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Technical notes & surgical techniques

Ruptured vertebral artery dissecting aneurysms involving a dominant posterior inferior cerebellar artery origin: A preferred indication for bypass surgery in clinical practice

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ABSTRACT

Background: In clinical practice, the optimal treatment approach for ruptured vertebral artery dissecting aneurysm (VADA) involving a posterior inferior cerebellar artery (PICA) remains unclear. Here, we report two cases of ruptured VADA involving a dominant PICA that were successfully treated with surgical occlusion with occipital artery (OA) to PICA bypass, while avoiding postoperative ischemia.

Case description: The first patient was a 47-year-old woman who presented with a Hunt–Hess grade III, diffuse subarachnoid hemorrhage (SAH) due to a ruptured right VADA involving a PICA. The PICA was dominant, supplying a wide vascular territory in the right cerebellum (the "PICA–anterior inferior cerebellar artery" variant). The second patient was a 56-year-old man who presented with a Hunt–Hess grade II, localized SAH due to a ruptured right VADA involving a PICA. The PICA was also dominant, supplying a wide vascular territory in the bilateral cerebellum (the "bihemispheric PICA" variant). Both patients were treated with OA–PICA bypass, which was followed by surgical trapping of the VADA in the first patient and proximal clipping in the second patient on the day of the SAH onset. The postoperative course was uneventful, and magnetic resonance imaging showed no apparent ischemic change in the brainstem and cerebellum in either patient.

Conclusions: For ruptured VADA involving a PICA, dominance of the involved PICA may be a practically preferred indication for bypass surgery because of the severity of ischemia when a dominant PICA is sacrificed and because the vascular anatomy of a dominant PICA makes anastomosis feasible.

1. Introduction

Ruptured vertebral artery dissecting aneurysm (VADA) is an important cause of subarachnoid hemorrhage (SAH), accounting for 3–5% of aneurysmal SAH cases, especially affecting young or middle-aged adults [1,2]. Because of a high propensity for rebleeding if untreated, urgent surgical or endovascular treatment is recommended [1]. Endovascular trapping has the best rationale for preventing rebleeding and, thus, has been the first-line treatment despite the risk of post-procedural medullary infarction [3–5]. With the development of stents and flow diverters, reconstructive endovascular techniques preserving the parent artery have also emerged as an effective endovascular treatment option in selected cases [6–13].

Ruptured VADA could occasionally involve the posterior inferior cerebellar artery (PICA), which complicates the treatment because sacrificing the PICA could lead to unfavorable prognosis resulting from the associated ischemia in the brainstem and cerebellum [13]. Various endovascular techniques with or without PICA preservation have been applied for ruptured VADA involving the PICA; however, the treatment effectiveness is less certain compared to that in ruptured VADA not involving the PICA [6,9,12,13]. Surgical revascularization of the PICA, such as occipital artery (OA) to PICA bypass and PICA to PICA bypass, is

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a definitive method to preserve the PICA flow [13–15]. However, such bypass procedures are technically challenging because they are strongly dependent on vascular anatomy that is amenable to the anastomosis. Hence, no consensus concerning the optimal treatment approach in clinical practice for ruptured VADAs involving a PICA exists. Nevertheless, when deciding whether the involved PICA should be preserved, the extent of the perfusion area of the PICA must be considered. The dominance of the involved PICA may be a principal factor indicating the preference for bypass surgery.

In this study, we report two cases of ruptured VADA involving a dominant PICA that were successfully treated by surgical occlusion with OA–PICA bypass, while avoiding ischemia in the brainstem and cerebellum.

2. Case presentation

2.1. Case 1

A previously healthy 47-year-old woman experienced a sudden headache and loss of consciousness and was admitted to our institution. There was no history of trauma, indication of connective tissue disorders, and taking antithrombotic drugs. The Glasgow Coma Scale score was 13 (E3V4M6) on admission (Hunt–Hess grade III). Computed tomography (CT) showed diffuse SAH (Fisher group 3) predominantly in the prepontine cistern (Fig. 1A). Cerebral angiography revealed a fusiform dilatation at the right intracranial VA that incorporated the origin of a large PICA into the dilatation (Fig. 1B, C). Due to its shape and location, the lesion was diagnosed as a ruptured VADA involving a PICA. The right PICA was dominant with an absent ipsilateral anterior inferior cerebellar artery (AICA), supplying a wide vascular territory in the right cerebellum (the "PICA–AICA" variant) (Fig. 1D). To prevent rebleeding while preserving the dominant PICA territory, urgent surgical intervention with OA–PICA bypass was performed. Written informed consent was obtained from a member of the patient's family preoperatively.

