Turk Neurosurg 34(3):490-498, 2024

Original Investigation

DOI: 10.5137/1019-5149.JTN.45317-23.1

Received: 21.08.2023
Accepted: 27.09.2023

Published Online: 05.03.2024

Aneurysms Located beyond the Origin of the Major Branches in the Posterior Circulation

Sang-Jeong SONG, Yoon-Soo LEE, Sang-Jun SUH

Daegu Fatima Hospital, Department of Neurosurgery, Daegu, Korea

Corresponding author: Yoon-Soo LEE ✉ paulyoonsoolee@daum.net

ABSTRACT

AIM: To evaluate the clinical and radiological features, treatment modalities, and outcomes of unusual aneurysms located beyond the origin of the major branches in the posterior circulation, and to introduce changes in the recent treatment trends due to rapid innovations in endovascular technology.

MATERIAL and METHODS: This was a retrospective study of patients who underwent treatment for these unusual aneurysms, including those that were identified in regular follow-up after treatment, between March 2009 and April 2023. Medical information including the radiological features of the aneurysms, incidences of rebleeding, associated vascular diseases, treatment modalities, and outcomes, was documented.

RESULTS: A total of 22 cases consisting of two unruptured and 20 ruptured aneurysms were included. Their locations were the posterior cerebral artery in four cases, the superior cerebellar artery in three, the anterior inferior cerebellar artery in two, and the posterior inferior cerebellar artery in 13. Sixteen were saccular, five fusiform, and one blister-like. Eight were pseudo-aneurysms and pre- or intra-operative rebleeding occurred in 13 (65%) of 20 cases with ruptured aneurysms. Five aneurysms coexisted with causative vascular diseases such as arteriovenous malformation, moyamoya disease, or dolichoectasia. Four cases were treated by microsurgical operations and 18 by endovascular operations. In one of the microsurgical cases and five of the endovascular cases, parent arteries were sacrificed. Stents were used in six cases, including low-profile stents in four. Intermediate guiding catheters were used in seven cases for distal access. Full recoveries were seen in 17 cases and death occurred in three.

CONCLUSION: Treatments for these aneurysms are technically demanding due to the high rate of rebleeding, difficult accessibility, and inevitable necessity of sacrifice of the parent artery in some cases. However, advancing endovascular techniques and devices enable distal access to the lesion and help preserve the parent artery.

KEYWORDS: Peripheral aneurysm, Posterior circulation, Endovascular operation, Intermediate guiding catheter, Low-profile stent

ABBREVIATIONS: AICA: Anterior inferior cerebellar artery, **AVM:** Arteriovenous malformation, **CT:** Computed tomography, **DE:** Dolichoectasia, **ER:** Emergency room, **Fr:** French, **ICH:** Intracerebral/cerebellar hemorrhage, **IVH:** Intraventricular hemorrhage, **MMD:** Moyamoya disease, **PCA:** Posterior cerebral artery, **PICA:** Posterior inferior cerebellar artery, **SAH:** Subarachnoid hemorrhage, **SCA:** Superior cerebellar artery, **SDH:** Subdural hemorrhage

INTRODUCTION

The posterior cerebral artery (PCA), superior cerebellar artery (SCA), anterior inferior cerebellar artery (AICA), and posterior inferior cerebellar artery (PICA) constitute the major branches of the posterior circulation of the brain. In comparison to the anterior circulation, variation of the arterial anatomy is relatively frequent (8). Aneurysms are usually located proximally at the origin of the major branches where the hemodynamic stresses are strenuous. Aneurysms located beyond the origin of the major branches in the posterior

Sang-Jeong SONG : 0009-0001-9300-4232 Yoon-Soo LEE : 0000-0003-2506-0168 Sang-Jun SUH : 0000-0003-2228-2793

circulation are very rare, and only a few case reports or short analyses have been published. According to these reports, the incidence of distal aneurysms was higher in the cerebellar arteries than in cerebral arteries, and the distal PICA was the most common site of location in the cerebellar arteries (2,4,6,8-10). Their etiology, treatment modality, and prognosis have not been evaluated sufficiently (6,8-10).

The size, location, and friability of these aneurysms should be considered to determine the feasibility and risk of surgical approaches such as direct clipping. In addition, their distal location and arterial tortuosity directly influence endovascular accessibility. No matter which treatment modality is chosen, it carries a considerable risk of unintended rupture or arterial occlusion which may lead to an unfavorable outcome.

The study objective was to evaluate the clinical and radiological features, treatment modalities, and outcomes of these unusual aneurysms located beyond the origin of the major branches in the posterior circulation. To the best of our knowledge, this report is the single largest study of these unusual aneurysms in Korea. Changes in treatment trends with the advancements in endovascular techniques and devices are also discussed.

MATERIAL and METHODS

This study was approved by the Institutional Review Board of Daegu Fatima Hospital (IRB 2023-06-003).

Patients who underwent surgical or endovascular operations to treat aneurysms located beyond the origin of the major branches in the posterior circulation, or those in regular follow-up after treatments in our institute between March 2009 and April 2023, were candidates for this study. When corresponding patients were encountered during the period, the incidence of rebleeding, location and shape of the aneurysm, treatment modalities; such as clipping, coiling, trapping, or proximal occlusion, adjunctive devices used; such as stents or intermediate guiding catheters, and operative findings were recorded precisely on the medical chart of each individual. The presence of any recurrences and clinical outcomes including the modified Rankin Scale were also evaluated and documented at the follow-up. These prospectively acquired data from the medical documents were reviewed retrospectively for this study.

