rate of braided stents, especially in cases with relatively significant vessel tortuosity and wide-necked aneurysms like ours. The overlapped LVIS Jr device is believed to have a flow diversion effect similar to that of the pipeline embolization device,[39] which is likely aiding in the occlusion of the aneurysm's neck. While it might be possible to use a stent with higher MCR such as flow redirection endoluminal device (FRED) or LVIS Blue (MCR 28%), a study by Matsuda et al. suggest that FRED is less likely to fully expand and may not adhere well to the vessel wall compared to LVIS Blue.[43] The ease of deployment appears to increase with lower MCR, being easier with LVIS Jr., followed by LVIS Blue, and more difficult with

Table 1 Characteristics of previously reported cases of endovascular treatment for large or giant basilar artery fenestrated aneurysm

Author/ Year	Rupture	Dome (mm)	Location	Shape	Procedure	Stent	Preservation of FL	Complication	Final RROC	Follow-up	Age	Sex	Symptoms
Present case	Unruptured	18	PBA	Saccular	Overlapping stent assisted coil	LVIS Jr*2	Preserved	Minor thalamic infarction	1	3Y	58	M	Asymptomatic
Rinaldo, et al.[17]/2022	Unruptured	giant	PBA	Bilobed	FD + coil, PAO	PED	Rt VA occlusion	Worsening diplopia and hemiplegia 1 month post- operation (peri-aneurysmal cerebral edema)	1	5Y	47	F	Cranial nerve VI palsy
Korkmaz, et al.[18]/2021	Unruptured	giant†	PBA	Saccular*	FD	-	Preserved	None	1*	-	50	M	Respiratory depression
Gaikwad, et al.[19]/2021	Unruptured	19	PBA	Bilobed	Cossing flow diverter technique	PED Flex	Preserved	None	1	3M	46	F	Headache
Schmidt, et al.[20]/2021	Unruptured	16	-	-	FD + coil	PED	-	-	1	12M	-	-	-
Alqahtani, et al.[21]/2017	Unruptured	20.5	PBA	Saccular	SAC	LVIS	Preserved	None	1	-	65	F	None
Choo, et al.[13]/2017	Unruptured	16.2	PBA	Bilobed	Double-barrel Stent-assisted	Solitaire AB, Enterprise	Preserved	None	1	5Y	51	F	None
Toth, et al.[22]/2016	Unruptured	16	PBA	Bilobed	FD + coil, PAO	PED	Lt FL + VA occlusion	Minor cerebellar infarction	1	6M	49	F	Balance disorder, blurred vision, numbness in the left upper limb
Park, et al.[23]/2015	Ruptured	18	PBA	Teardrop	SAC	Enterprise*2	Preserved	Asymptomatic cerebral infarction (cerebellum, corpus callosum)	1	-	38	M	Headache
Consoli, et al.[24]/2013	Unruptured	20	PBA	Saccular	Kissing FD stents	PED*2	Preserved	None	1	7M	32	F	Sudden headache with diplopia
Gruber, et al.[25]/2010	Unruptured	14	PBA	Saccular	Waffle-cone technique	Enterprise	Preserved	Recanalization	2	6M	38	M	Headache, hazy vision, dizziness
Iihara , et al.[26]/2008	Unruptured	27	-	Saccular	Endovascular trapping	-	-	Left hemiplegia due to cerebral edema	-	6M	48	M	-
Greenberg , et al.[27]/2007	Unruptured	23	PBA	Saccular	Stentgraft + PAO (Lt.VA)	Jo-stentgraft*2	Rt FL + Lt.VA occlusion	None	1	1W	65	M	Subarachnoid hemorrhage 2 years before treatment
Peluso, et al.[1]/2007	Ruptured	17	-	-	Coil	-	-	Death due to subarachnoid hemorrhage	1	-	70	F	-
Yoon, et al.[28]/2004	Unruptured	15	PBA	Saccular	Coil	-	Preserved	None	2	19M	67	M	Chronic headache
Islak, et al.[29]/2002	Unruptured	14	PBA	Saccular*	Coil	-	Preserved	Recanalization	2*	5Y	35	F	Intractable headache

