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Original Article

Treatment Outcomes of Stent-Assisted Coil Embolization for Ruptured Vertebral Artery Dissecting Aneurysms: The Preservation of Branches May Improve the Prognosis

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Objective: Subarachnoid hemorrhage due to ruptured vertebral artery dissecting aneurysm (rVADA) is associated with a high frequency of acute rebleeding and requires early treatment following onset. Parent artery occlusion (PAO) or stent-assisted coiling (SAC) embolization is selected as a treatment option according to the individual patient condition. This report is a retrospective examination evaluating the treatment outcomes for rVADA.

Methods: The subjects were 20 rVADA patients (16 men and 4 women) who underwent endovascular treatment at our institution. The mean patient age was 52.9 years. Ten patients each were allocated to the PAO group and SAC group. We evaluated and compared the following parameters: presence of hemorrhagic complications, presence of ischemic complications, requirement of retreatment, and Glasgow Outcome Scale (GOS) after 90 days.

Results: The reasons for selecting SAC were contralateral occlusion or a small diameter in three patients, the posterior inferior cerebellar artery (PICA) involvement in three patients, perforating artery from dissected lesion in five patients, and anterior spinal artery in one patient. There was no rebleeding in any patient. Symptomatic ischemic complications were observed in four patients in the PAO group and in one in the SAC group. Hyper-intense lesions in the brainstem on MRI DWI were noted in five patients in PAO group and in one in the SAC group. Retreatment was required for three patients in the PAO group and for four in the SAC group. Favorable outcomes (GOS 4, 5) after 90 days were observed for three patients in the PAO group and for eight patients in the SAC group ($p = 0.0257$).

Conclusion: SAC that can preserve branches is a useful treatment option for rVADA. Further studies on a greater number of subjects are required to establish the optimal dose of antiplatelet agents and anticoagulants, and for stent selection.

Keywords ▶ ruptured vertebral artery dissecting aneurysm, endovascular treatment, stent-assisted coil embolization, treatment results, preservation of branches

Introduction

Ruptured vertebral artery dissecting aneurysm (rVADA) causes subarachnoid hemorrhage. The re-rupture rate in the acute phase is high, and the prognosis of patients with rebleeding is poor. To prevent rebleeding, early treatment should be performed.[1–3] Parent artery occlusion (PAO) by endovascular treatment facilitates the initiation of treatment following diagnosis. This procedure was established to prevent rebleeding.[4,5] On the other hand, lesion-site occlusion may induce ischemia involving the basilar artery region in patients with bilateral dissecting lesions or contralateral vertebral artery (VA) occlusion. When the posterior inferior cerebellar artery (PICA) branches from the site of dissection, PAO may induce ischemia involving this region. Several studies reported the usefulness of stent-assisted coiling (SAC) or reconstructive techniques for maintaining affected-side VA and PICA blood flow.[6,7] Microanatomical findings revealed that the perforating arteries to the medulla oblongata branched from the VA. Furthermore, recent advances in cerebral angiography have facilitated the visualization of

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the perforating arteries.[8] However, PAO may induce sequelae that reduce the functional prognosis, such as Wallenberg syndrome, through occlusion of the brainstem perforator region.[9,10] To prevent brainstem infarction and improve the functional prognosis, SAC in which both the PICAs and the perforating arteries are preserved may be useful. Few studies have reported the results of treatment, focusing on the preservation of the perforating arteries, for intracranial rVADA. At our hospital, PAO and SAC are selected to treat rVADA through detailed investigation of individual patients. In this study, we retrospectively examined the results of treatment for rVADA in the PAO and SAC groups.

Materials and Methods

Patient background

The subjects were 20 patients with subarachnoid hemorrhage related to rVADA who had undergone endovascular treatment at our hospital between 2009 and 2019. We retrospectively examined medical records and radiological findings. Patients in whom computed tomography (CT) led to a diagnosis of subarachnoid hemorrhage, and cerebral angiography demonstrated fusiform dilatation or a pearl and string sign of the intracranial VA were regarded as having rVADA. We excluded patients with the basilar artery lesions, the PICA-localized lesions, or traumatic lesions, as well as those treated by conservative treatment or craniotomy.

Prior to all treatments, informed consent was received. The protocol of this study was approved by the clinical research ethics review board of our hospital. This study was conducted according to the Helsinki Declaration in 1964 and ethical standards established through revisions thereafter. The opt-out was published on the homepage of our hospital.

Therapeutic strategies

After a diagnosis of subarachnoid hemorrhage was made, sedation and intubation for respiratory care with ventilator, if necessary, were performed. Antihypertensive drug was administered to maintain the systolic blood pressure ≤140 mmHg. Four-vessel digital subtraction angiography (DSA) and three-dimensional (3D) rotational angiography (3D RA) were performed to evaluate the site, shape, aneurysmal diameter, normal blood vessel diameter, and branches from the periphery of the lesion. The presence of the contralateral VA and posterior communicating arteries and their diameters were investigated to assess a collateral pathway. If possible, cone-beam CT was performed in addition to 3D RA to examine the presence of the perforating arteries. After diagnostic cerebral angiography, treatment was performed under general anesthesia.