2.1.1. Surgery

The surgical procedure was performed with the patient in the park bench position and under general anesthesia on the day of the SAH onset (Video 1). After harvesting the OA and performing right lateral suboccipital craniectomy, the caudal loop of the right PICA was exposed and found to have a sufficient diameter as a recipient vessel (Fig. 1E). The OA was anastomosed to the PICA in an end-to-side fashion (Fig. 1F). Finally, the VADA was trapped with two aneurysm clips at the proximal and distal VA, and the PICA was permanently clipped at its origin to avoid retrograde aneurysm filling, thereby ensuring that blood flow in adjacent perforators was preserved (Fig. 1G). Indocyanine green

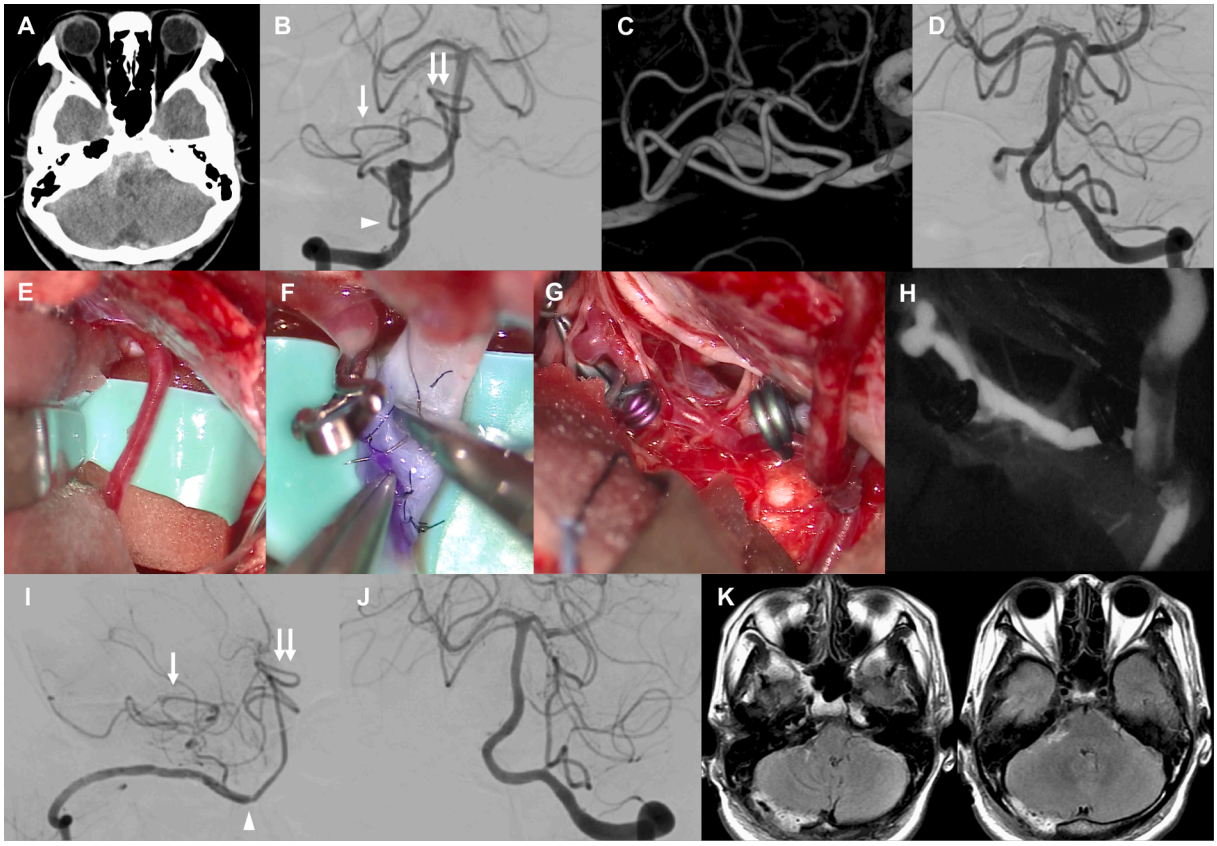
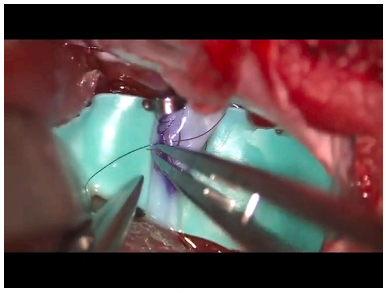


