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CLINICAL ARTICLE

Endovascular treatment of basilar artery trunk aneurysms

Joonho Chung · Hyeonseon Park · Yong Cheol Lim · Dong-Keun Hyun · Yong Sam Shin

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Abstract
Background There has been little reported on the endovascular experience of basilar artery (BA) trunk aneurysms due to its low incidence. The purpose of this study is to report the results of endovascular treatment (EVT) of BA trunk aneurysms.
Methods Between 2004 and 2008, eight BA trunk aneurysms were treated by EVT. Five patients presented with subarachnoid hemorrhage, one had intracranial mass effect, and in two of the patients the aneurysms were found incidentally. Four lesions were saccular aneurysms, three of them were found with BA fenestration. Three lesions were dissecting aneurysms and one was a giant fusiform aneurysm. The mean follow-up period of clinical outcome was 17.1 months (range, 6–32 months). Angiographic follow-up data was obtained in six patients for period of a mean of 15.6 months (range, 6–25 months).
Results Four patients with saccular aneurysms were treated by stent-assisted coil embolization except for one patient that was treated without a stent. Three patients with dissecting aneurysms were treated by a single stent placement. One of these dissecting aneurysms rebled in 4 days after stent placement and was secured by BA occlusion. One giant fusiform aneurysm was treated by bilateral vertebral artery (VA) occlusion after balloon test occlusion. Six patients (75.0%) had excellent or good clinical outcomes, one patient whose aneurysm rebled became vegetative, and one patient with bilateral VA occlusion died. Follow-up angiograms showed that four lesions had complete occlusion and two had neck remnant.
Conclusions The endovascular catheterization of these lesions tends to be relatively simple compared to more complex neurosurgical approaches. EVT, especially using a stent, could be a valuable therapeutic method in treating BA trunk aneurysms.

Keywords Basilar artery trunk · Aneurysms · Endovascular treatment

J. Chung · H. Park · D.-K. Hyun
Department of Neurosurgery, Inha University School of Medicine, Incheon, Republic of Korea

Y. C. Lim
Department of Neurosurgery,
Ajou University School of Medicine,
Suwon, Republic of Korea

Y. S. Shin (✉)
Department of Neurosurgery, Seoul St. Mary's Hospital,
The Catholic University of Korea,
505, Banpo-Dong, Seocho-Gu,
137-701, Seoul, Republic of Korea
e-mail: nsshin@catholic.ac.kr

Introduction

Basilar artery (BA) trunk aneurysms are rare, and are considered to comprise less than 1% of intracranial aneurysms [24, 35]. Anatomically, these aneurysms originate from the region of the vertebrobasilar junction (VBJ) to the origin of the superior cerebellar artery (SCA). These lesions are among the most difficult to manage surgically because of their deep location, dense collection of vital cranial nerves, and perforating arteries to the brain stem [3, 8, 21, 37]. Furthermore, their rarity limits the acquisition of experience in treating these lesions. The endovascular approach to this area is comparatively easy, so the first choice of treatment has changed over the last 10 years [9, 14, 19, 34–36]. However, there has been less reported on the endovascular experience of these aneurysms due to their

low incidence. Thus, we describe our experience of endovascular treatment (EVT) in eight consecutive patients with BA trunk aneurysms.

Materials and methods

Between October 2004 and December 2008, there were eight consecutive patients with eight BA trunk aneurysms among 355 patients who underwent endovascular treatment. There were five women and three men whose ages ranged from 24 to 66 years (mean 43 years). Basilar artery bifurcation, vertebral artery (VA), and SCA aneurysms were excluded.

As shown in Table 1, five patients presented with subarachnoid hemorrhage (SAH) and one patient suffered from intracranial mass effect. The aneurysms were incidentally discovered in two patients. Among the five patients with SAH, two were Hunt-Hess (HH) grade 2, one was grade 3, and two were grade 4. Based on angiographic data obtained at the time of embolization, the aneurysms were classified by their characteristics. Dissecting aneurysms with pseudo-sacs were identified in three patients. Four patients had saccular aneurysms and one had a giant fusiform aneurysm. Among four patients with saccular aneurysms, aneurysms arising from BA fenestrations were identified in three patients. Various techniques of EVT, such as simple coiling, stent-assisted coiling, parent artery occlusion, and stenting without coiling were performed.