PAO

After 5 or 7 Fr sheath was inserted into the bilateral femoral arteries, a 5 or 7 Fr guiding catheter was guided into the VA. A microcatheter was guided to the lesion site through a preceding guidewire, and embolization using the detachable platinum coils was performed. The coils were placed in the site of dilation to occlude the site for a short segment.

SAC

SAC was selected for lesions without a collateral pathway to the basilar artery region such as contralateral VA occlusion/stenosis and hypoplasia, lesions involving the PICA, and lesions from which the perforating arteries were present. Two antiplatelet drugs were administered through a nasogastric tube ≥30 minutes before stenting. Heparin was administered after stenting. A stent was inserted using the trans-cell or jailing/half-jailing techniques on an individual-patient basis, and the site of dilatation was embolized with coils.

Postoperative clinical/radiological examination

After treatment, CT, MRI, and angiography were performed for evaluation. In the SAC group, general anesthesia was continued for additional angiography the following day to confirm the presence of additional enlargement. The clinical course was evaluated based on the presence of postoperative hemorrhagic/ischemic complications, MRI-diffusion-weighted imaging (DWI) findings, and Glasgow Outcome Scale (GOS) score 90 days after surgery.

Statistical analysis

The following items were compared between the SAC and PAO groups: age, sex, Hunt & Kosnik (H & K) classification before surgery, preoperative hemorrhage, lesion side, lesion site, presence of arteries originated from VA involving the PICA, symptomatic ischemic complications, high-signal-intensity lesions on postoperative MRI-DWI, hemorrhagic complications including rebleeding, and GOS score after 90 days. Latent risk factors were identified using the Mann–Whitney U test for quantity scales and Fisher's exact test for category scales. A p value of 0.05 was regarded as significant. For statistical analysis, we used JMP pro 12 software.

Table 1 Demographic data and clinical characteristics of patients

Variable	SAC group	PAO group	p value
No. of cases	10	10	
Mean age	54.0	51.7	0.5930
Male	7 (70%)	9 (90%)	0.2636
Severe SAH (HK 4, 5)	4 (40%)	6 (60%)	0.3711
Preoperative rebleeding	4 (40%)	4 (40%)	1.0000
Time from arrival to treatment	55.2	31.2	0.0299
<24 Hr	3 (30%)	8 (80%)	
24–48 Hr	3 (30%)	1 (10%)	
>48 Hr	4 (40%)	1 (10%)	
Right side	7 (70%)	2 (20%)	0.0205
Location			
PICA distal	5 (50%)	5 (50%)	
(extracranial PICA)	-4	0	
PICA involved	3 (30%)	1 (10%)	
PICA proximal	0	2 (20%)	
No PICA (AICA-PICA)	2 (20%)	2 (20%)	
Perforator	9 (90%)	5 (50%)	0.0510
Contralateral VA occlusion/stenosis	3 (30%)	1 (10%)	0.3558

AICA: anterior inferior cerebellar artery; PAO: parent artery occlusion; PICA: posterior inferior cerebellar artery; SAC: stent-assisted coiling; VA: vertebral artery

Results

Statistical data and clinical characteristics

A total of 20 patients with ruptured dissecting vertebral artery aneurysms were treated, with a mean age of 52.9 years (range: 38–76 years). They consisted of 16 males and 4 females. Preoperative hemorrhage was observed in eight patients: before transportation by ambulance in five, in ambulance in two, and in the primary care room in one patient. There was no rebleeding after admission. The preoperative H & K grade was evaluated as I in two patients, II in six, III in three, IV in seven, and V in two patients; severe-status patients accounted for 45%. There were no differences in the age, sex, severity (H & K grade: IV, V), or incidence of preoperative hemorrhage between the SAC and PAO groups (**Table 1**).

Angiography findings

All patients had unilateral lesions. Nine patients (45.0%) had right lesions. Lesions were present at an area proximal to the bifurcation of the PICA (PICA proximal type) in two patients and they involved the PICA (PICA-involved type) in four (three in the SAC group, one in the PAO group). Distal PICA lesions (PICA distal type) were noted in 10 patients (five in the SAC group and five in the PAO group). However, in four of the five patients in the SAC group, the PICA branched from the extracranial portion (extracranial PICA). There was no bifurcation of the PICA from the VA (no PICA) in four patients (two in the SAC group, two in the PAO group). In the four patients, the anterior inferior cerebellar artery (AICA)-PICA branched from the basilar artery. The PICA did not originate from the intracranial VA in eight patients, consisting of “no PICA (AICA-PICA)” and “extracranial PICA” patients. In these patients, the perforating arteries were visualized. Absence of the contralateral VA or hypoplasia was noted in four patients.