All pre-, intra-, and post-procedural angiographic images were reviewed and their radiological features were evaluated in detail. Any aneurysms located beyond the origin of the major branch but within the first segment of each branch were termed “proximal” aneurysm, and those further beyond the first segment were termed “distal” aneurysm. Aneurysms were classified into “saccular”, “fusiform”, or “blister-like” aneurysms according to their shapes. They were also assigned as “typical”, “dissecting”, or “pseudo-” aneurysm according to the types of presumed pathogenesis based on their characteristics on the angiographical images. A typical aneurysm referred to the usual type that can also be found elsewhere in the brain, regardless of the presence of lobulations. Delayed filling of contrast and stagnation at the late phase, an abrupt morphological change during an angiographic session, complete disruption of the coil structure on the angiogram, or indisputable evidence on the microscopic surgical view were indicators used to determine a pseudo-aneurysm. Any associated or causative vascular disease such as arteriovenous malformation (AVM), moyamoya disease (MMD), or dolichoectasia (DE) was checked. The timing of rebleeding was specified as pre- or intra-operative, if any. The patient’s profiles, treatment modalities including operative techniques and devices, and outcomes were analyzed.

RESULTS

Overall, 22 cases from 21 patients were included in this study. One patient (Case 2 and 3) had recurrence after coil embolization for a ruptured aneurysm and underwent additional clipping for a recurred unruptured coiled aneurysm. For this patient, each operation was counted and evaluated separately. The patient demographics, clinical and radiological features, treatment modalities, and outcomes are detailed in Table I. There were five males (22.7%) and 17 females (77.3%) ranging in age from 29 to 92 years (mean age of 54.95). There were two cases with unruptured aneurysms (9.1%) and 20 with ruptured ones (90.9%). Out of 20 ruptured aneurysms, 14 resulted in subarachnoid hemorrhage (SAH) mainly and the remaining six resulted in intracerebral/cerebellar hemorrhage (ICH), intraventricular hemorrhage (IVH), or spontaneous subdural hemorrhage (SDH) with minimal or without obvious SAH. Eight cases (Case 8, 12, 15, 16, 17, 18, 21, and 22) belonged to a clinically poor-grade (grade 4 or 5) according to the World Federation of Neurological Surgeons grading system. The aneurysm location was PCA in four cases (4 distal locations), SCA in three (3 distal locations), AICA in two (1 proximal, 1 distal location), and PICA in 13 (4 proximal, 9 distal locations). The aneurysm shape was “saccular” in 16 cases including one giant aneurysm, “fusiform” in five, and “blister-like” in one. The type of presumed pathogenesis was “typical” in ten cases, “dissecting” in four, and “pseudo-” in eight. Rebleeding occurred in 13 (65%) of 20 cases with ruptured aneurysms, including three pre-operative, eight intra-operative, and two pre- and intra-operative onsets. Associated or causative vascular diseases were seen in five cases, including three AVM cases, one MMD, and one DE. Microsurgical operations (clippings) were performed in four cases and endovascular operations in 18, including 17 coilings and one flow diversion. In one out of four clipping cases, trapping of the parent artery was required due to the friability of the aneurysm. In four out of 17 coiling cases, the parent artery could not be preserved, and coil trapping, including the obliteration of both the parent artery and the aneurysm, was performed. In another one of the 17 coiling cases, the distal aneurysm was inaccessible and the parent artery proximal to the lesion was occluded. In six cases of endovascular operations, stents were used. Especially, in the four most recent cases, low-profile stents such as LVIS Jr. (MicroVention, Tustin, CA, USA) and Neuroform Atlas (Stryker Neurovascular, Kalamazoo, MI, USA), which are compatible with 0.017-inch or 0.0165-inch microcatheters, were used. Intermediate guiding catheters were used in seven cases for access to the distal lesion. Low-profile stents and intermediate guiding catheters were not

Table I: Twenty-Two Cases of Aneurysms Located Beyond the Origin of the Major Branches in the Posterior Circulation

Case	Sex/ Age (years)	Presentation			Aneurysm				Causative Disease	Operation	Adjunctive Endovascular Devices		Recurrence	mRS
		M/S	Main Hm	R/U	Location	Shape	Type	Rebleeding			Stent	IC		
1	F/64	Drowsy	IVH	R	Lt Dist PICA	Saccular	Typical	-	-	Clip	-	-	-	0
2	F/60	Drowsy	SAH	R	Lt Dist PICA	Saccular	Typical	IntraOP	-	Coil	-	-	+	0
3	F/60	Alert	-	U	Lt Dist PICA	Saccular	Typical	-	-	Clip	-	-	-	0
4	F/47	Drowsy	SAH	R	Rt Dist PICA	Saccular	Typical	-	-	Clip	-	-	-	0
5	M/51	Drowsy	SAH	R	Rt Prox AICA	Saccular	Typical	-	AVM	Coil	-	-	-	0
6	M/49	Drowsy	SAH	R	Lt Dist PCA	Saccular	Typical	-	AVM	Coil	-	-	-	0
7	F/64	Drowsy	SAH	R	Lt Dist PCA	Saccular (Giant)	Typical	IntraOP	-	Coil trapping	-	-	-	0
8	F/79	Semicoma	SAH	R	Rt Dist SCA	Fusiform	Pseudo-	PreOP	-	Coil Prox occlusion	-	-	-	5
9	F/53	Drowsy	IVH	R	Lt Dist PICA	Saccular	Typical	-	-	Coil	-	-	-	0
10	F/29	Drowsy	ICH, IVH	R	Lt Dist AICA	Saccular	Pseudo-	IntraOP	-	Coil	-	DAC	-	0
11	F/56	Drowsy	ICH, IVH	R	Lt Dist PICA	Saccular	Typical	IntraOP	AVM	Coil	-	Navien	-	0
12	M/52	Stupor	SAH	R	Rt Prox PICA	Blister	Pseudo-	IntraOP	-	Coil	Enterprise 2	-	-	0
13	M/57	Drowsy	SAH	R	Lt Prox PICA	Fusiform	Dissecting	-	-	Coil	Enterprise 2	-	-	0
14	F/46	Drowsy	SAH	R	Lt Dist SCA	Saccular	Pseudo-	IntraOP	-	Coil trapping	-	Navien	-	0
15	F/46	Semicoma	SAH	R	Rt Prox PICA	Saccular	Pseudo-	Pre/IntraOP	-	Coil	LVIS Jr	-	+	0
16	F/68	Semicoma	SDH, ICH	R	Lt Dist PCA	Saccular	Pseudo-	IntraOP	MMD	Clip trapping	-	-	NA	6
17	F/66	Semicoma	SAH	R	Lt Dist PCA	Fusiform	Dissecting	IntraOP	DE	Coil trapping	-	SOFIA	-	3
18	F/41	Stupor	ICH, IVH	R	Lt Dist PICA	Saccular	Pseudo-	PreOP	-	Coil	-	SOFIA	-	0
19	F/48	Alert	-	U	Lt Prox PICA	Fusiform	Dissecting	-	-	Flow diversion	LVIS Jr#2	-	-	0
20	F/42	Drowsy	SAH	R	Rt Dist PICA	Saccular	Typical	-	-	Coil	Neuroform Atlas	SOFIA	-	0
21	F/92	Coma	SAH, ICH	R	Rt Dist PICA	Saccular	Pseudo-	Pre/IntraOP	-	Coil trapping	-	SOFIA	NA	6
22	M/39	Semicoma	SAH	R	Rt Dist SCA	Fusiform	Dissecting	PreOP	-	Coil	Neuroform Atlas	-	NA	6

