Online January 14, 2021
Journal of Neuroendovascular Therapy 2021; 15: 565–573 DOI: 10.5797/jnet.oa.2020-0157

Original Article

Target Embolization of Dilated Post-PICA Segment for Ruptured PICA-Involved Type Vertebral Artery Dissecting Aneurysm

Koichiro Shindo,[1,2] Tatsuya Ogino,[1,2] Hideki Endo,[1,2,3] Mamoru Fukuda,[1] Megumi Matsuda,[1] Daisuke Yamashita,[1] Daishi Yamaguchi,[1] Ryunosuke Yoshihara,[1] Masahiro Morishita,[1] Yasuyuki Tatsuta,[1,2] Suguru Sakurai,[1,2] Masanori Kyono,[1] Daigo Goto,[1] Taku Asanome,[1] Toshiaki Osato,[1] and Hirohiko Nakamura[1]

Objective: In parent artery occlusion (PAO) for ruptured vertebral artery dissecting aneurysms (RVADA), target embolization using coils in a short segment to occlude only the vasodilated area containing the rupture point is selected as a first-choice procedure at our institute. We focused on RVADA involving the posterior inferior cerebellar artery (PICA) and evaluated the treatment results.

Methods: This study consisted of eight cases with RVADA involving the PICA which were treated between October 2007 and January 2020. Based on radiological findings such as the bleb, the rupture points were located at the affected vertebral artery (VA) distal to PICA in all cases. Target embolization, by which only coiling at the dilated segment distal to the VA was performed. We aimed to preserve blood flow to the PICA. The incidence and extent of medullary infarctions, and neurological outcome were retrospectively assessed.

Results: Regarding the diameter of bilateral VA, there were no differences in six cases while the affected VA with RVADA were larger in the remaining two cases. PICA was preserved in all cases but one in which occlusion of complementary PICA was observed. Postoperative medullary infarction was not noted. There was no rebleeding during the follow-up period. However, recanalization of the VA was observed in four cases and additional coil embolization was performed. All patients were discharged with a good outcome (modified Rankin Scale [mRS] 0; seven patients, mRS 2; one patient).

Conclusion: Target embolization preserving the PICA in PICA-involved type RVADA was considered to be an effective treatment method for cases whose rupture point was located in the VA distal to PICA orifice.

Keywords ▶ target embolization, vertebral artery dissecting aneurysm, PICA involved type, subarachnoid hemorrhage

Introduction

In parent artery occlusion (PAO) for ruptured vertebral artery dissecting aneurysms (RVADA), target embolization in which only the site of vasodilation involving the point of rupture is embolized with coils in a short segment is selected as a first-choice procedure at our hospital. In this study, we evaluated the results of treatment for posterior inferior cerebellar artery (PICA)-involved type RVADA.

[1]*Department of Neurosurgery, Nakamura Memorial Hospital, Sapporo, Hokkaido, Japan*
[2]*Center for Endovascular Neurosurgery, Nakamura Memorial Hospital, Sapporo, Hokkaido, Japan*
[3]*Department of Neurosurgery, Nakamura Memorial South Hospital, Sapporo, Hokkaido, Japan*

Received: August 11, 2020; Accepted: November 27, 2020
Corresponding author: Koichiro Shindo. Department of Neurosurgery, Nakamura Memorial Hospital, South 1, West 14, Chuo-ku, Sapporo, Hokkaido 060-8570, Japan
Email: k.shindo04hmrfc@gmail.com

Materials and Methods

Patient background

In all, 26 patients with RVADA were treated at our hospital between October 2007 and January 2020. Of these, PAO was selected for 23, stent-assisted coil embolization for 1, coil embolization with preservation of the vertebral artery (VA) trunk for 1, and direct surgery for 1. Based on the site of VA dissection, RVADA were classified into four types: the pre-PICA type in which the site of dissection is present on a side proximal to the PICA bifurcation, post-PICA type in which the site of dissection is present on a side distal to

the PICA bifurcation, PICA-involved type in which the PICA branches from the site of dissection, and PICA-absent type in which the PICA is absent at the V4 segment. The 26 patients consisted of 1 with a pre-PICA type aneurysm, 11 with post-PICA type aneurysms, 8 with PICA-involved type aneurysms, and 6 with PICA-absent type aneurysms. For all PICA-involved type patients, PAO was selected. In this study, we retrospectively evaluated the radiological findings, results of endovascular treatment, and outcome in the eight PICA-involved type patients who underwent PAO. The outcome was assessed based on the modified Rankin Scale (mRS) score on discharge from our hospital or 3 months after treatment.