Treatment

The PAO and SAC groups each consisted of 10 patients. The reasons for SAC selection included occlusion of the contralateral VA in one patient, contralateral PICA ending VA in one, hypoplasia of the contralateral VA in one, PICA-involved type in three, perforating arteries in five, and anterior spinal artery in one. In two patients, several factors were present. In the SAC group, the following stents were used: Enterprise VRD (Johnson & Johnson Codman, Miami, FL, USA) in five patients, Lvis (Terumo Corporation, Tokyo, Japan) in two patients, Neuroform (Stryker, Fremont, CA, USA) in two, and coronary stent (balloon expandable stent) in one patient (**Table 2**).

Postoperative course (Table 3)

DWI demonstrated high-signal-intensity lesions in 4 (40.0%) of 10 patients in whom assessment using MRI was conducted in the SAC group and in 6 (85.7%) of 7 similar patients in the PAO group ($p = 0.1340$). Brainstem lesions were noted in one (10.0%) in the SAC group and in five (71.4%) in the PAO group ($p = 0.1409$). Symptomatic ischemic complications in one (10.0%) in the SAC group and in four (40.0%) in the PAO group ($p = 0.3034$) were related to brainstem lesions. The incidence was slightly lower in the SAC group, although there were no significant differences in the image assessment or clinical symptoms.

There were no hemorrhagic complications in either group. In two patients in the SAC group, ventriculoperitoneal shunting for normal pressure hydrocephalus was required. It was performed under antiplatelet therapy, but there was no intracranial hemorrhage. Additional treatment was required for four patients in the SAC group and for three in the PAO group. There were no complications related to additional treatment in any patient.

Concerning the outcome after 90 days, the GOS scores were five in five patients, four in three, and three in two in the SAC group. In the PAO group, the scores were five in two patients, four in one, three in three, two in one, and one in three (**Fig. 1**). In the SAC group, the prognosis was significantly better ($p = 0.0257$).

Of the patients with a poor prognosis after 90 days, it was associated with initial damage in two in the SAC group; there was no involvement of posttreatment ischemic complications. Of seven patients in the PAO group, a poor prognosis was associated with initial damage in three, severe cerebral vasospasm in one, and ischemic complications of the medulla oblongata in three patients.

Representative cases in the PAO and SAC groups

*PAO group (***Fig. 2***)*

A 62-year-old man. The H & K grade was evaluated as 3. DSA demonstrated pearl and string signs at the V4 segment of the left VA and distal area of the PICA. Contralateral VA blood flow was sufficient and PAO was selected.

Under general anesthesia, the procedure was performed. A 7Fr sheath was inserted into the right femoral artery. A 7Fr OPTIMO 100 cm (Tokai Medical Products, Aichi, Japan) was guided into the left VA. A 5Fr sheath was inserted into the left femoral artery and a 5Fr guiding catheter was inserted into the right vertebral artery. An Excelsior 1018 (Stryker, Kalamazoo, MI, USA) was anterogradely guided to the site of dilatation via the left VA. An Excelsior SL10 (Stryker) was retrogradely guided beyond the union through the right VA. A coil mass involving the site of dilatation to the proximal stenotic site was formed using 18 and 10 coils, and PAO was achieved. After awakening from general anesthesia, right hemiplegia was observed. MRI revealed paramedian infarction of the left medulla oblongata. Paralysis was severe and the GOS score after 90 days was 3, SD.

SAC case (Case 3, **Fig. 3***)*

A 46-year-old man. He was brought to our hospital by ambulance with headache, which had persisted for 1 week. CT led to a diagnosis of subarachnoid hemorrhage. The H & K grade was evaluated as 2. DSA demonstrated fusiform dilatation of the right VA. There was no PICA bifurcation from the V4 segment of the right VA and the AICA-PICA was present. However, the bifurcation of a perforating artery was observed on the dorsal side; therefore, SAC was selected.

After general anesthesia was induced, a 7Fr sheath was inserted into the right femoral artery and a 5Fr sheath was inserted into the left femoral artery. A 7Fr OPTIMO (Tokai Medical Products) was inserted into the right VA. Aspirin at 200 mg and cilostazol at 100 mg were administered through a nasogastric tube. An Enterprise VRD 4.5 mm × 22 mm (Codman, Miami, FL, USA) was inserted to the V4 segment to cover the site of dilatation. Using the trans-cell technique, an Excelsior SL-10 (Stryker) was guided to the site of dilatation and coil embolization was performed. After first-coil insertion, systemic heparinization was conducted in order to maintain the activated coagulation time (ACT) at ≥250 seconds. The perforating artery was preserved, and no high-signal-intensity lesions were noted on MRI-DWI the day after SAC. Cerebral angiography demonstrated slight proximal dilatation and additional coils were inserted. Cerebral angiography 4 days after SAC confirmed no recurrence. The patient was discharged 15 days after SAC. The GOS score after 90 days was 5, GR.