AICA: *Anterior inferior cerebellar artery,* ***AVM:*** *Arteriovenous malformation,* ***DE:*** *Dolichoectasia,* ***Dist:*** *Distal,* ***F:*** *Female,* ***Hm:*** *Hemorrhage,* ***IC:*** *Intermediate guiding catheter,* ***ICH:*** *Intracerebral/ cerebellar hemorrhage,* ***IntraOP:*** *Intra-operative,* ***IVH:*** *Intraventricular hemorrhage,* ***M:*** *Male,* ***MMD:*** *Moyamoya disease,* ***mRS:*** *Modified Rankin Scale,* ***M/S:*** *Mental status,* ***NA:*** *Not applicable,* ***PCA:*** *Posterior cerebral artery,* ***PICA:*** *Posterior inferior cerebellar artery,* ***PreOP:*** *Pre-operative,* ***Pre/IntraOP:*** *Pre- and intra-operative,* ***Prox:*** *Proximal,* ***R:*** *Ruptured,* ***SAH:*** *Subarachnoid hemorrhage,* ***SCA:*** *Superior cerebellar artery,* ***SDH:*** *Subdural hemorrhage,* ***U:*** *Unruptured.*

available in the early period of this study. Recurrences were diagnosed in two cases after coil embolization, and one of them underwent additional microsurgical clipping. Full clinical recoveries without any deficits were observed in 17 cases, moderate disability in one, severe disability in one, and deaths occurred in the remaining three.

Illustrative Cases

Case 4 (Figure 1): A 47-year-old female presented with a drowsy mentality after a sudden headache. After being diagnosed with SAH at a local hospital, she was transferred to our institute. A vertebral angiogram showed a wide neck saccular aneurysm at the far distal PICA. The left PICA was absent, and the right PICA supplied the right PICA territory and then crossed the midline to supply the left PICA territory. The aneurysm was located in the left hemisphere. Endovascular access to the far distal lesion seemed impossible, and microsurgical clipping was performed via a midline suboccipital craniotomy. Although the aneurysm had a slight irregular morphology, a typical aneurysm was confirmed during the microsurgery. The patient recovered fully without any recurrences.

Case 10 (Figure 2): A 29-year-old female visited the emergency room (ER) with a drowsy mentality after an abrupt headache one day previously. The computed tomography (CT) results showed that the main lesions were due to cerebellar hemorrhage and IVH. However, with the suspicion of a vascular lesion on the axial images of the brain CT angiography, a cerebral angiography was performed. The vertebral angiogram showed a saccular aneurysm at the left distal AICA. Intra-aneurysmal contrast remained stagnated throughout the late phase. A 6 French (Fr) guiding catheter was located at the left vertebral artery, but the navigation of a microcatheter into the left AICA was impossible because it coursed downward at an acute angle. An approach via the right vertebral artery with reinforcement of the support using an intermediate guiding catheter enabled distal access into the aneurysm. During the insertion of the second coil, disruption of the coil frame occurred and intra-operative rebleeding was observed. After the rapid insertion of additional coils, the leakage was controlled. Even with the rebleeding event, the patient showed a stable clinical course and recovered fully. The latest angiographic follow-up after 2.5 years showed no recurrences with a patent distal flow at the AICA.

Case 16 (Figure 3): A 68-year-old female with underlying MMD presented with a deep semicomatous mentality. The brain CT and CT angiography revealed an aneurysm at the left distal PCA with surrounding ICH, and a massive SDH was compressing the left hemisphere. A wide craniotomy was performed and the SDH was evacuated. Then, the aneurysm was exposed in a microsurgical field via a subtemporal approach. However, due to the friability of the aneurysm, intra-operative rebleeding persisted. With no choice, the parent artery was trapped using two clips. The patient already had diffuse irreversible brain damage and died three days later.

Case 18 (Figure 4): A 41-year-old female presented with a stuporous mentality. She experienced an episode of sudden headache and dizziness four days previously and then another severe episode just before the abrupt deterioration of consciousness. The brain CT showed cerebellar hemorrhage and IVH in addition to acute hydrocephalus. At first, the patient was diagnosed with a usual hypertensive cerebellar hemorrhage by a neurosurgeon on duty, and she underwent a ventriculostomy to relieve the hydrocephalus. During a later medical conference, the possibility of aneurysmal bleeding was suggested, and she underwent cerebral angiography. A saccular but bilobulated aneurysm was found at the left distal PICA. The posterior lobe of the aneurysm was visualized first followed slowly by the anterior lobe in a delayed fashion, and the contrast remained somewhat stagnated in the late phase. A 7Fr guiding catheter along with an intermediate guiding catheter was installed at the left vertebral artery. With this maximized support reaching up to the origin of the PICA, navigation of a microcatheter to the lesion was not difficult, despite its long distal route. Delicate control of the microcatheter was required to occlude the bilobulated aneurysm. Eventually, the patient made a full recovery. The latest angiographic follow-up after two years showed some disruption of the coil structure, but the aneurysm remained completely occluded with a patent distal flow of the PICA.