Fig. 1. Case 1. (A) Preoperative computed tomography showing diffuse subarachnoid hemorrhage predominantly in the prepontine cistern. (B, C, D) Preoperative cerebral angiography and three-dimensional angiography showing a right vertebral artery dissecting aneurysm (VADA) involving a large posterior inferior cerebellar artery (PICA). The right PICA is dominant with an absent ipsilateral anterior inferior cerebellar artery (AICA), supplying a wide vascular territory in the right cerebellum (the "PICA–AICA" variant) (arrow and double arrows). Note the caudal loop that is expected to be amenable to anastomosis (arrowhead). (E) Intraoperative photograph showing the caudal loop of the right PICA that was prepared as the recipient through lateral suboccipital craniectomy. (F) An occipital artery to PICA bypass was performed. (G) The VADA was clipped at the proximal and distal VA; the PICA origin was also clipped. (H) Indocyanine green videoangiography demonstrating bypass patency and no residual aneurysmal filling. (I, J) Postoperative cerebral angiography showing disappearance of the dissected lesion and preservation of the blood supply in the original right PICA territory (arrow and double arrows). Note the caudal loop that was successfully anastomosed (arrowhead). (K) Postoperative fluid-attenuated inversion recovery magnetic resonance imaging showing no apparent ischemic change in the brainstem and cerebellum. VADA = vertebral artery dissecting aneurysm PICA = posterior inferior cerebellar artery. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

videoangiography confirmed the bypass patency and absence of residual aneurysmal filling (Fig. 1H).



Video 1.

2.1.2. Postprocedural course

The postoperative course was uneventful. Cerebral angiography showed the disappearance of the dissected lesion and preservation of the blood supply in the original right PICA territory (Fig. 1I, J). Magnetic resonance imaging performed 7 days after the surgery demonstrated no apparent ischemic change in the brainstem and cerebellum (Fig. 1K). The patient was discharged without neurological deficit 30 days postoperatively.

2.2. Case 2

A 56-year-old man with a history of hypertension experienced a sudden headache and was admitted to our institution. There was no history of trauma, indication of connective tissue disorders, and taking antithrombotic drugs. The Glasgow Coma Scale score was 15 (E4V5M6) on admission (Hunt–Hess grade II). CT showed localized SAH (Fisher group 3) in the right cerebellopontine cistern (Fig. 2A). CT angiography revealed an irregular stenotic and dilated lesion at the right intracranial VA that incorporated the origin of a large PICA into the lesion. Due to its shape and location, the lesion was diagnosed as a ruptured VADA involving a PICA. The right PICA was dominant with a hypoplastic contralateral PICA, supplying a wide vascular territory in the bilateral cerebellum (the "bihemispheric PICA" variant) (Fig. 2B). To prevent rebleeding while preserving the dominant PICA territory, urgent surgical intervention with OA–PICA bypass was performed. Written informed consent was obtained from the patient and a member of the patient's family preoperatively.