Discussion

rVADA causes subarachnoid hemorrhage. Their pathological changes differ from those in saccular aneurysms.[11] The early re-rupture rate is high and early treatment is necessary.[1–3] PAO was established to prevent re-rupture as early and accurately as possible after diagnosis.[4,5] According to a multicenter registration survey (JR-NET3)[12] in Japan, 530 sessions of PAO were performed on 610 patients with non-saccular vertebral artery aneurysms between 2010 and 2013. The success rate of the procedure was 93.8%. In 59.1%,

Table 2 Characteristics of stent-assisted coiling group

Case No.	Age	Sex	Preoperative condition			Characteristics of the lesion				
			HK	Rebleed	Duration from Adm to Op	Side	Location	Perforator	ASA	Contralateral VA
1	75	M	2	No	96	R	PICA distal (extracranial PICA)	Present	Present	Occlusion*
2	42	M	3	Prehp	96	L	PICA involved*	Present	Present*	Patent
3	46	M	2	No	48	R	non PICA (AICA-PICA)	Present*	Not described	Patent
4	50	M	4	Prehp	24	R	PICA distal (extracranialPICA)	Present*	Not described	Patent
5	49	M	4	No	48	R	PICA involved*	Not described	Proximal (V2)	PICA end*
6	53	F	4	Prehp	48	R	PICA distal (extracranialPICA)	Present*	Distal	Patent
7	56	M	2	Prehp	24	L	non PICA (AICA-PICA)	Present* 3 branches	Proximal (V2)	Patent
8	60	F	4	No	24	R	PICA distal (extracranial PICA)	Present	Distal	Hypoplastic*
9	53	M	2	No	72	R	PICA distal	Present* 3 branches	Not described	Patent
10	57	F	2	No	72	L	PICA involved*	Present	Not described	Patent

*The reason for choosing SAC. AICA: anterior inferior cerebellar artery; ASA: anterior spinal artery; ASA: aspirin; CLP: clopidgrel; CLZ: cilostazol; M & M: mortality and morbidity; PICA: posterior inferior cerebellar artery; prehp: pre-hospital; SAC: stent-assisted coiling; VA: vertebral artery

the outcome was favorable. Ischemic and hemorrhagic complications were observed in 15.8 and 2.6%, respectively, but there was no influence on the prognosis. However, the results of PAO for ruptured vertebral-basilar artery dissection suggested medullary infarction as a prognostic factor. Endo et al.[9] reported medullary infarction in 47.4%, and that the length of vertebral artery occlusion was longer in the infarction group, emphasizing that the prognosis of patients with major infarction, such as hemimedullary or inferodorsolateral infarction, is particularly poor.[9] Aihara et al.[10] reported that the incidence of medullary infarction was 30%, suggesting that medullary infarction is a significant risk factor for non-severe subarachnoid hemorrhage. The first goal of treatment for rVADA is to prevent re-rupture, but it is necessary to select treatment considering the functional prognosis.

Anatomical examination revealed that the perforating arteries from the VA and the PICA were involved in medullary blood flow, and that net-like anastomosis was present on the surface of the medulla oblongata. The origins of the perforating arteries and the lateral spinal artery depend on their positional relationships with the PICA.[13] When the PICA branches from the intracranial VA, it is the source of the perforating arteries for the lateral surface of the brain stem and of the blood supply of the ipsilateral cerebellum. There is no perforating artery or lateral spinal artery from the AICA-PICA coming from the basilar artery to the lateral surface of the brain stem. The extracranial PICA has the perforating arteries to the dorsal medulla oblongata and the lateral spinal arteries. These findings suggest that intracranial PICA occlusion or PICA-free intracranial VA occlusion at the site of dissection induces Wallenberg syn-

Treatment			Antiplatelet			Complication			Prognosis		M & M
Stent	1st Coil	Total coil No.	ASA	CLP	CLZ	Symptomatic infarction	DWI HI lesion	Rebleed	Retreat	GOS @90d	
Tsunami 3-15	GDC10 360 soft 4-8	8		(75)	100	No	No	No		4	
Neuroform EZ 3.5-30		0	200		100	No	No	No	POD14	5	
Entreprise 17	Target ULTRA helical 4-15	3	200		100	No	PICA area distal	No	POD1	5	
Enterprise 23	Target NANO 3-10	4	300		200	No	No	No		3	Initial damage NPH
Lvis 4.5-23	ED3.5-8 ultra3-8	5 3	300	225		No	No	No		3	Initial damage
Enterprise 28	Target ULTRA 3.5-8	4	300		200	No	PICA area distal	No		5	
Enterprise 30	XL360 soft 3-9	9	300		200	No	PICA area distal	No	POD142	5	
Neuroform Atlas 3.0-21	ED Extrasoft 3-4	6	300		(200)	No	No	No		4	
Enterprise 39	ED Extrasoft 2.5-3	7	300		200	Hemiparesis	Paramedian medulla	No	POD17	4	Cerebral infarction
Lvis 4.5-23	ED Extrasoft 2.0-2	1	300	300		No	No	No		5	