Radiographic assessment

Diagnosis of subarachnoid hemorrhage was made using computed tomography (CT). RVADA were diagnosed using cerebral angiography. For angiography, an AXION Artis dBA (Siemens Healthcare, Forchheim, Germany) was used before May 2019 and an Artis Q BA Twin (SIEMENS) was used thereafter. Based on cerebral angiography findings, that is, conventional digital subtraction angiography (DSA) and three-dimensional (3D) rotational angiography, the shape/extent of dissection and its anatomical positional relationship with the PICA or anterior spinal artery (ASA) were evaluated.

The presence of brainstem infarction was confirmed using the diffusion-weighted image (DWI) and T2-weighted image (T2WI) obtained by 1.5-T or 3-T magnetic resonance imaging (MRI) within 48 hours after PAO. Short TE magnetic resonance angiography (MRA) was performed to obtain vascular information after PAO. In addition, at our hospital, MRI/MRA are routinely performed at least twice, at 7 and 14 days after the procedure to confirm the presence of cerebral vasospasm. Regarding MRA findings within 48 hours after PAO as a control, the presence of recanalization was evaluated on MRA after the procedure.

Treatment

To prevent rerupture, endovascular treatment was performed under general anesthesia within 24 hours after arrival.

For endovascular treatment, only the site of vasodilation involving the point of rupture was embolized with coils in a short segment, as described above. In general, a PICA-preserved procedure was adopted. Based on bleb formation at the site of VA dilatation on cerebral angiography, the point of rupture was considered to be present at the post-PICA segment of the VA in all patients. Only the area distal to the PICA bifurcation was occluded to preserve anterograde blood flow from the VA to the PICA.

A 6Fr 25cm sheath was inserted into the right femoral artery, and a 4Fr 25cm sheath was inserted into the left femoral artery or right radial artery. A 6Fr 95cm guiding catheter was guided into the affected-side VA through the 6Fr 25cm sheath. A 4Fr catheter for diagnostic angiography was inserted into the contralateral VA through the 4Fr 25cm sheath. After guiding the guiding catheter, systemic heparinization was conducted.

As a rule, short segment- and tight packing-targeted PAO was performed using the double catheter method. For framing, a coil larger than the short diameter of the dilated site was selected. After frame formation, embolization with soft coils was performed. Regarding the "pearl and string" shape, the site of dilatation (pearl area) involving bleb formation suggesting the point of rupture was primarily embolized. Meanwhile as to the fusiform shape, only the post-PICA segment of the dilated site was embolized to preserve the PICA (**Fig. 1**).

When angiography through the 4Fr catheter for diagnostic angiography confirmed reflux to the affected-side VA distal to the site of occlusion, we considered PAO to be accomplished and angiography through the affected-side guiding catheter was conducted. When blood flow to the post-PICA segment was absent, we considered complete occlusion to be achieved. Anterograde blood flow to the PICA was confirmed and the procedure was completed. In general, systemic heparin was naturally reversed. However, it was reversed using protamine sulfate when conducting invasive procedures, such as ventricular drainage, immediately after the procedure. After the procedure, the oral administration of cilostazol at 200 mg/day or aspirin at 100 mg/day was started.

Results

Background characteristics of the patients are shown in **Table 1**. The subjects consisted of four males (50%) and four females (50%), with a mean age of 53.6 ± 4.2 years (range: 46–60 years). The condition on admission was assessed using the Hunt and Kosnik grade. The grade was evaluated as III in four patients (50%), IV in one (12.5%), and V in three (37.5%). Before PAO, the degree of VA development was also examined to find that no patient exhibited hypoplasia of the contralateral VA. The shape of dissection was evaluated as "pearl and string" in six patients and fusiform in two patients.