2.2.1. Surgery

The surgical procedure was performed on the day of the SAH onset. The OA was anastomosed to the caudal loop of the right PICA, which had a sufficient diameter as a recipient vessel, in an end-to-side fashion (Fig. 2C, D). Finally, the VADA was occluded proximally with one

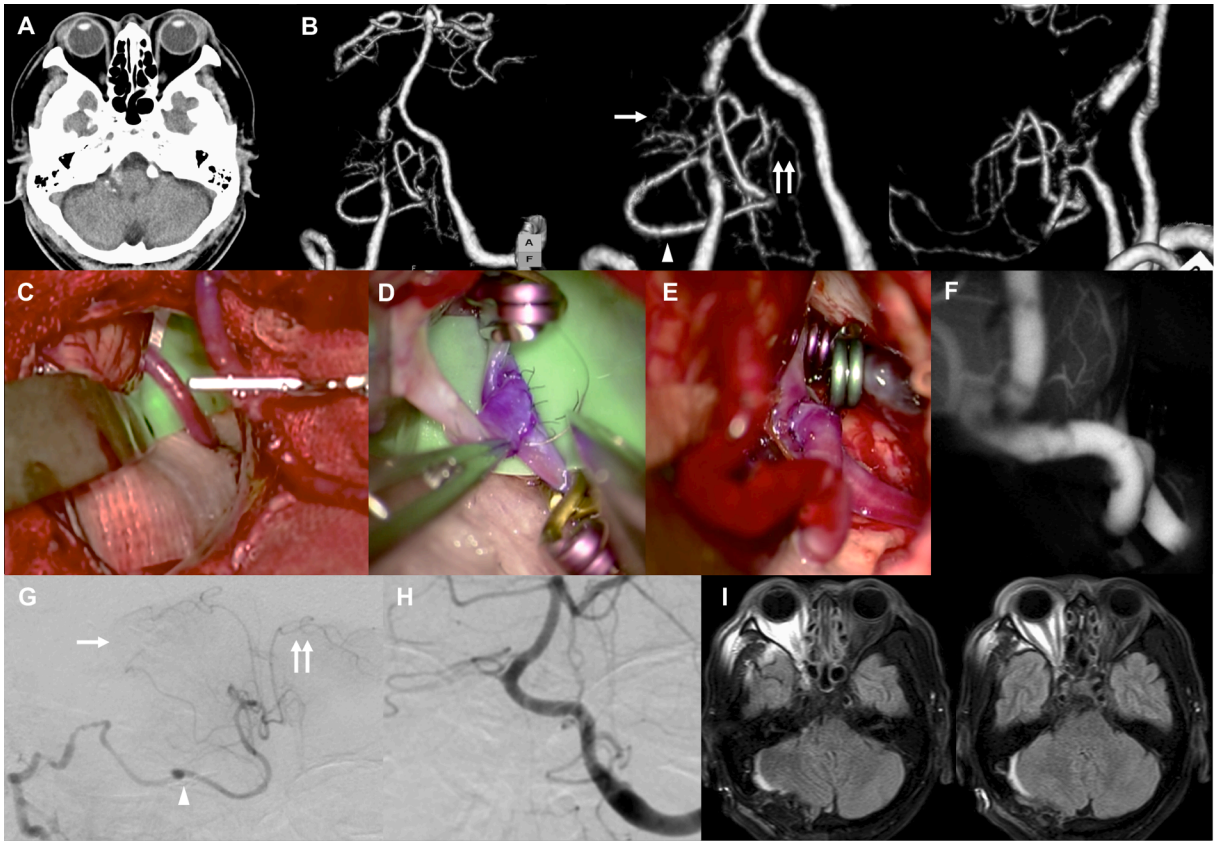


Fig. 2. Case 2. (A) Preoperative computed tomography showing localized subarachnoid hemorrhage in the right cerebellopontine cistern. (B) Preoperative computed tomography angiography showing a right vertebral artery dissecting aneurysm (VADA) involving a large posterior inferior cerebellar artery (PICA). The right PICA is dominant with a hypoplastic contralateral PICA, supplying a wide vascular territory in the bilateral cerebellum (the "bihemispheric PICA" variant) (arrow and double arrows). Note the caudal loop that is expected to be amenable to anastomosis (arrowhead). (C) Intraoperative photograph showing the caudal loop of the right PICA that was prepared as the recipient through lateral suboccipital craniectomy. (D) An occipital artery to PICA bypass was performed. (E) The VADA was clipped at the proximal VA; the PICA origin was also clipped. (H) Indocyanine green video angiography demonstrating bypass patency and no residual aneurysmal filling. (I, J) Postoperative cerebral angiography showing disappearance of the dissected lesion and preservation of the blood supply in the original right PICA territory (arrow and double arrows). Note the caudal loop that was successfully anastomosed (arrowhead). (K) Postoperative fluid-attenuated inversion recovery magnetic resonance imaging showing no apparent ischemic change in the brainstem and cerebellum. 1VADA = vertebral artery dissecting aneurysm PICA = posterior inferior cerebellar artery. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

aneurysm clip at the proximal VA because the distal end of the VADA was located at a high position, i.e., just proximal to the VA union. The PICA was permanently clipped at its origin to avoid retrograde aneurysm filling, thereby ensuring blood flow preservation in adjacent perforators (Fig. 2E). Indocyanine green videoangiography confirmed the bypass patency and the absence of residual aneurysmal filling (Fig. 2F).

2.2.2. Postprocedural course

The postoperative course was uneventful. Cerebral angiography showed the disappearance of the dissected lesion and preservation of the blood supply in the original right PICA territory (Fig. 2G, H). Magnetic resonance imaging performed 3 days after the surgery demonstrated no apparent ischemic change in the brainstem and cerebellum (Fig. 2I). The patient was discharged without neurological deficit 25 days postoperatively.

3. Discussion