drome. Furthermore, the perforating arteries primarily branch from the distal vertebral artery or proximal basilar artery on the ventral side of the medulla oblongata.[14] These perforating arteries branch between points 14-mm proximal and 16-mm distal to the vertebrobasilar junction. They are frequently observed around the foramen cecum of the medulla oblongata, and anastomosis with the contralateral vertebral, basilar, or anterior spinal arteries is also detected. However, if anastomosis from other blood vessels is absent, occlusion of the distal VA may cause medial medullary syndrome. Advances in cerebral angiography have facilitated the visualization of the perforating arteries. In particular, the resolution of cone-beam CT is high, and this procedure is useful for the visualization of the perforating arteries.[8] It is necessary to predict the occurrence of medullary infarction related to the perforating artery occlusion,

Table 3 Clinical outcome

Variable	SAC group	PAO group	p value
	10	10	
Hemorrhagic complication	0	0	
Ischemic complication			
DWI hyperintensity	4 (40%)	6 (60%)	0.1340
Medulla lesion	1 (10%)	5 (50%)	0.1409
※Not examined	0	3 (30%)	
Symptomatic	1 (10%)	4 (40%)	0.3034
Retreatment	4 (40%)	3 (30%)	0.6392
Outcome (GOS at 90d)			
5	5 (50%)	2 (20%)	
4	3 (30%)	1 (10%)	
3	2 (20%)	3 (30%)	
2	0	1 (10%)	
1	0	3 (30%)	

DWI: diffusion-weighted imaging; GOS: Glasgow Outcome Scale; PAO: parent artery occlusion; SAC: stent-assisted coiling

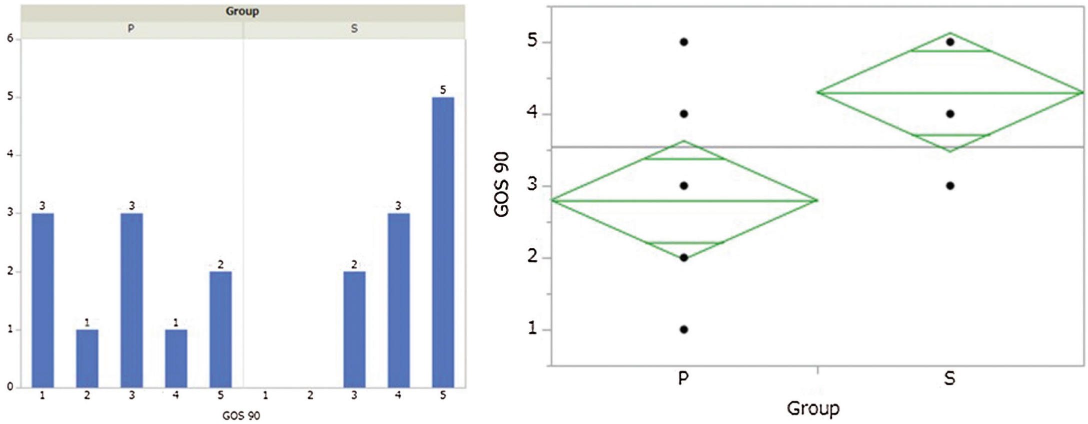

Fig. 1 GOS after 90 days. Clinical outcomes were compared between PAO and SAC. P means the PAO group and S means the SAC group. The prognosis was significantly favorable in the SAC group (p = 0.0257, OR: 0.36; 0.11–0.81). GOS: Glasgow Outcome Scale; PAO: parent artery occlusion; SAC: stent-assisted coiling