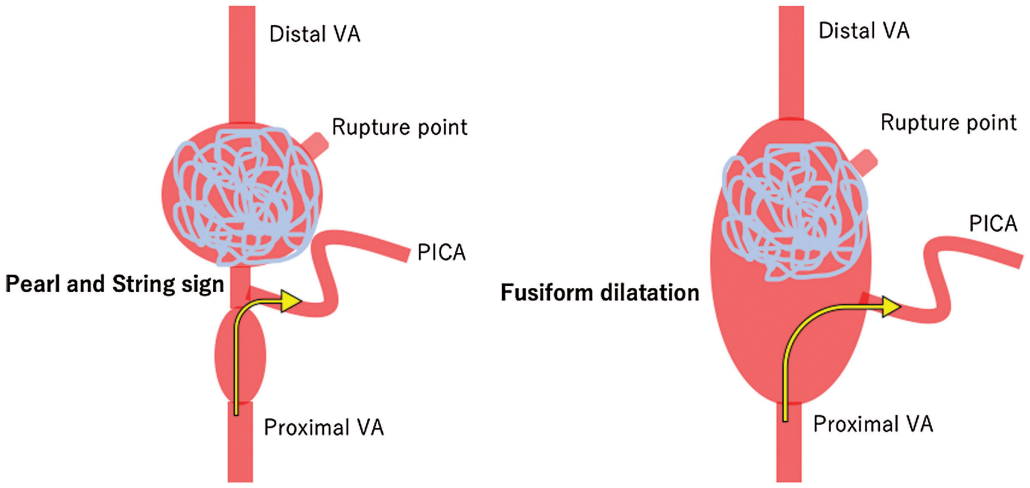

Fig. 1 Schema of the treatment strategy. Target embolization of the VA dilated area involving the point of rupture is performed to prevent rebleeding. If the point of rupture is in the VA distal to the PICA, target embolization is performed only on the dilated post-PICA segment. Blood flow to the PICA should be preserved to prevent medullary infarction. PICA: posterior inferior cerebellar artery; VA: vertebral artery

Before the procedure, rerupture occurred in two patients (25%); it occurred during transportation in one and during examination in one patient.

PAO was performed using a single catheter in two patients (25%) and double catheters in six (75%) patients. The entire mean length of a coil mass at a working angle was 9.1±2.5 mm. Bare platinum coil was used in seven patients (87.5%) and hydrogel coil was used in one (12.5%) patient. PAO was accomplished in all patients and there was no intraoperative rerupture. In one patient, diffuse asymptomatic infarction involving the anterior inferior cerebellar artery (AICA) region was observed. In one patient, subfalcine herniation-related cerebral infarction involving the bilateral anterior cerebral artery regions was noted. In patients in whom the PICA trunk branched from the extracranial area, the complementary PICA was occluded, but the PICA was able to be preserved in seven patients. There was no postoperative brainstem infarction in any patient (0%). Furthermore, there was no postoperative rerupture. However, recanalization of the embolized VA was observed in four patients (50%). Cerebral angiography demonstrated that the recanalized VA which were flattened but retaining blood flow through a cavity retaining a tubular structure, suggesting true-lumen recanalization. Even at the time of confirming recanalization, blebs were considered to be occluded, but additional embolization was scheduled after confirming recanalization, targeting complete occlusion. Under general anesthesia, embolization was performed by guiding a microcatheter to the site of recanalization, additionally placing a coil, and subsequently conducting coiling at an area just distal to the PICA bifurcation. Recanalization was confirmed 8–14 days after initial procedure. There was no recanalization after additional treatment in any patient. All patients were discharged with a favorable outcome (mRS score 0: 7 patients, 2: 1 patient).

Representative cases

Case 1 (**Fig. 2**). A 59-year-old woman. Occipital pain suddenly developed and she consulted a local clinic after 2 days. During consultation, loss of consciousness was noted. CT revealed subarachnoid hemorrhage and she was referred to our hospital. On arrival, the Glasgow Coma Scale (GCS) score was 6 (E1V1M4). The Hunt and Kosnik grade was evaluated as V. Cerebral angiography revealed a fusiform dissecting aneurysm of the right VA. Based on bleb formation, we considered the point of rupture to be present at the post-PICA segment of the VA. Under general anesthesia, target embolization of the post-PICA segment involving the point of VA rupture was performed. Subsequently, right ventricular drainage was conducted to control acute obstructive hydrocephalus. Postoperative MRI did not reveal brainstem infarction. After 1 month, ventriculoperitoneal shunting for secondary hydrocephalus was performed. The patient was discharged through recovery rehabilitation with a mRS score of 0.