We report two cases of ruptured VADA involving a dominant PICA that were successfully treated with surgical occlusion with OA–PICA bypass in acute settings, while avoiding ischemia in the brainstem and cerebellum. In cases with ruptured VADA involving a dominant PICA, surgical occlusion with PICA revascularization could minimize postoperative ischemia. In addition, the vascular anatomy of a dominant PICA makes anastomosis feasible. Thus, the dominance of PICA may be a practically preferred indication for bypass surgery.

Treatment for ruptured VADA involving a PICA is complex because the dual goals of preventing rebleeding and maintaining perfusion of the brainstem and cerebellum should be considered and numerous factors that may limit treatment altogether, such as aneurysmal configuration, presence of collaterals, and systemic conditions, exists. Reconstructive endovascular techniques using stents or flow diverters with or without coiling are ideal treatment options for VADA if the affected lesions have a feasible anatomy; however, in case of rupture, there are several procedural problems, such as low immediate occlusion rates and the need for antithrombotic therapy [6–13]. For ruptured VADA involving a PICA, this technique requires that the aneurysm be left partially open to ensure adequate PICA flow, which in turn puts patients at high risk of recanalization and could cause bleeding [6]. VA trapping with VA–PICA stenting is another effective endovascular technique, but application for this procedure are strongly dependent on the morphology of the aneurysm and branching [12]. Thus, parent artery occlusion remains the most reliable treatment for ruptured VADA involving a PICA, and the important matter to consider in clinical practice is whether to sacrifice or revascularize the involved PICA.

The consequences of PICA occlusion range from silent occlusion to infarction in the brainstem or cerebellum with swelling, hemorrhage, and death [16]. Hence, there is a reciprocal relationship in anatomy between ipsilateral PICA and AICA and between bilateral PICAs, with an inverse relationship between the sizes of the two [16–19]. A variant of a dominant PICA is a large PICA with a small or absent ipsilateral AICA (the PICA–AICA variant), as was shown in Case 1 [18]. Another variant is a large PICA with a small or absent contralateral PICA (the bihemispheric variant), as was shown in Case 2 [19]. If the PICA is dominant, the collateral circulation is likely to be poor, thereby leading to unfavorable PICA occlusion outcomes. In addition, the proximal part of the PICA provides critical perforators that supply blood to the highly eloquent medulla. Moreover, a reciprocal relationship between the perforators from the PICA and those from other arteries, such as the AICA, VA, and basilar artery, also exists [16,17]. The perforators from the PICA may also be more predominant when the PICA is dominant. Although there are reports of performing balloon occlusion tests as a criterion for deciding whether to sacrifice the vessel, there is no clear indication for the sacrifice with the results, especially in the cases with SAH [3]. Accordingly, preserving the PICA should be considered essential when the involved PICA is dominant.