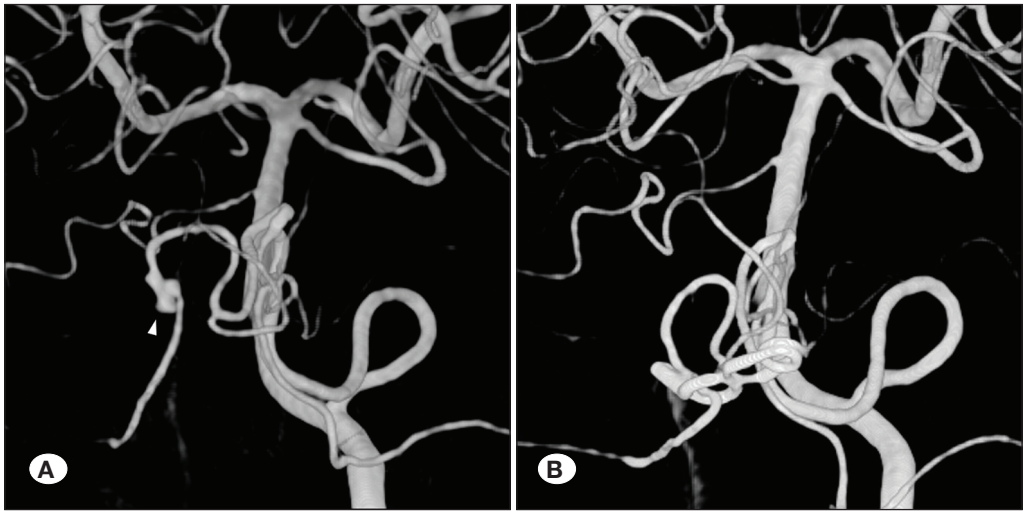

Figure 1: Case 4. **A)** Vertebral angiogram from the posterior view shows a wide neck saccular aneurysm (white arrowhead) at the far distal posterior inferior cerebellar artery (PICA). The left PICA is absent, and the right PICA crosses the midline to supply the left PICA territory. The aneurysm was located in the left hemisphere. **B)** Vertebral angiogram from the posterior view after a microsurgical clipping reveals no aneurysmal remnant.

Case 20 (Figure 5): A 42-year-old female was admitted to the ER with a drowsy mentality after an episode of headaches. A brain CT showed evidence of SAH. A vertebral angiogram revealed a saccular aneurysm with a small daughter sac at the bifurcation of the right distal PICA from where the cortical arteries branched off. A 6Fr guiding catheter with a coaxial intermediate guiding catheter was established in the right vertebral artery, and the tip of the intermediate guiding catheter was located just at the origin of the PICA. Despite its long and tortuous course to the aneurysm, navigation of a microcatheter to the lesion was feasible, and the aneurysm was embolized successfully. Meanwhile, the distal flow into one of the cortical branches was slightly delayed. The microcatheter was inserted into the compromised branch and a Neuroform Atlas stent was installed. The patient's clinical course was uneventful and the follow-up angiogram after seven months showed no recurrences.