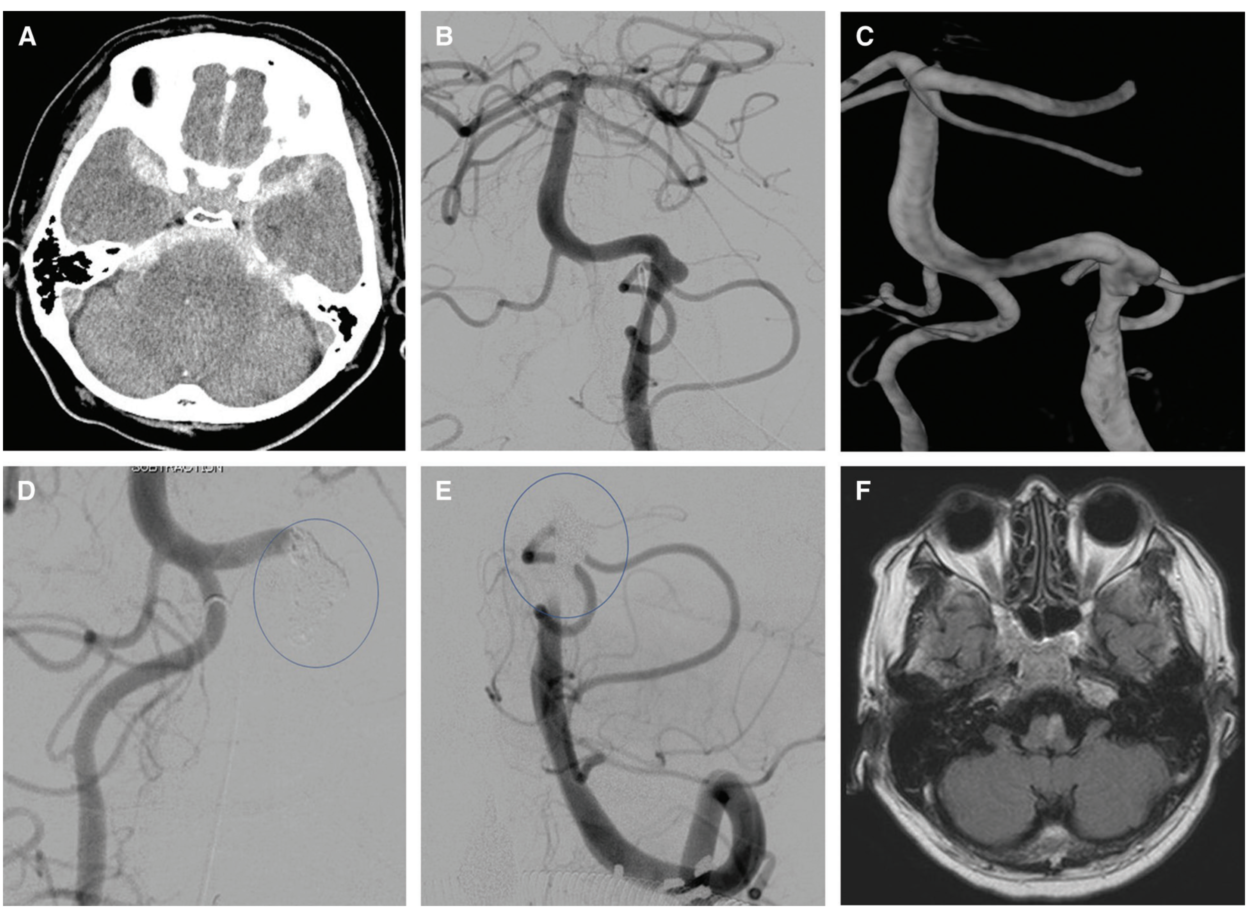

Fig. 2 A 62-year-old man. (**A**) CT showing the subarachnoid hemorrhage. (**B**) DSA showing the pearl and string sign in left vertebral artery distal to the posterior inferior cerebellar artery. (**C**) Three-dimensional rotational angiography showing the patent right vertebral artery. Post-procedural DSA showing antegrade flow from the right VA to the basilar artery (**D**) and from the left VA to the PICA (**E**). (**F**) Postoperative MRI showing left paramedian medullary infarction. CT: computed tomography; DSA: digital subtraction angiography; MRI: magnetic resonance imaging; PICA: posterior inferior cerebellar artery; VA: vertebral artery