The treatment results were classified as follows: complete occlusion, neck remnant, and incomplete occlusion [26]. Complete occlusion designated aneurysms in which no residual neck was detected, neck remnant referred to lesions with residual filling of part of the neck of the aneurysm, and incomplete occlusion was defined as the presence of contrast agent filling the body and/or dome of the aneurysm.

Follow-up angiograms were obtained in six patients for mean period of 15.6 months (range, 6–25 months). Clinical outcome was graded according to the Glasgow Outcome Scale (GOS) [17] and the period of clinical follow-up was an average of 17.1 months (range, 6–32 months).

Results

Table 1 shows the characteristics of the patients and the follow-up angiographic and clinical results.

One giant fusiform aneurysm (case 1) was treated by parent artery occlusion. The dominant vertebral artery (VA), which was the left VA in this case, was completely occluded after the balloon test occlusion. However, the aneurysm was incompletely occluded so that additional treatment (right

Table 1 Data of patients and aneurysms with clinical and angiographic results

Case no.	Age	Sex	Initial presentation	HHG	FG	Size (L × D, mm)	Shape	Hydro	1st Tx	Initial result	2nd Tx	Results of 2nd Tx	Cx	Initial outcome (GOS)	Angiographic FU (month)	Final result	Clinical FU (month)	Final outcome (GOS)
1	28	F	Mass effect	0	0	35×25	Giant (fusiform)	No	Lt VA occlusion	ICO	Rt VA occlusion	CO		5	no			5
2	28	F	Incidental	0	0	3×3	Dissecting An	Moderate	Stent only	CO				2	12	CO	20	2
3	34	M	SAH	4	3	3×3	Dissecting An	Moderate	Stent only	ICO				2	24	CO	32	1
4	24	F	SAH	4	3	8×5	Dissecting An	Moderate	Stent only	ICO	Basilar occlusion	CO	Rebled	4	no		9	4
5	61	M	SAH	2	3	8×7	Saccular (lateral)	No	Stent-coiling	NR				1	12	NR	12	1
6	46	M	Incidental	0	0	20×15	Saccular (fenestration)	No	Stent-coiling	CO				1	25	CO	26	1
7	54	F	SAH	3	3	6×6	Saccular (fenestration)	No	Coiling	NR				1	12	NR	12	1
8	66	F	SAH	2	3	2×2	Saccular (fenestration)	No	Stent-coiling	CO				1	6	CO	6	1

An aneurysm, *HHG* Hunt-Hess grade, *FG* Fisher grade, *Hydro* hydrocephalus, *L* length, *D* diameter, *Lt* left, *Rt* right, *SAH* subarachnoid hemorrhage, *CO* complete occlusion, *NR* neck remnant, *ICO* incomplete occlusion, *Cx* complication, *Tx* treatment, *FU* follow-up, *GOS* Glasgow Outcome Scale

VA occlusion) was performed. Because the bilateral posterior communicating arteries (PcoA) showed good collateral flow from the anterior circulation to the posterior circulation, it was thought that bilateral VA occlusion was one of the possible treatment options. The aneurysm was completely occluded according to the final radiographic result. However, the patient died because bilateral VA occlusion caused acute brain stem edema 3 days after admission. The bilateral PcoAs might have been insufficient to supply enough blood flow to the brain stem.

Three patients with dissecting aneurysms (cases 2, 3, and 4) were treated by a single stent placement without coil embolization. One of these patients (case 4) suffered from rebleeding of the aneurysm 2 days after treatment. This bleeding was stopped by BA occlusion with coiling. The aneurysm was completely occluded according to the final radiographic result. However, the patient lived in a vegetative state during 9 months of clinical follow-up. The other two dissecting aneurysms were completely occluded according to the 12-month (case 2) and 24-month (case 3) angiographic follow-up and the patients had excellent or good clinical outcomes according to the 20-month (case 2) and 32-month (case 3) clinical follow-up.