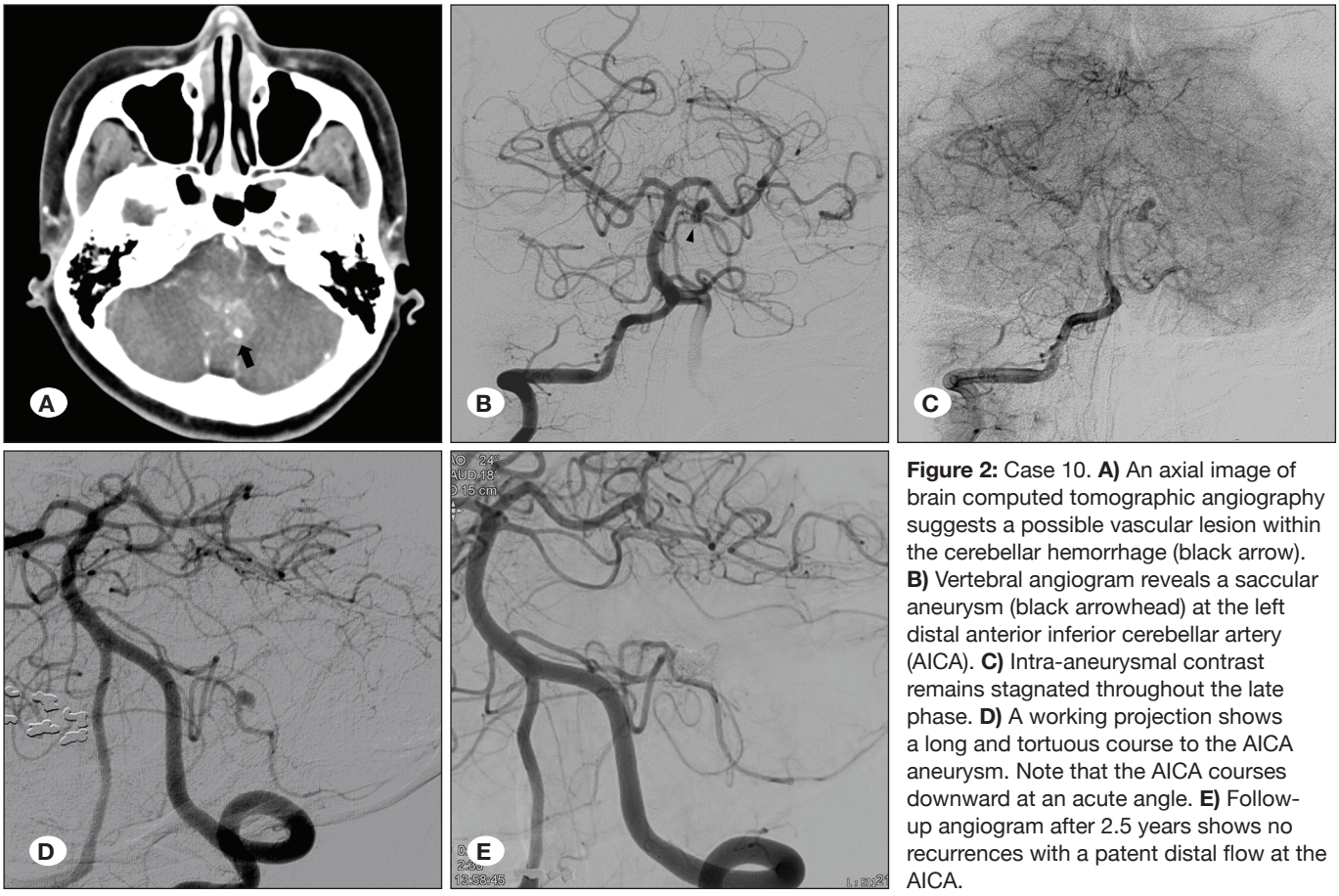

Figure 2: Case 10. **A)** An axial image of brain computed tomographic angiography suggests a possible vascular lesion within the cerebellar hemorrhage (black arrow). **B)** Vertebral angiogram reveals a saccular aneurysm (black arrowhead) at the left distal anterior inferior cerebellar artery (AICA). **C)** Intra-aneurysmal contrast remains stagnated throughout the late phase. **D)** A working projection shows a long and tortuous course to the AICA aneurysm. Note that the AICA courses downward at an acute angle. **E)** Follow-up angiogram after 2.5 years shows no recurrences with a patent distal flow at the AICA.

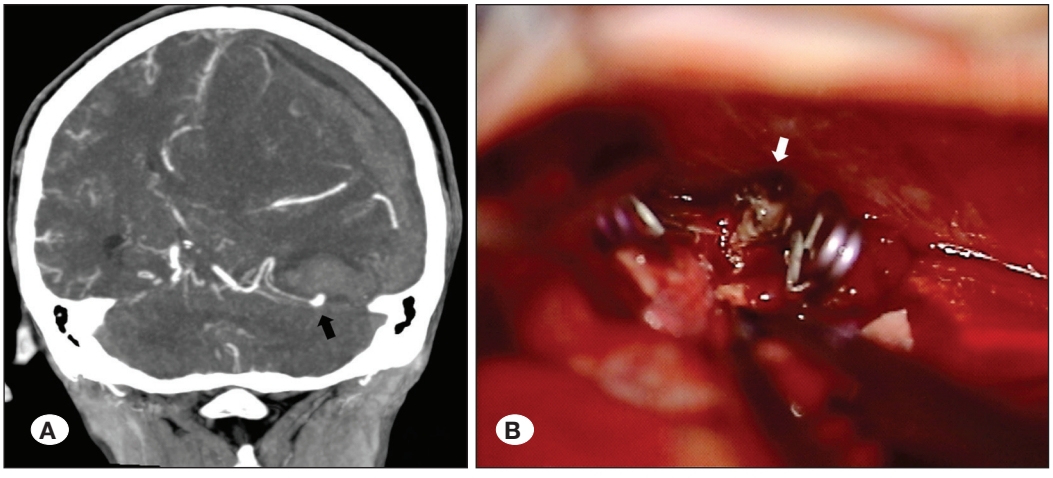

Figure 3: Case 16. **A)** A coronal section of computed tomographic angiography reveals an aneurysm at the left distal posterior cerebral artery (black arrow). Massive subdural hemorrhage is compressing the left hemisphere resulting in a subfalcine herniation. **B)** A microsurgical view shows a friable pseudo-aneurysm (white arrow) treated by trapping using clips.