Case 2 (**Fig. 3**). A 53-year-old patient. Right occipital pain and nausea developed. Headache was noted the following morning. The patient was transported to a local

Table 1 Summary of patient characteristics

Case number	Age (years)/ Sex	H&K grade	Dissecting side	Re-rupture before operation	Aneurysm shape	Number of microcatheter	PICA patency	Coil	coil mass size(mm)	Re-rupture after operation	Brain stem infarction	Discovery of recurrence	mRS at discharge
1	46M	5	R	–	P&S	1	+	Bare	8.5	–	–	Day 9	0
2	53M	3	R	–	P&S	2	+	Bare	6.7	–	–	Day 10	0
3	59F	5	R	+	Fusiform	2	+	Bare	8.5	–	–	–	0
4	54F	4	L	–	P&S	1	+	Bare	5.4	–	–	Day 8	2
5	53M	3	L	–	P&S	2	+	Bare	8.3	–	–	–	0
6	51M	5	R	+	P&S	2	+	Bare	11	–	–	–	0
7	53F	3	L	–	fusiform	2	co-PICA-occlusion	Bare	14.2	–	–	–	0
8	60F	3	Bil (L:rupture, R:non-rupture)	–	L:P&S, R:P&S	2	+	Hydro	9.9	–	–	Day 14	0

Bare: bare platinum coil; Bil: bilateral; co-PICA: complementary posterior inferior cerebellar artery; H&K: Hunt and Kosnik; Hydro: hydrogel-coated coil; L: left; mRS: modified Rankin Scale; PICA: posterior inferior cerebellar artery; P&S: pearl and string sign; R: right; VA: vertebral artery