One lateralized saccular aneurysm on the mid-basilar artery (case 5) was treated by stent-assisted coil embolization. On the 1-year angiographic and clinical follow-up, the patient had a neck remnant of the aneurysm and an excellent clinical outcome.

Three patients had saccular aneurysms arising from the BA fenestration (cases 6, 7, and 8). One was treated by coil embolization without a stent and the other two were treated by stent-assisted coil embolization. Follow-up angiographies (6–25 months of follow-up) showed two complete occlusions (cases 6 and 8) and one neck remnant (case 7) of the aneurysms. All three patients had excellent outcomes according to the 6 to 26-month clinical follow-up.

Overall, six patients (75.0%) were successfully treated in a single session, whereas two patients (cases 1 and 4) required additional endovascular treatment. After the initial EVT, three aneurysms (37.5%) were completely occluded, two (25%) had a neck remnant, and the other three (37.5%) were incompletely occluded.

For the initial clinical outcomes, six patients (75.0%) had excellent or good clinical outcomes, one patient (12.5%) who had an aneurysm rebled became vegetative, and the other patient (12.5%) died. The follow-up clinical outcomes were not much different from the initial clinical outcomes. In case 3, the patient's clinical outcome was improved from GOS 2 (good) to GOS 1 (excellent) during 32 months of follow-up.

Follow-up angiographies were not performed for case 1 (died) and case 4 (vegetative state), and six (75.0%) of the eight patients had follow-up angiography. Four aneurysms were completely occluded and the other two had neck remnant. In case 3, the initially incomplete occlusion of the aneurysm became a complete occlusion during 2 years.

Illustrative cases

Case 3

A 34-year-old male patient presented with SAH and initial HH grade was 4. His brain computed tomography (CT) revealed hydrocephalus so that extraventricular drainage (EVD) was performed. The ruptured dissecting aneurysm on BA trunk was found on cerebral angiography (Fig. 1a). The pseudo-sac was too small and risky to perform embolization with coils. Thus, a single balloon-mounted coronary stent (TAXUS Liberte 3 mm×16 mm, Boston Scientific) was deployed between mid-basilar and basilar bifurcation (Fig. 1b). After stenting, the aneurysm was incompletely occluded (Fig. 1c). However, no further procedure was performed because the blood flow into the pseudo-sac was decreased. He recovered to GOS 2 at his discharge. Follow-up angiogram at 24 months showed that the aneurysm was completely occluded (Fig. 2d). He was GOS 1 on 32-month clinical follow-up.

Case 5

A 61-year-old male patient presented with sudden severe headache (HH grade 2). His CT revealed SAH and a wide-necked lateralized aneurysm on mid-basilar artery was identified on cerebral angiography (Fig. 2a). Using the "Jailing" technique [5, 15], a self-expandable intracranial stent (Neuroform, 3.5 mm×20 mm, Boston Scientific) was deployed on the BA. Embolization of the aneurysm with coils was then done. The post-procedural angiography showed a residual neck (Fig. 2b). He showed excellent (GOS 5) clinical outcome and the residual neck of the aneurysm was unchanged (Fig. 2c) on clinical and angiographic follow-up at 12 months.

Case 6

A 46-year-old male patient presented with headache. His magnetic resonance images (MRI) and angiography (MRA) revealed a large aneurysm on the BA. On his cerebral angiography, a large saccular aneurysm arising from a BA fenestration was identified (Fig. 3a). It was very difficult to identify the size of the aneurysm neck so that stent-assisted coil embolization was performed for saving at least one of two parent arteries of the fenestration. Using the "Jailing" technique [5, 15], a self-expandable intracranial stent (Neuroform, 3.5 mm×20 mm, Boston Scientific) was deployed on the left limb of the fenestration. Embolization of the aneurysm with coils was then done. The post-