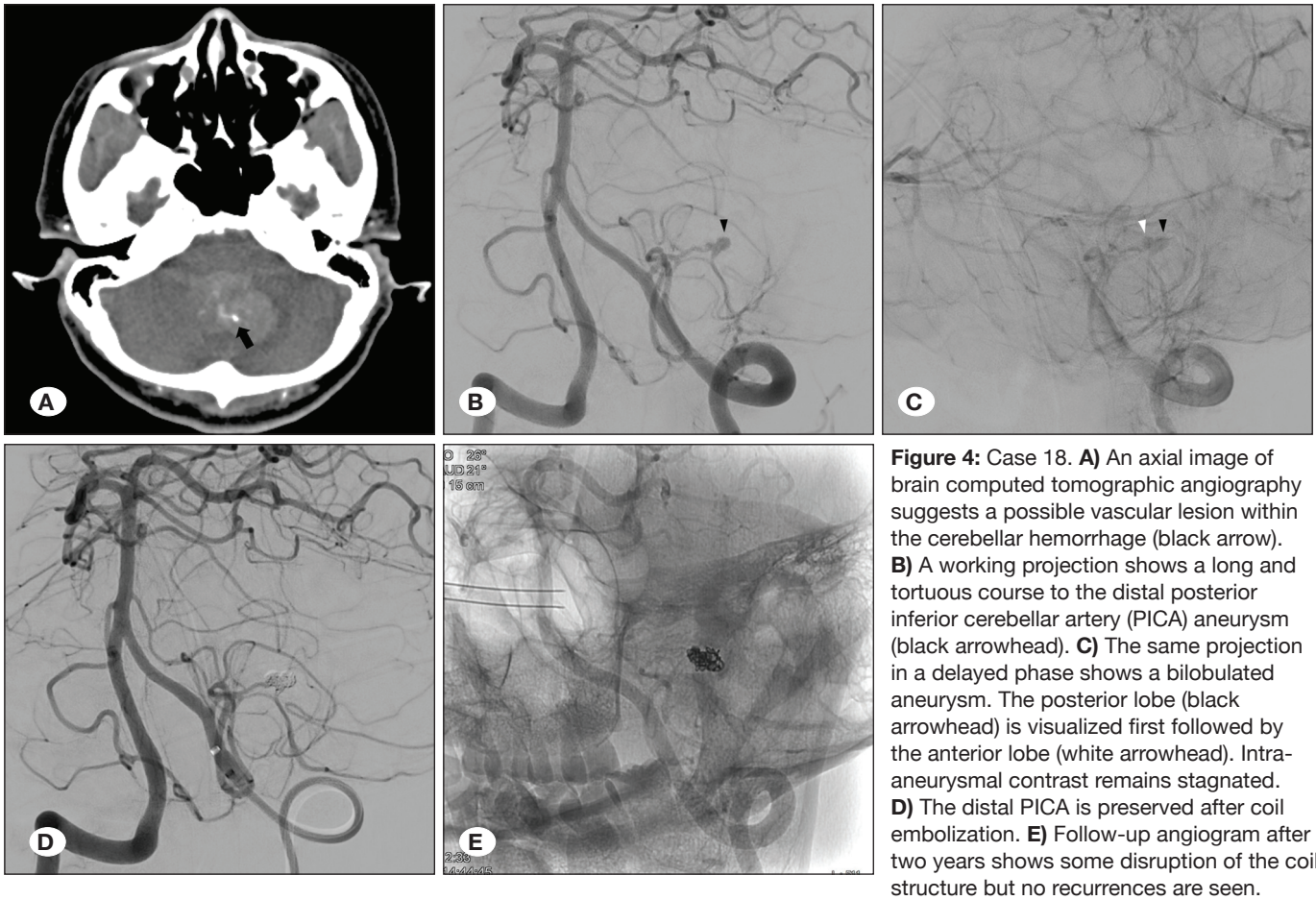

Figure 4: Case 18. **A)** An axial image of brain computed tomographic angiography suggests a possible vascular lesion within the cerebellar hemorrhage (black arrow). **B)** A working projection shows a long and tortuous course to the distal posterior inferior cerebellar artery (PICA) aneurysm (black arrowhead). **C)** The same projection in a delayed phase shows a bilobulated aneurysm. The posterior lobe (black arrowhead) is visualized first followed by the anterior lobe (white arrowhead). Intra-aneurysmal contrast remains stagnated. **D)** The distal PICA is preserved after coil embolization. **E)** Follow-up angiogram after two years shows some disruption of the coil structure but no recurrences are seen.

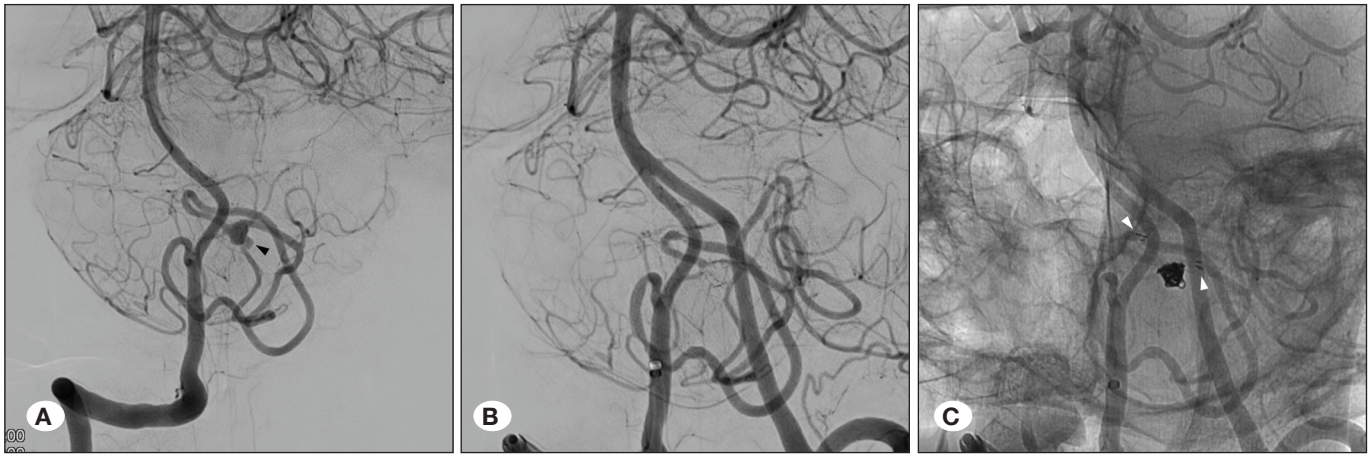

Figure 5: Case 20. **A)** Vertebral angiogram in a working projection revealed a saccular aneurysm (black arrowheads) with a small daughter sac at the bifurcation of the right distal posterior inferior cerebellar artery from where the cortical arteries branch off. **B)** Both cortical arteries are preserved after coil embolization. **C)** Note that a low-profile stent (white arrowheads) is installed to maintain the distal flow.

DISCUSSION

Aneurysms located beyond the origin of the major branches in the posterior circulation are challenging surgical lesions for neurosurgeons. Due to the rare incidence, their pathogenesis remains unclear. Furthermore, their distal location at the small parent artery makes endovascular accessibility uncertain, and the friable nature of these aneurysms makes surgical manipulation cumbersome and risky. Moreover, it is already known that complexity from wide variations of the vascular anatomy exists in the posterior circulation and the designated territory for each artery can be inconsistent. Occlusion of the artery during a procedure can lead to unpredictable results, ranging from clinical silence to death (8). The unexpectable risks of procedure-related hemorrhage and ischemia are the main obstacles to the treatments of these aneurysms.

Although most of the articles on these unusual aneurysms are case reports or small-scale studies, some authors have attempted to perform comprehensive studies. Tokimura et al. reported the largest study of 30 distal PICA aneurysms where 27 underwent treatment (22 by microsurgical and 5 by endovascular operations), with nuance of preference for early endovascular treatment over delayed microsurgery (10). Rodriguez-Hernandez et al. described microsurgically treated distal aneurysms of whole intracranial arteries, including 16 distal PCAs and 40 distal cerebellar artery aneurysms, and demonstrated a fourfold increase in the incidence of distal aneurysms in the posterior circulation (9). Hou et al. conducted a literature review on endovascular treatment for 55 distal SCA aneurysms and suggested endovascular treatment as an efficient and safe option since no fatal procedure-related complications occurred (1). Peluso et al. reported 13 distal aneurysms from cerebellar arteries with an incidence of 0.6% out of all treated aneurysms. These 13 aneurysms were all treated by endovascular parent artery occlusion, and the authors emphasized that this prodecure is technically easy and can be performed in the acute phase of hemorrhage, even in poor-grade patients (8).