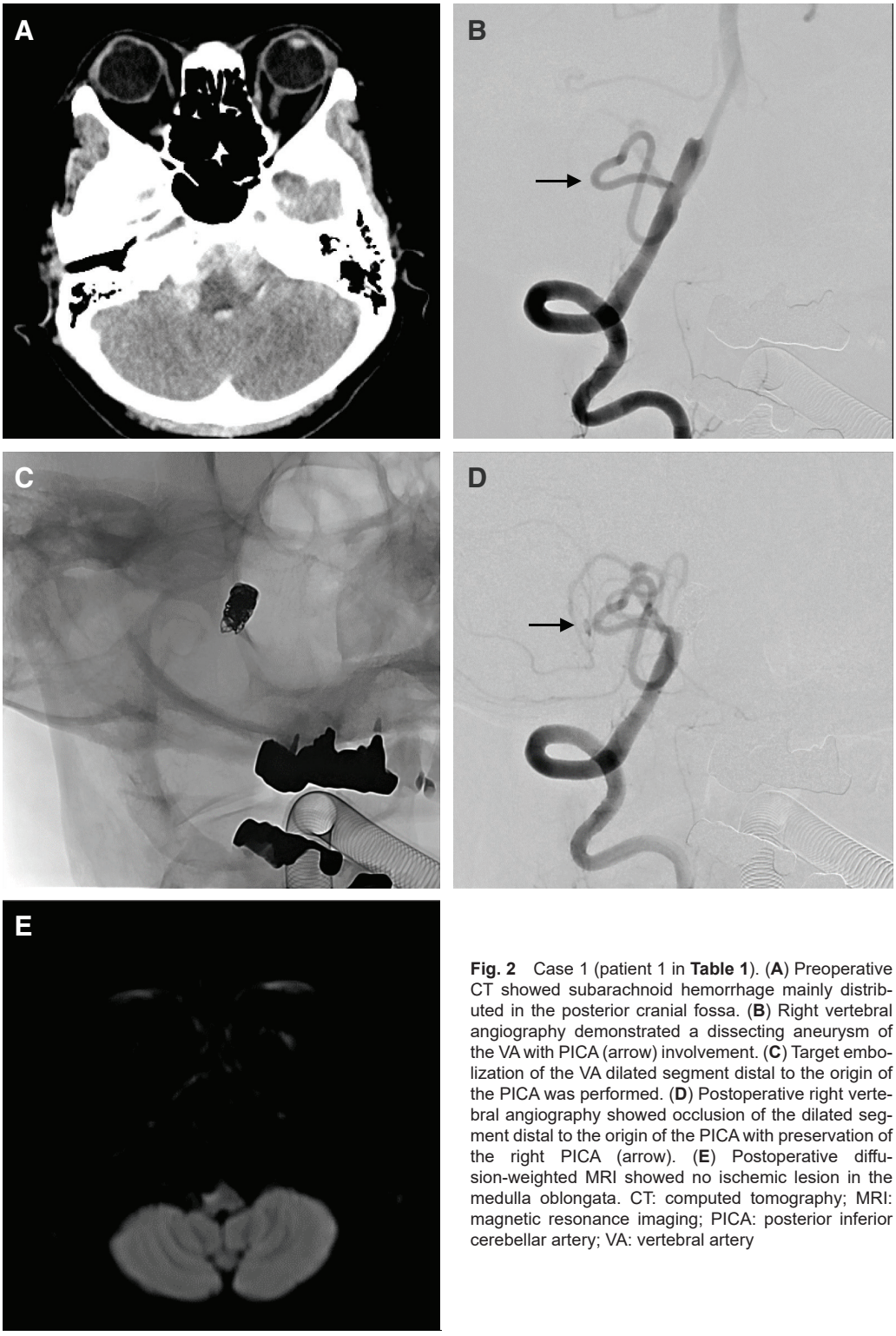

Fig. 2 Case 1 (patient 1 in **Table 1**). (**A**) Preoperative CT showed subarachnoid hemorrhage mainly distributed in the posterior cranial fossa. (**B**) Right vertebral angiography demonstrated a dissecting aneurysm of the VA with PICA (arrow) involvement. (**C**) Target embolization of the VA dilated segment distal to the origin of the PICA was performed. (**D**) Postoperative right vertebral angiography showed occlusion of the dilated segment distal to the origin of the PICA with preservation of the right PICA (arrow). (**E**) Postoperative diffusion-weighted MRI showed no ischemic lesion in the medulla oblongata. CT: computed tomography; MRI: magnetic resonance imaging; PICA: posterior inferior cerebellar artery; VA: vertebral artery

hospital by ambulance. CT revealed subarachnoid hemorrhage and the patient was referred to our hospital. On arrival, the GCS score was 14 (E4V4M6). The Hunt and Kosnik grade was evaluated as III. Cerebral angiography demonstrated a "pearl and string" sign of the right VA, leading to a diagnosis of RVADA. Under general anesthesia, target embolization of the pearl-like dilated area of the post-PICA segment with bleb formation was performed. For hydrocephalus control, a lumbar drain was inserted. After 10 days, MRA revealed a change in the vascular