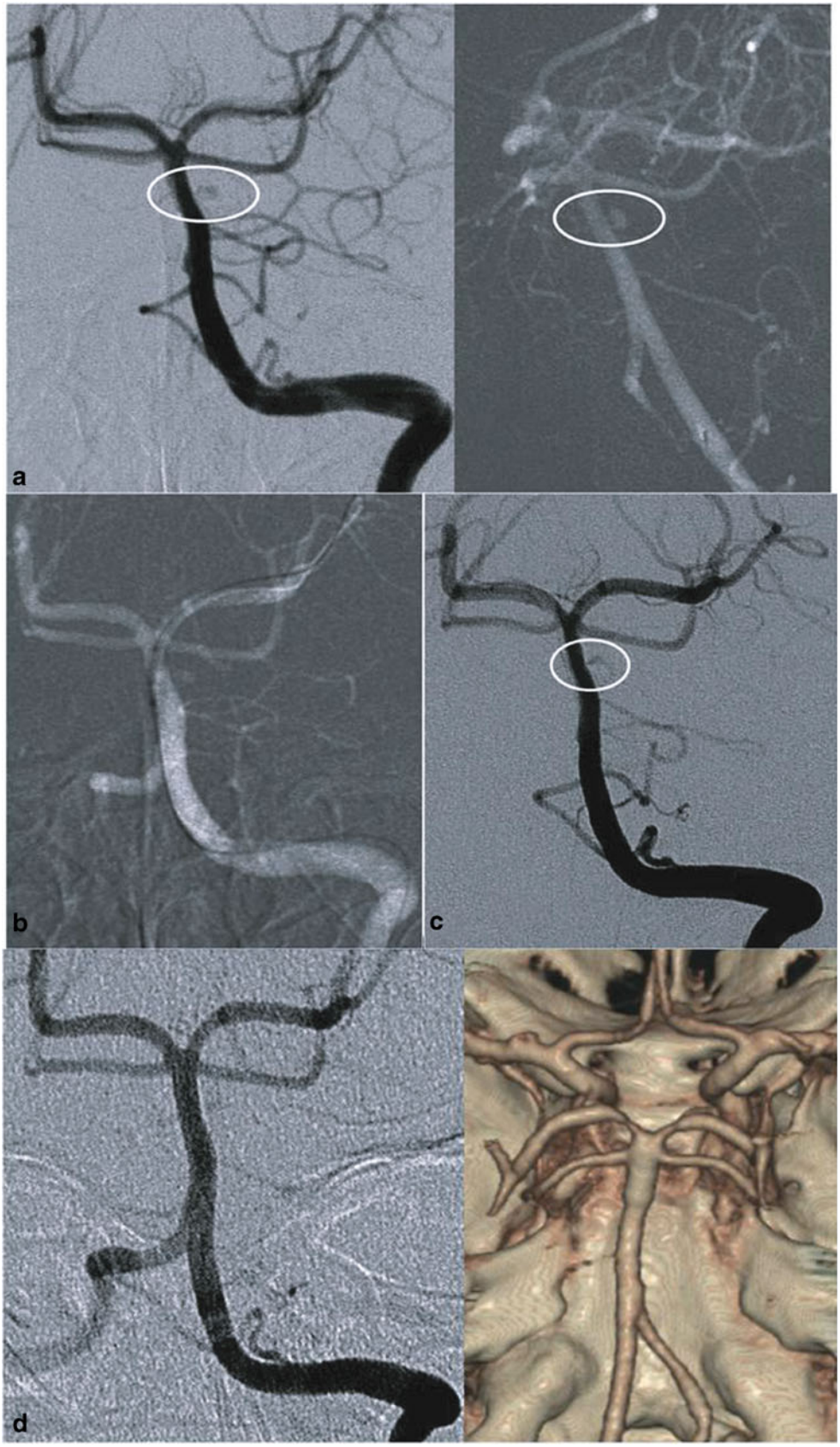

Fig. 1 A 34-year-old male patient presented with subarachnoid hemorrhage (SAH) and initial Hunt-Hess (HH) grade was 4. **a** The ruptured dissecting aneurysm on basilar artery (BA) trunk was found on cerebral angiography. **b** A balloon-mounted coronary stent (3 mm× 16 mm) was deployed between mid-basilar and basilar bifurcation. **c** After stenting, the aneurysm was occluded incompletely. However, no further procedure was performed because the blood flow into the pseudo-sac was decreased. **d** Follow-up angiogram at 24 months showed that the aneurysm was completely occluded