Based on the previous reports, the majority of patients presented with SAH as a consequence of rupture of these peripheral aneurysms (1,2,6,8,10). Similarly, 14 of the 20 ruptured cases (70%) in this study presented with SAH on the initial brain CT. The remaining six cases (30%) showed ICH, IVH, or spontaneous SDH without obvious or with minimal SAH. One patient (Case 18) was thought to have a usual cerebellar hemorrhage but a ruptured distal PICA aneurysm was diagnosed afterwards. In addition, a recent study reported that approximately 20% of these distal aneurysms were not identified on initial CT and magnetic resonance angiography (4). For these reasons, the incidence of these peripheral aneurysms may have been underestimated, and, in fact, they may not be as rare as reported in the literature. To prevent the misdiagnosis of this unusual disease as a hypertensive ICH or non-aneurysmal SAH, a detailed and targeted inspection to identify the source of the hemorrhage is required.

Several authors have reported that peripheral aneurysms are relatively frequent in the PICA in comparison with other major branches in the posterior circulation (4,7,9). This study also showed a similar tendency; 59.1% in the PICA, 18.2% in the PCA, 13.6% in the SCA, and 9.1% in the AICA. The PICA has the most complex and tortuous course in the cerebellar arteries with considerable anatomical variations (4,8). The predisposition of the PICA to the formation of peripheral aneurysms may be attributed to the hemodynamic stress caused by this distinctive anatomical feature. Similar to other studies, 72.7% of the aneurysms in this study were saccular, 22.7% were fusiform, and 4.6% were blister-like. Although most of these peripheral aneurysms are saccular, they tend to have increased frequencies of non-saccular morphology (9). In this study, regarding the presumed pathogenesis type, typical or usual aneurysms accounted for 45.5%, dissecting aneurysms for 18.2%, and pseudo-aneurysms for 36.4%. An increased incidence of dissecting and pseudo-aneurysms could be related to a high incidence of rebleeding. Indeed, 50% of the dissecting aneurysms and 100% of the pseudo-aneurysms in this study experienced pre- or intra-operative rebleeding compared to 30% of the typical aneurysms. Moreover, six of 16 saccular aneurysms (37.5%) were friable pseudo-aneurysms which all rebled. Therefore, a saccular morphology for this specific aneurysm should not be interpreted as a stable aneurysm. Several reports have described the association of peripheral aneurysms in the posterior circulation with coexisting vascular disease, such as AVM, MMD, or DE (4,5,8-11). The increased hemodynamic stress triggered by those causative vascular diseases and developmental inferiority of arterial durability, as well as the influence of angiogenetic factors produced by malformation, are generally proposed to explain the etiology (4).

For more than 20 years, microsurgical and endovascular techniques have been competing with each other in the field of aneurysm treatment. In recent years, cases of endovascular operations have outnumbered microsurgical operations. This trend seems not exceptional for the treatment of peripheral aneurysms in the posterior circulation. Microsurgical operation for the posterior circulation is generally considered difficult and challenging and is associated with high risk because of neurovascular complexity and limited accessibility, as well as unfamiliarity with the surgical approach. According to older reports regarding these peripheral aneurysms, delayed microsurgical operations were preferred for good-grade patients and early endovascular operations for poor-grade patients (2,10). Although some authors reported good microsurgical outcomes (9), endovascular operations have been regarded to be technically easier and less traumatic and therefore gained popularity (1,4,6,8,10). Regardless of the treatment modalities, unintended rupture or parent artery occlusion may occur frequently during the procedures to treat these peripheral aneurysms. However, due to the small caliber of distal arteries, the consequence of leakage may be less fatal, and achievement of hemostasis can be easier when compared to cases of usual proximal aneurysms. In addition, occlusions of distal arteries tend to bring fewer ischemic complications than ones of proximal arteries, although the consequences may be inconsistent. Several authors have described cases of parent artery occlusion (trapping) or proximal occlusion for these aneurysms (1,2,6,8), and good outcomes with subclinical or

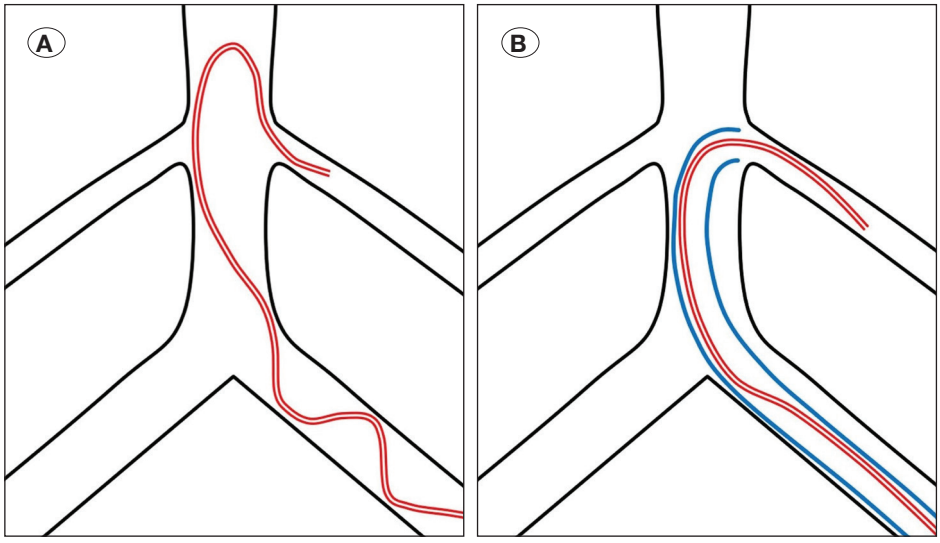

Figure 6: Illustrations depict the different statuses of a microcatheter without **(A)** and with **(B)** an intermediate guiding catheter when the microcatheter is pushed after selection into the origin of the target branch. Creating a curve at the tip of an intermediate guiding catheter by steam-shaping and locating its tip toward the origin of the target branch are key requirements to maximize the support, as well as to overcome the acute angle of the target branch.

even no ischemia have been frequently achieved, especially when the distal branch rather than main trunk is occluded. In the literature review of Hou et al., it was reported that 94.4% of distal branch occlusion cases experienced good recovery compared with 61.9% after main trunk occlusion (1). Lubicz et al reported three cases of parent artery occlusion in which no ischemia was observed (6). Peluso et al. also stated that five of eleven patients after parent artery occlusions had no infarction on magnetic resonance images (8). In this study, parent arteries were sacrificed in six cases; one microsurgical case and five endovascular cases. Four of the six cases were poor-grade initially, and their outcomes were also poor. The remaining two cases demonstrated complete recovery.