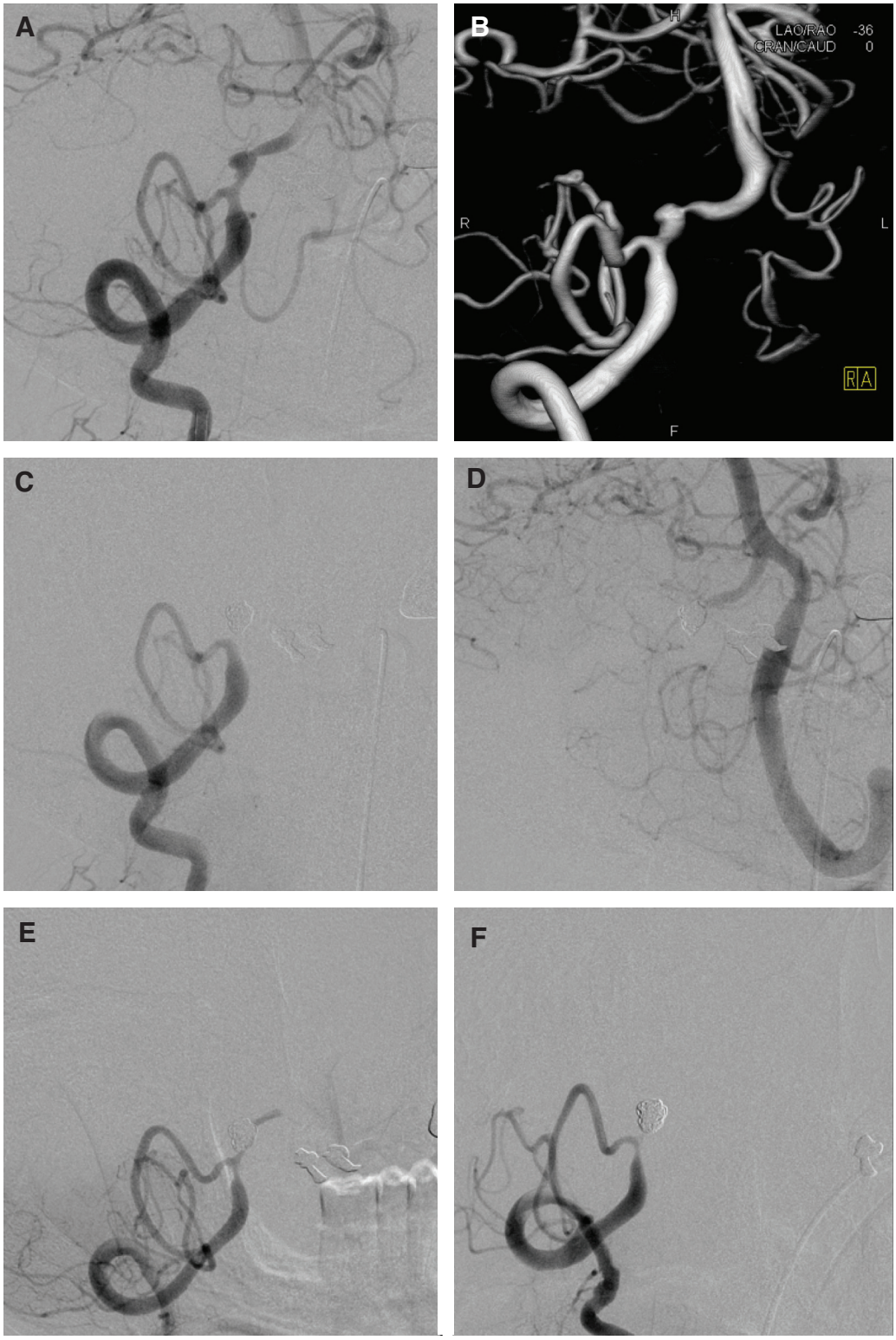

Fig. 3 Case 2 (patient 2 in **Table 1**) (**A**) Right vertebral angiography demonstrated a V4 dissecting aneurysm involving the PICA with pearl-and-string sign. (**B**) Three-dimensional reconstruction digital subtraction angiography before surgery. (**C**) Target embolization of the distal VA dilated segment (pearl part) was performed. Postoperative right vertebral angiography showed occlusion of the distal VA dilated segment. (**D**) Postoperative left vertebral angiography showed retrograde blood flow in the post-PICA segment of the VA. (**E**) Ten days after the first operation, recanalization of the distal VA was confirmed. (**F**) Coil embolization was immediately performed again using the same procedure as in the first endovascular surgery. PICA: posterior inferior cerebellar artery; VA: vertebral artery

shape proximal to a coil mass and recanalization of the right VA. Cerebral angiography suggested true lumen recanalization with bleb occlusion. Subsequently, additional embolization was conducted under general anesthesia. During the postoperative course, there was no recanalization or rerupture. The patient was discharged with an mRS score of 0.

Discussion

RVADA treatment is selected by comprehensively evaluating several factors such as the dominancy of the VA, positional relationship with the PICA or ASA, and shape of dissection. Recently, surgical strategies by endovascular treatment may be increasingly adopted rather than direct surgery.[1] As endovascular treatment procedures, internal trapping in which a parent artery involving the site of dissection is occluded, proximal occlusion in which a parent artery proximal to the site of dissection is occluded, followed by flow alteration to the site of dissection, stent-assisted coil embolization, and reconstructive treatment in which VA blood flow is preserved by inserting a flow diverter are selected. The preventive effects of internal trapping involving the PICA bifurcation on rupture are the most marked, but the risk of incident perforator infarction is high.[2] Concerning proximal occlusion, the risk of incident perforator infarction is low, but blood flow to the site of dissection remains; therefore, rerupture may occur.[3] Radical treatment after the balloon occlusion test (BOT) in the chronic stage is recommended.[4] Regarding a reconstructive method to preserve a parent artery, the recurrence rate is high after stent-assisted coil embolization,[5] but the results of flow-diverter insertion are relatively favorable. However, the number of patients is limited and the incidence of hemorrhagic/thrombotic complications remains to be clarified.[6] Thus, the respective procedures have merits and demerits.