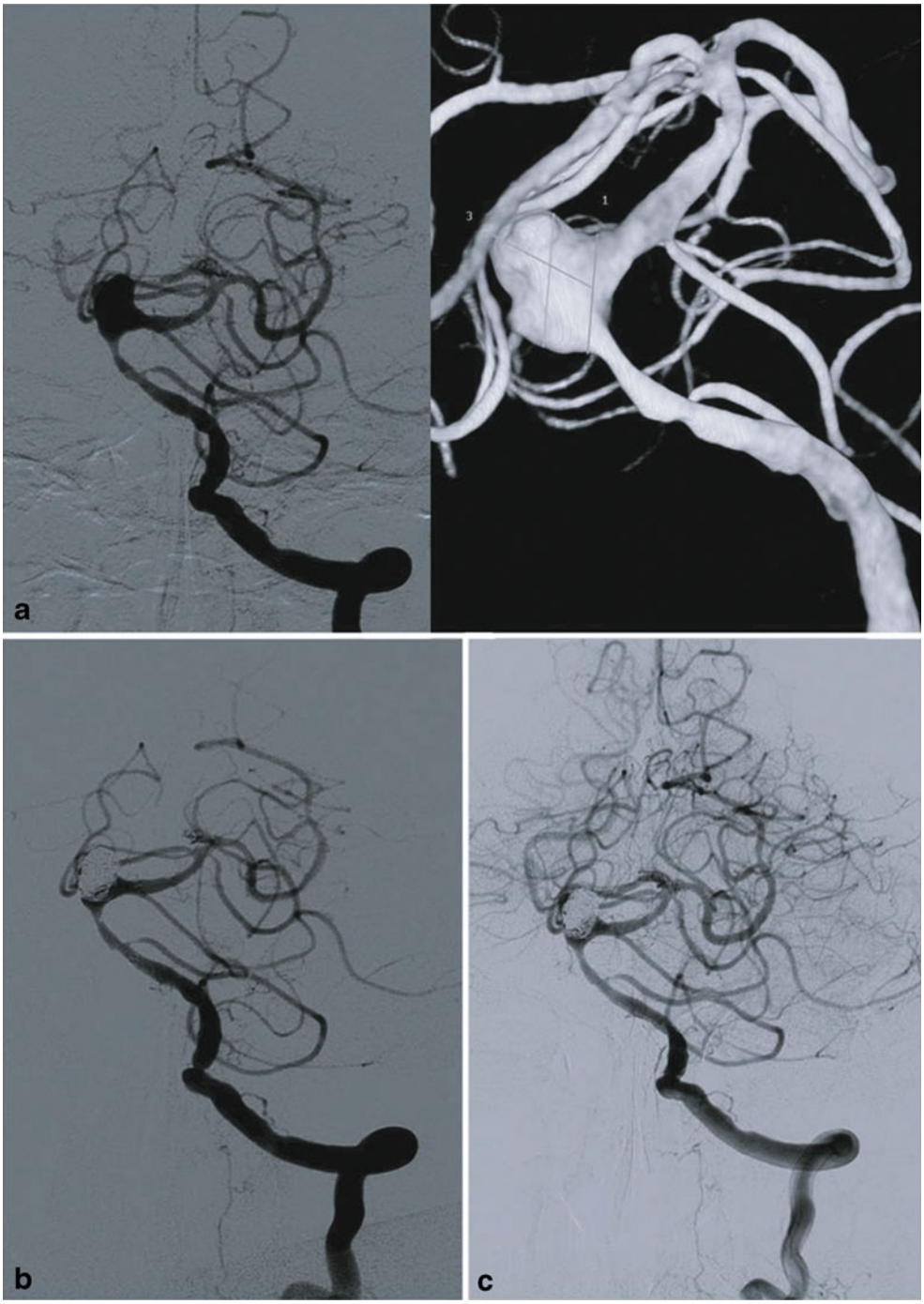

Fig. 2 A 61-year-old male patient presented with subarachnoid hemorrhage (SAH). **a** On his cerebral angiography, a wide-necked lateralized aneurysm on mid-basilar artery was identified. **b** After performing stent-assisted coil embolization, the post-procedural angiography showed a residual neck. **c** The residual neck of the aneurysm was unchanged on angiographic follow-up at 12 months