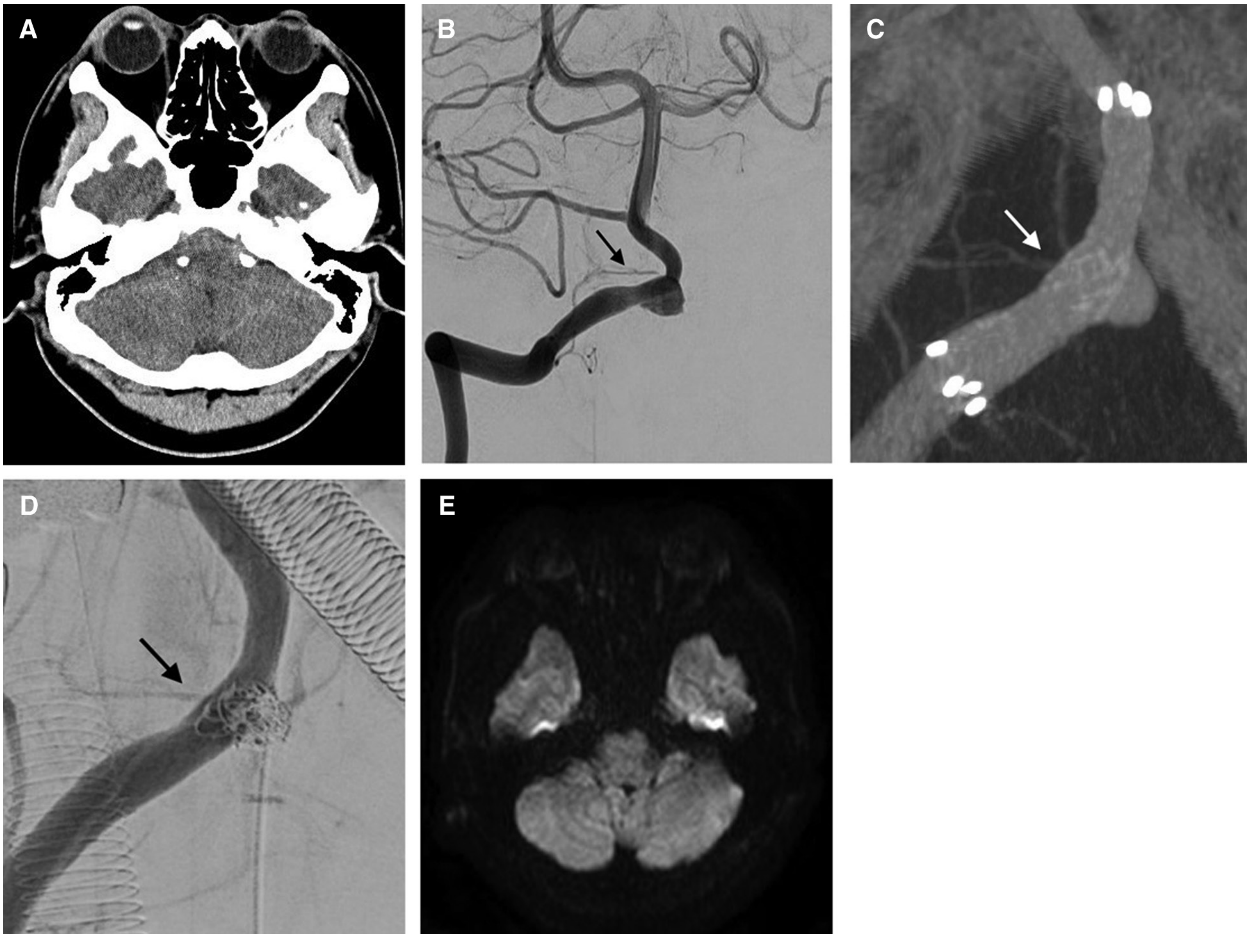

Fig. 3 A 46-year-old man. (**A**) CT showing the subarachnoid hemorrhage in the prepontine cistern. (**B**) DSA showing the dissected aneurysm in the right vertebral artery. (**C**) Cone-beam CT showing the perforating artery originating from the dissected lesion. The perforating artery was successfully preserved on cone-beam CT after stent placement (**C**) and after coil embolization on DSA (**D**). (**E**) MRI DWI the next day revealed no infarction in the brainstem. CT: computed tomography; DSA: digital subtraction angiography; MRI DWI: magnetic resonance imaging diffusion-weighted imaging

and consider a treatment method by evaluating medullary blood supply from the perforating artery, the anterior spinal artery, and the lateral spinal artery, in addition to the positional relationship between the PICA origin and lesion before endovascular treatment.

A recent study reported a treatment method to maintain anterograde blood flow using neck bridge or flow diverter stents for lesions involving the PICA or VADA with hypoplasia or occlusion of the contralateral VA. A meta-analysis involving patients with rupture demonstrated no significant differences in the incidence of acute complications, re-rupture rate, or prognosis during a mean follow-up of 23.8 months between reconstructive and deconstructive treatments.[15] A subsequent meta-analysis found that the complete occlusion rate immediately after treatment was higher in the deconstructive treatment group, whereas there was no significant difference in the long-term outcome.[16]