Endo et al. reported that lateral medullary syndrome was a prognostic factor after internal trapping and that its risk was high when the extent of embolization was ≥15 mm.[7] A perforator to the lateral medullary region, as an etiological factor for lateral medullary syndrome, branches from the VA in 31% of patients, the PICA in 22%, the AICA in 20%, basilar artery in 16%, and these four arteries in 11%.[8] A previous study found that the mean distance from the union to the bifurcation was 7.8 mm (0–20 mm) when a perforator branched from the right VA and 7.0 mm (1–22 mm) when a perforator branched from the left VA.[9] Therefore, when performing embolization of the post-PICA segment of the VA, short-segment embolization may also be significant for the prevention of medullary infarction. Tashiro et al.[10] reported that short-segment tight packing of a dilated area prevented rerupture.[10] At our hospital, a similar method was also adopted and its preventive effects on rerupture are expected.

At our hospital, imaging of the bilateral internal carotid arteries and contralateral VA in addition to the affected-side VA is performed to evaluate whether PAO of the affected VA is possible on preoperative cerebral angiography. In addition, the degree of posterior communicating artery and contralateral VA development is always confirmed. There is no criterion to evaluate whether PAO of the dominant VA is possible, but one study reported that PAO was possible regardless of the vascular diameter when the non-dominant-side VA was connected with the union.[11] At our hospital, PAO is performed without conducting the (BOT) when the contralateral VA does not suggest a trace. When the contralateral VA is not connected with the union, the BOT should be conducted and reconstructive treatment or bypass-combined treatment must be considered.

Treatment using the double catheter method is adopted as a basic strategy at our hospital. When performing short segment, PAO, "pearl and string"-shaped aneurysms can be relatively readily occluded. However, fusiform aneurysms are sometimes difficult to occlude. After making a coil cage, filling with smaller coils with gradual downsizing was performed. However, when the coil gap is marked, tight packing of the distal part with coils with 1–2 mm diameter through the distal-most microcatheter in the mid-phase of embolization may be effective. As such, a strategy facilitates accurate bleb occlusion, the expanded area of the post-PICA segment was initially embolized, followed by embolization of the distal PICA. In all eight patients, target embolization of the VA was achieved with bleb occlusion. When inserting microcatheters to a dilated area, one microcatheter should be guided into the true lumen and the other should be guided into the pseudolumen involving the point of rupture. However, it is not always possible to distinguish the true lumen or pseudolumen on angiography. Patients in whom embolization of the true lumen or pseudolumen led to recanalization have been reported.[12,13] Embolization for longer segment may reduce the incidence of recanalization; recanalization must be considered for short segment embolization with preservation of the PICA. Occlusion of a distal normal blood vessel may reduce the risk of recanalization, but we did not perform such

embolization to avoid the risk of perforator infarction rather than the risk of recanalization. Assuming cases in which occlusion is not achieved, whether it is possible to secure a contralateral VA- or posterior communicating artery-mediated access route for reaching a distal normal blood vessel must be evaluated before surgery. In this study, recanalization was sometimes observed, but follow-up should be conducted considering the risk of recanalization. If recanalization is noted, it may be managed in the absence of rerupture by promptly performing additional embolization.

In the eight patients, the point of rupture was possibly present at the post-PICA segment of the VA. The dilated area of the post-PICA segment was embolized with coils to preserve anterograde blood flow from the pre-PICA segment to the PICA. In this treatment method, an entry to the site of dissection remained, differing from internal trapping or proximal occlusion. The preservation of anterograde blood flow from the pre-PICA segment of the VA to the PICA may enlarge the dissected cavity, but affected-side vertebral arteriography at completion of the procedure confirmed the reduction of the pre-PICA segment blood flow in all patients. This may be associated with the effects of distal flow reduction related to a flow outlet switch to the PICA, which has a smaller diameter than the VA, through the isolation of a distal blood vessel.[14] Distal flow reduction may reduce the remaining dissected vascular wall blood pressure and change the direction of blood flow, reducing the load on the entry zone of the dissected cavity. Mizutani et al.[15] examined serial changes in the pathology of an aneurysm after onset and reported that intima-related spontaneous repair began 1 week after onset, followed by circumferential involvement. Furthermore, the incidence of rebleeding 1 month after subarachnoid hemorrhage was ≤10% and the longest interval from subarachnoid hemorrhage until rebleeding was 41 days.[16] Concerning treatment methods at our hospital, the point of rupture is embolized in the acute phase, but a spontaneous cure-dependent strategy is adopted for the remaining site of dissection; therefore, careful postoperative follow-up should be continued for at least 2 months.