procedural angiography showed complete occlusion of the aneurysm (Fig. 3b). The aneurysm was maintained completely occluded on angiographic follow-up at 25 months (Fig. 3c). He had excellent (GOS 5) clinical outcome.

Discussion

Posterior circulation aneurysms have a well-known association with high morbidity rates and they often have a fatal outcome [13, 16, 27]. Vertebro-basilar lesions are especially among the most difficult to manage surgically [3, 21]. However, an endovascular approach to this area is comparatively easy, so the first choice of treatment has been changing in the last 10 years [9, 14, 19, 35, 36]. Endovascular navigation through the vertebrobasilar system tends to be simple, and safe catheterization of a BA trunk aneurysm can be performed in most cases [34].

Except for AICA aneurysms, BA trunk aneurysms originated from the branching site are rare. These aneurysms

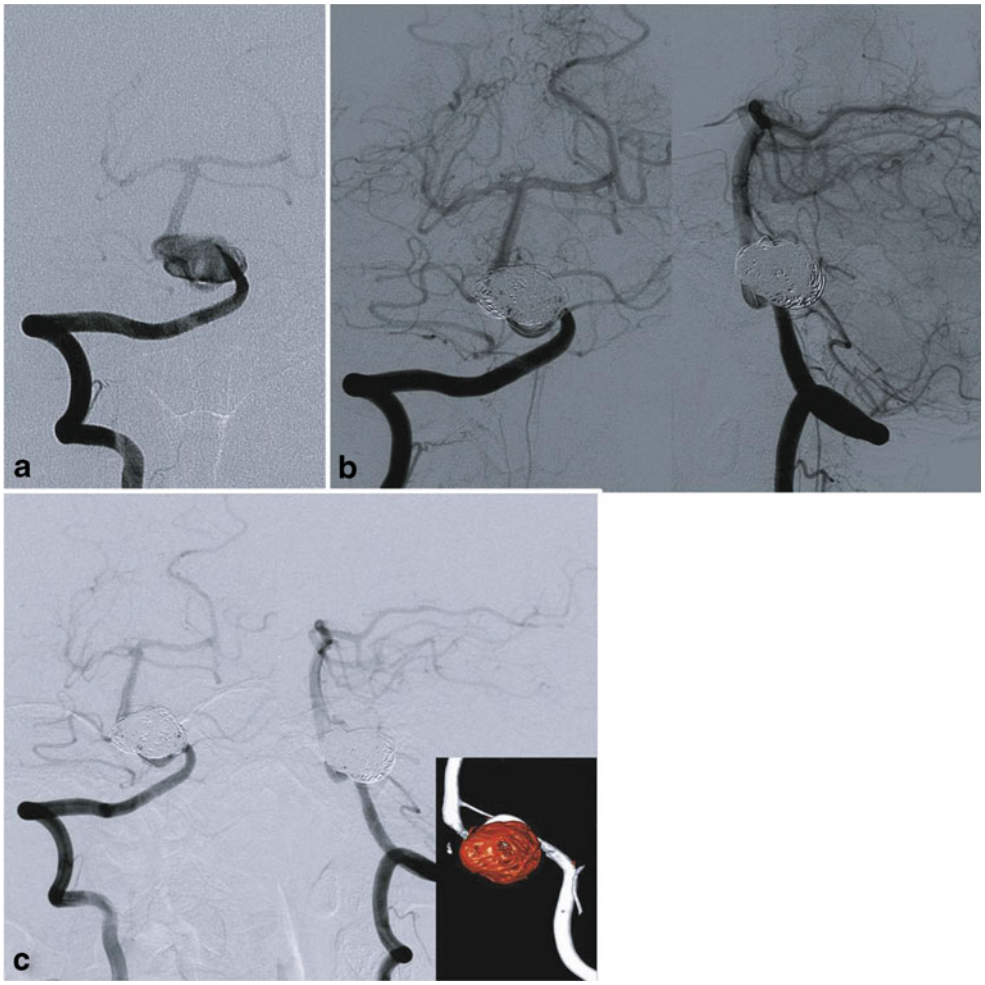

Fig. 3 A 46-year-old male patient presented with headache. **a** On his cerebral angiography, a large saccular aneurysm arising from a basilar artery (BA) fenestration was identified incidentally. **b** After performing stent-assisted coil embolization, the post-procedural angiography showed complete occlusion of the aneurysm. **c** The aneurysm was completely occluded on angiographic follow-up at 25 months

showed characteristic features such as lateral aneurysms, multiple aneurysms, dissecting aneurysms, and various vascular anomalies such as BA fenestration and a persistent primitive hypoglossal artery [14]. In general, most BA trunk aneurysms are lateral wall lesions so that the balloon-assisted procedure or the placement of a stent across the neck of a BA trunk aneurysm may be more controllable than that in terminal aneurysms [34]. In our cases, we experienced three dissecting aneurysms, one giant fusiform aneurysm, one lateral aneurysm, and three aneurysms arising from the BA fenestration.

For the initial angiographic results, there were three complete occlusions (one dissecting aneurysm and two saccular aneurysms arising from the BA fenestration), two neck remnants (one lateralized saccular aneurysm and one saccular aneurysm arising from the BA fenestration), and three incomplete occlusions (one giant fusiform aneurysm and two dissecting aneurysms). For