Note: PBA indicates proximal basilar artery; FL, fenestrated limb; RROC, Raymond–Roy occlusion classification; FD, flow diverter; PAO, parent artery occlusion; PED, pipeline embolization device; VA, vertebral artery; SAC, stent-assisted coil; LVIS, low-profile visualized intraluminal support; Rt, Right; Lt, Left

* In this table, information not available from the images or descriptions has been left blank, and we have evaluated and described the shape and occlusion rate details based on the images in the literature where these were not provided.

† Size was not mentioned in the paper but was described as GIANT because the aneurysm was strongly compressing the brainstem on MRI. The actual size is unknown.

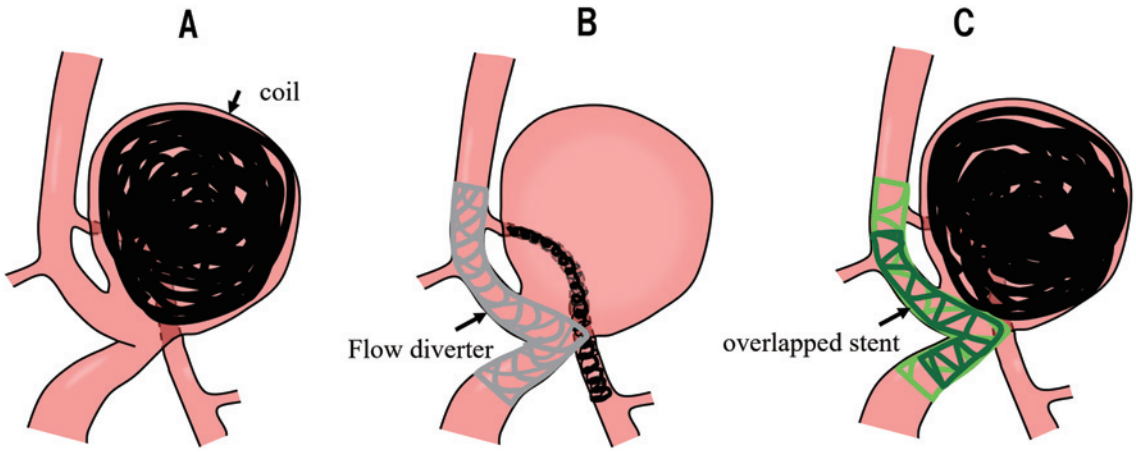

Fig. 3 Treatment options.
A: Coil embolization without stent placement.
B: Flow diverter (FD).
C: Overlapping stent with coil embolization.

FRED. Therefore, we chose a more manageable LVIS Jr. for the tortuous vessel and achieved a flow diversion effect by overlapping them.

While the efficacy of treating large PBAFAs using OSCE remains unexplored, we achieved a safe, successful, and complete treatment. This report represents a single-case study, and it is essential to accumulate more experience to establish the treatment's efficacy for large PBAFAs.

Conclusion

Paying attention to fenestrations is vital when dealing with PBAFAs. They appear to be at high risk of enlargement and rupture and therefore require high-quality treatment. The endovascular treatment of large PBAFAs demands a thorough understanding of vascular anatomy and hemodynamics, along with knowledge of the device characteristics and the principles of flow diversion, to prevent recurrence and complications. The OSCE with the triple catheter technique is a viable treatment option for large PBAFAs.

Informed Consent

Informed consent has been obtained from the patient in this case report.

Conflicts of Interest Disclosure

The authors and all co-authors have no conflicts of interest of disclosure. Authors who are members of the Japan Neurosurgical Society have registered online for self-reported COI Disclosure Statement Forms.

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