Conclusion

We reported the results of target embolization of a dilated area involving the point of rupture while preserving the PICA in patients with PICA-involved type RVADA. Recanalization of the VA is sometimes observed in the subacute phase and careful follow-up is necessary. However, this procedure may reduce the risk of incident brainstem perforator infarction and may be an option of acute-phase treatment for PICA-involved type RVADA.

Disclosure Statement

The author completed self-reporting of conflicts of interest to the Japanese Society for Neuroendovascular Therapy. The authors declare no conflicts of interest.

References

1) Nakamura H, Fujinaka T, Nishida T, et al: Endovascular therapy for ruptured vertebral artery dissecting aneurysms: results from nationwide, retrospective, multi-center registries in Japan (JR-NET3). *Neurol Med Chir (Tokyo)* 2019; 59: 10–18.
2) Satow T, Iihara K, Sakai N, et al: Endovascular treatment for ruptured vertebral artery dissecting aneurysms: results from Japanese registry of neuroendovascular therapy (JR-NET) 1 and 2. *Neurol Med Chir (Tokyo)* 2014; 54 Suppl 2: 98–106.
3) Kim BM, Shin YS, Kim SH, et al: Incidence and risk factors of recurrence after endovascular treatment of intracranial vertebrobasilar dissecting aneurysms. *Stroke* 2011; 42: 2425–2430.
4) Iihara K, Sakai N, Murao K, et al: Dissecting aneurysms of the vertebral artery: a management strategy. *J Neurosurg* 2002; 97: 259–267.
5) Cho DY, Choi JH, Kim BS, et al: Comparison of clinical and radiologic outcomes of diverse endovascular treatments in vertebral artery dissecting aneurysm involving the origin of PICA. *World Neurosurg* 2019; 121: e22–e31.
6) Maus V, Mpotsaris A, Dorn F, et al: The use of flow diverter in ruptured, dissecting intracranial aneurysms of the posterior circulation. *World Neurosurg* 2018; 111: e424–e433.
7) Endo H, Matsumoto Y, Kondo R, et al: Medullary infarction as a poor prognostic factor after internal coil trapping of a ruptured vertebral artery dissection. *J Neurosurg* 2013; 118: 131–139.
8) Krayenbühl H, Yasargil MG: The vascular diseases in the area of the vertebral artery and basilar artery: an anatomical and pathological. *Clin Neuroradiol Study* Thieme, Stuttgart, 1957.
9) Akar ZC, Dujovny M, Gómez-Tortosa E, et al: Microvascular anatomy of the anterior surface of the medulla oblongata and olive. *J Neurosurg* 1995; 82: 97–105.
10) Tashiro R, Yoshida M: Targeted internal trapping to dilated portion for ruptured vertebral artery dissection. *JNET J Neuroendovasc Ther* 2019; 13: 155–160.

11) Zoarski GH, Seth R: Safety of unilateral endovascular occlusion of the cervical segment of the vertebral artery without antecedent balloon test occlusion. *AJNR Am J Neuroradiol* 2014; 35: 856–861
12) Yon KI, Jae HS, Je HB: Antegrade recanalization of parent artery after internal trapping of ruptured vertebral artery dissecting aneurysm. *J Korean Neurosurg Soc* 2012; 51: 301–304.
13) Tanabe J, Moroi J, Yoshioka S, et al: Recanalization of a ruptured vertebral artery dissecting aneurysm after occlusion of the dilated segment only. *Surg Neurol Int* 2014; 5: 150.
14) Kikuchi T, Miyamoto S, Takahashi JC, et al: Flow reduction treatment for complex giant cerebral aneurysm: concept and problems to be solved. *Jpn J Neurosurg (Tokyo)* 2013; 22: 742–748. (in Japanese)
15) Mizutani T, Kojima H, Asamoto S: Healing process for cerebral dissecting aneurysms presenting with subarachnoid hemorrhage. *Neurosurgery* 2004; 54: 342–347.
16) Mizutani T, Aruga T, Kirino T, et al: Recurrent subarachnoid hemorrhage from untreated ruptured vertebrobasilar dissecting aneurysms. *Neurosurgery* 1995; 36: 905–911; discussion 912–913.