the final angiographic results, complete occlusion was achieved in one giant aneurysm, three dissecting aneurysms, and two saccular aneurysms arising from the BA fenestration. A neck remnant was achieved in one lateralized saccular aneurysm and one saccular aneurysm arising from the BA fenestration. Two of the three patients with incomplete occlusion showed a poor clinical result (GOS 4 or 5) and the other one whose follow-up angiography showed complete occlusion had a good clinical result (GOS 1). The follow-up angiographic results of the patients with initially complete occlusion and neck remnant were well tolerable. Their clinical results were also good (GOS 1 or 2). In our cases, the patients with VBJ aneurysms or lateral aneurysms tended to have good angiographic and clinical results whereas the patients with dissecting aneurysms or fusiform aneurysms had some morbidity and/or mortality.

VBJ aneurysms originate at the union of both VAs. VBJ aneurysms as well as lateral aneurysms are thought to arise from hemodynamic stresses, like other intracranial aneurysms. An aneurysm in this location is filled from both VAs and there is a relatively high incidence of recanalization [34]. In our cases, however, VBJ aneurysms arising from BA fenestrations were well tolerable and have not been changed on 6- to 25-month follow-up angiography. In our opinion, therefore, these lesions could be secured by simple coiling or stent-assisted coiling. During coil embolization of these lesions, it

is mandatory to obtain an angiographic view that demonstrates both limbs of the fenestration to perform a safe delivery of coils [18, 34, 38]. The incidence of an aneurysm being present when a fenestration is noted is reported to be 7% [30]. However, the incidence of fenestration when a VBJ aneurysm is present is reported to be 35.5% [6]. Thus, when a VBJ aneurysm is present, an associated fenestration should be strongly suspected. Three-dimensional digital subtraction angiography may be a useful tool for estimating aneurysm orientation, origin of perforating arteries, and for allowing the reconstruction of vascular images at various angles. There are many articles regarding EVT of aneurysms associated with the fenestration [18, 19, 33, 38]. Most of the cases achieved good clinical and angiographic outcomes.