Distal accessibility is necessary for endovascular operations, and the role of the intermediate guiding catheter seems crucial. In one of the study cases, before intermediate guiding catheters became commercially available, the distal aneurysm was inaccessible and proximal occlusion was inevitable. In contrast, distal access was successful in all seven cases where intermediate guiding catheters were used. The installation of an intermediate guiding catheter up to the origin of the target branch helps to maximize the support and enables the distal advancement of the microcatheter to a further range. The AICA often courses downward at an acute angle from its origin in the basilar artery. The PICA may also start at an acute angle, although it usually makes a less sharp turn at its origin in the vertebral artery. Nevertheless, creating a curve at the tip of an intermediate guiding catheter by steam-shaping and locating its tip toward the origin of the target branch can certainly help to overcome the acute angle and distal access (Figure 6). These peripheral aneurysms often have a wide neck with atypical morphology, but, with the utilization of newly developed low-profile stents, the parent artery of a peripheral aneurysm can be preserved, minimizing the risk of ischemia. In addition, flow diversion using one or more low-profile stents can be a feasible and efficient option, but only for suitable unruptured cases if the lesion is located relatively proximally, as in Case 19. Continuing innovations in endovascular techniques and devices will continue to raise the treatment success rate for peripheral aneurysms in the posterior circulation. However, further large-scale studies with long-term follow-up data are required to elucidate the feasibility and durability of endovascular operations for these aneurysms.

The clinical outcomes of these peripheral aneurysms can be variable because of the high incidence of rebleeding (3, 10). In this study, all patients without rebleeding recovered fully, whereas eight of 13 patients with rebleeding recovered fully. The initial clinical grade seems to be closely related to the outcome, as with cases of usual aneurysms. In this study, all 14 cases categorized with an initial good-grade demonstrated full recovery without any neurological deficits, while only three of eight cases with poor-grade showed full recovery.

CONCLUSION

Aneurysms located beyond the origin of the major branches in the posterior circulation are rare cerebrovascular disorders. Their friable nature and distal location at a small tortuous branch are related to a high rate of rebleeding and the inevitable necessity of the sacrifice of the parent artery, which makes the treatment technically demanding. However, rapid advancements in endovascular technology, such as low-profile stents and intermediate catheters, enable distal access to the lesion and help preserve the parent artery. Endovascular operations are playing a gradually increasing role in the treatment of these unusual peripheral aneurysms, replacing some portion of traditional microsurgery.

AUTHORSHIP CONTRIBUTION

Study conception and design: YSL

Data collection: SJeS, YSL, SJS

Analysis and interpretation of results: SJS, YSL

Draft manuscript preparation: SJeS, YSL

Critical revision of the article: YSL

All authors (SJeS, YSL, SJS) reviewed the results and approved the final version of the manuscript.

REFERENCES

1. Hou K, Li G, Wang X, Xu K, Yu J: Endovascular treatment for peripheral superior cerebellar artery aneurysms: current state and future considerations. World Neurosurg 127:423-433, 2019
2. Ishikawa E, Yanaka K, Meguro K, Narushima K, Suzuki K, Wada M, Nose T: Treatment of peripheral aneurysms of the posterior circulation. No Shinkei Geka 28:337-343, 2000
3. Ishikawa T, Suzuki A, Yasui N: Distal posterior inferior cerebellar aneurysms-report of 12 cases. Neurol Med Chir 30:100-108, 1990
4. Krahulik D, Vaverka M, Hrabalek L, Trnka S, Kocher M, Cerna M: Distal aneurysms of cerebellar arteries-case series. Brain Sci 10:538, 2020
5. Lee SH, Koh JS, Bang JS, Kim GK: A case of ruptured peripheral aneurysm of the anterior inferior cerebellar artery associated with an arteriovenous malformation: A less invasive image-guided transcortical approach. J Korean Neurosurg Soc 46:577-580, 2009
6. Lubicz B, Leclerc X, Gauvrit JY, Lejeune JP, Pruvo JP: Endovascular treatment of peripheral cerebellar artery aneurysms. AJNR Am J Neuroradiol 24:1208-1213, 2003
7. Park JS, Lee TH, Seo EK, Cho YJ: Aneurysms of distal posterior inferior cerebellar artery. J Korean Neurosurg Soc 44:205-210, 2008
8. Peluso JP, van Rooij WJ, Sluzewski M, Beute GN: Distal aneurysms of cerebellar arteries: Incidence, clinical presentation, and outcome of endovascular parent vessel occlusion. AJNR Am J Neuroradiol 28:1573-1578, 2007
9. Rodriguez-Hernandez A, Zador Z, Rodriguez-Mena R, Lawton MT: Distal aneurysms of intracranial arteries: Application of numerical nomenclature, predilection for cerebellar arteries, and results of surgical management. World Neurosurg 80:103-112, 2013
10. Tokimura H, Yamahata H, Kamezawa T, Tajitsu K, Nagayama T, Sugata S, Takiguchi K, Taniguchi A, Niiro M, Hirahara K, Takasaki K, Oyoshi T, Arita K: Clinical presentation and treatment of distal posterior inferior cerebellar artery aneurysms. Neurosurg Rev 34:57-67, 2011
11. Yun YI, Chang CH, Kim JH, Jung YJ: Treatment for subarachnoid hemorrhage due to ruptured posterior cerebral arterial dolichoectasia with aortic arch anomaly. J Cerebrovasc Endovasc Neurosurg 25:69-74, 2023