As the limitations of stenting, acute occlusion or thromboembolism may occur; therefore, administration of antiplatelet drugs is necessary, and postoperative rebleeding related to administration of antiplatelet drugs or anticoagulants may develop in patients with rupture. Based on results of SAC for ruptured saccular aneurysms, the incidence of complications was slightly higher than that in patients with unruptured aneurysms. Muto et al.[17] performed SAC on 40 patients with ruptured saccular aneurysms, administered antiplatelet drugs after treatment, and reported that a favorable outcome was achieved in 82.5%, whereas the incidences of stent occlusion, rebleeding within 3 weeks, and ischemic complications in the dominant region were 7.5, 12.5, and 7.5%, respectively, concluding that SAC is appropriate when treatment using a simple technique is difficult. On the other hand, Bechan et al.[18] compared 45 ruptured aneurysm patients with 47 unruptured aneurysm patients, and reported that the incidence of complications in the former (11%) was significantly higher than that in the latter (2.2%), suggesting that the indication of SAC should be carefully considered. In the two groups, antiplatelet drugs were administered after stenting or the completion of the procedure, but the timing of starting administration may have been delayed, considering the interval until the effects of antiplatelet drugs appear. We administered antiplatelet drugs before stenting and heparin after first-coil insertion. A symptomatic ischemic complication was observed in one patient with a perforating artery occlusion, and its incidence was slightly lower than that in the PAO group (n = 4). Furthermore, there was no in-stent thrombosis or distal embolism. A consensus has not been reached regarding drugs to be administered in the acute phase of rupture, dose, and timing of administration, but administration of antiplatelet drugs before stent insertion may be necessary to prevent ischemic complications related to stenting.

In the treatment of subarachnoid hemorrhage, invasive procedures are required, such as ventricular drainage or third ventriculostomy for acute hydrocephalus and ventriculoperitoneal shunting for secondary normal pressure hydrocephalus. When performing these procedures, it is controversial whether the administration of antiplatelet drugs should be continued. According to a meta-analysis of 13 studies, single antiplatelet drug increases the risk of hemorrhage during third ventriculostomy in the acute phase of subarachnoid hemorrhage, but asymptomatic or minor hemorrhage is observed in most cases. Dual antiplatelet therapy (DAPT) increases the incidence of major hemorrhage.[19] In our series, ventriculoperitoneal shunting was required in 2 of the 10 patients in the SAC group and performed under continued DAPT. There was no postoperative hemorrhagic complication in any patient, including these two patients. However, careful surgical procedures are necessary.

Dissecting cerebral aneurysms develop due to disruption of the internal elasticlamina. Increased blood flow destroys the media. In addition, destruction of the adventitia induces subarachnoid hemorrhage. Outgrowth of collagen fibers following thrombus formation is the process of vascular-wall repair, but a few weeks are required for repair. Stenting may facilitate branch preservation, promoting the healing process. An experiment using a rat model revealed that organized fibrins appeared around the stent wire 7 days after stent insertion and that intimal neoplasia was noted on Day 14.[20] SAC for dissecting cerebral aneurysms may prevent rebleeding through thrombus formation related to coil insertion at the site of dilatation with thinning, facilitating the preservation of parent artery/branch blood flow by stent insertion and promoting the healing process of the affected blood vessel. Currently, three types of stent are available for the treatment of cerebral aneurysms. These stents have respective characteristics related to differences in the manufacturing methods (laser cut or braided) or structure (closed or open). For coil insertion, jailing/half-jailing, trans-cell, or jack-up techniques are used. In patients with dissecting cerebral aneurysms, especially in those with ruptured aneurysms, the lesion site may be fragile; therefore, a suitable device or technique should be selected on an individual-patient basis, considering parent artery or lesion site stress and the characteristics of each device.

In the SAC group, additional treatment was required for four patients (40%). The interval from initial to additional treatment was 1 day in 1, ≤30 days in 2, and 142 days in 1. There was no rebleeding in any patient. Angiography demonstrated regrowth at the site of dilatation and treatment with additional coils was performed. In patients with dissecting cerebral aneurysms, disruption of the internal elastic lamina may make the vascular wall fragile in the acute phase of rupture. Outgrowth of collagen fibers is involved in the mechanism of vascular-wall repair,[11] but the vascular wall is thin, fragile, and unstable. The fragility of the vascular wall may remain despite the disappearance of blood flow to the site of dilation on angiography. It may be responsible for recurrence. It is necessary to perform several sessions of angiography, carefully examine the presence of recurrence, and consider additional treatment.

This study has the following limitations: First, the incidence of rVADA is lower than that of ruptured saccular aneurysms, and the number of patients at a single institution is limited. Second, MRI-based assessment was not always performed for all patients. It is difficult to perform MRI in severe cases with unstable circulatory/respiratory conditions, so the assessment of patients with medullary infarction or its site remains insufficient. Third, the long-term outcomes in stent-treated patients are unclear. For most patients treated by SAC, the postoperative follow-up period is ≤2 years, with a maximum of 10 years. We should accumulate more data of SAC which can preserve the perforating arteries for the long-term outcomes to be clarified.

Conclusion

SAC for rVADA prevented rebleeding and the incidence of postoperative ischemic complications was low. The prognosis was more favorable than that after PAO. The preservation of branches from the site of dissection, including a penetrating branch, in addition to the PICA improves the prognosis. The optimal doses of antiplatelet drugs/anticoagulants and stent selection should be further investigated in a larger number of patients.

Disclosure Statement

The authors declare no conflicts of interest.

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