BA dissecting aneurysms accounted for roughly 1.0% of all cases of SAH, and for no less than 10.5 and 4.5% of posterior circulation and overall cranial vessel dissections [29]. The main clinical presentations are SAH. Prognosis is primarily defined by the initial clinical presentation and is generally favorable in patients with brain ischemia, but is uncertain in SAH. In our case, two of the three patients with dissecting aneurysms presented with SAH and one patient showed poor clinical outcome (GOS 4), because the BA takes a well-protected course adjacent to the clivus and therefore lacks exposure to mechanical strain. In the absence of a plausible trigger, however, it may be assumed that BA dissecting aneurysm are based on a localized vasculopathy. This view is corroborated by the detection of abnormalities in other vascular beds in 41.7% of the patients with BA dissection [29]. Optimal management of these lesions is challenging and treatment decisions have to be made on a case-by-case basis.

Various endovascular strategies have been proposed to treat ruptured vertebra-basilar artery dissecting aneurysms, including proximal parent vessel occlusion, internal coil trapping, stent-assisted coil embolization, stent-only therapy (multiple overlapping stents, double or triple stents), covered stent placement, and a stent-within-a-stent technique [1, 2, 4, 7, 8, 12, 20, 22, 25, 28, 31, 32, 38]. Internal coil trapping of the dissected segment has been considered one of the most reliable methods for preventing rebleeding. However, this procedure cannot be applied to a ruptured vertebro-basilar artery dissecting aneurysm that involves the BA and/or the dominant VA with poor collaterals [32]. In our cases, we experienced that parent artery occlusion was not a good option for treating these lesions because the BA had poor collateral circulations. These poor collateral circulations of BA led to the brain stem infarction and resulted in poor clinical outcomes (cases 1 and 4).

Multiple overlapping stents may be an effective option for these lesions although the use of a single stent may be insufficient to prevent rebleeding. In 2004 and 2005, we could not try double or triple stenting for dissecting aneurysms. At that time, our hospital did not have any kind of self-expandable intracranial stent. Only a single balloon-mounted coronary stent (TAXUS Liberte 3 mm× 16 mm, Boston Scientific) was tried to place the dissected intimal flap to the vessel wall. The results from the experiences of two cases with single stenting in the patients with BA dissecting aneurysms (cases 2 and 3) made us keep using the single stenting for the BA dissecting aneurysm. However, in case 4, the aneurysm rebled after 2 days of the initial treatment. Now, we will not use a single stent for treating the BA dissecting aneurysm. It is thought that stent-assisted coiling, multiple-overlap stenting, and the stent-within-a stent technique are more effective in preventing rebleeding of these lesions.

Giant fusiform aneurysms at the BA trunk tend to have a poor natural history [11, 21], and the surgical management for these aneurysms remains controversial. For these aneurysms, parent artery (BA trunk) occlusion may offer a potentially long-lasting cure [11]. In our case, there was only one patient with a giant fusiform aneurysm. The patient was treated by bilateral VA occlusion rather than BA trunk occlusion. However, parent artery occlusion was not a good option for this patient because the BA had poor collateral circulations. The brain stem infarction with edema resulted in death (case 1). The treatment strategy for these aneurysms is difficult when the collateral supply from the anterior circulation is poor. Various kinds of bypass surgery should be tried for endovascular trapping of giant fusiform BA trunk aneurysms [17]. In our opinion, stent-only therapy is also an attractive reconstructive option. Recently, single stenting (Pipeline stent) may provide a safe and definitive constructive treatment option. This stent represents the first endovascular construct specifically engineered to function as a stand-alone device for the endovascular reconstruction of segmentally diseased parent vessel [10]. It may achieve complete aneurysm occlusion without embolization coils in giant fusiform aneurysms. Mid-term follow-up showed that endovascular reconstruction represents a safe, durable, and curative treatment [9, 23]. This therapy may be worthy of the future-standard treatment option for the BA trunk aneurysm. However, we have no experience with this flow-diverting stent because it is not currently available in our country. As the technique and tools of EVT have been developed, these lesions may be easily treated by EVT and the outcome will be improved.

Conclusions

The endovascular catheterization of these lesions tends to be relatively simple compared to more complex neurosurgical approaches. EVT, especially using a stent, could be a valuable therapeutic method in treating BA trunk aneurysms.

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Conflicts of interest None.

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