The vascular anatomy of dominant PICA makes anastomosis feasible. Performing anastomosis in deep and narrow operative corridor near the brainstem and cranial nerves is technically challenging, especially in patients with SAH in the acute settings [20]. In addition, the procedure is more arduous if the recipient vessel has a small diameter. Previous cadaver studies reported that the mean diameter of the caudal loop of a PICA is 1.2–1.7 mm [20,21]. In our cases, the dimeters of the caudal loop were 1.4 mm and 1.8 mm in Case 1 and 2, respectively, which were sufficient recipient vessel diameters; the anastomosis was successfully performed without considerable difficulty. Thus, a dominant PICA with a larger diameter could be a feasible recipient vessel for the anastomosis. However, it should be noted that this surgery is a lengthy posterior cranial fossa operation, which carries the risk of being invasive, especially in the elderly and patients in poor general condition. Postoperative cerebrospinal fluid leakage and lower cranial nerve palsy are also well-known complications, although they did not occur in our cases.

Surgical and endovascular methods for the occlusion of ruptured VADA after PICA revascularization are available [1,4,13]. Although additional endovascular occlusion is a less invasive and safer option for this fragile aneurysm, there is an advantage in attempting surgical occlusion as endovascular occlusion typically requires placement of coils over some length of the dissected lesion, which could further occlude critical perforators [22]. In surgical occlusion, trapping is the first choice to prevent rebleeding, and proximal occlusion is chosen as the next option when distal securement is difficult [1,13]. However, it should be particularly noted that proximal occlusion without PICA occlusion could lead to recurrence and subsequent rebleeding because the aneurysm is sometimes still open to retrograde flow from the distal end of the VA [9]. Therefore, the PICA origin should also be occluded to reduce the retrograde flow and facilitate thrombosis of the aneurysm. If indocyanine green videography performed after the procedure confirms that retrograde blood flow has not reached the aneurysm, the risk of rebleeding should be low, as was the case in Case 2.

However, parent artery occlusion cannot be applied simply in cases where the contralateral vertebral artery (VA) is aplastic or hypoplastic [3,6,11]. In such cases, reconstructive treatment should be applied or balloon test occlusion must be done to evaluate the collateral blood flow. Hence, the treatment of ruptured VADA still has many challenges. From a pathological viewpoint, the most theoretical method for preventing rebleeding in ruptured VADA is to seal intimal tears and medial defects, especially in the entry zone [23]. If imaging studies could identify the accurate entry and the relationship between the PICA origin and the true or false lumen, more suitable treatment strategies may be established in the future. In clinical practice, optimal treatment must be carefully determined based on patient status and neurosurgeon's experience; nevertheless, examining the vascular anatomy is vital when weighing the benefits against the potential risks of different treatment options in the context of ruptured VADA involving a PICA. If other conditions allow for performing direct surgery, the dominance of the PICA may be a practically preferred indication for bypass surgery.

4. Conclusions

We report two cases of ruptured VADA involving a dominant PICA. The cases were successfully treated with surgical occlusion with OA–PICA bypass while avoiding ischemia in the large PICA territory. For ruptured VADA involving a PICA, dominance of the involved PICA may be a practically preferred indication for bypass surgery because of the severity of ischemia when the PICA is sacrificed and because the vascular anatomy of a dominant PICA allows anastomosis feasible.

CRediT authorship contribution statement

Taichiro Imahori: Conceptualization, Methodology, Investigation, Writing - original draft, Writing - review & editing, Project administration, Funding acquisition. **Yusuke Yamamoto:** Investigation.

Shinichi Miura: Investigation. **Masashi Higashino:** Investigation. **Masahiro Sugihara:** Investigation. **Takashi Mizobe:** Writing - review & editing. **Hideo Aihara:** Writing - review & editing. **Kohkichi Hosoda:** Writing - review & editing. **Kazuhiro Tanaka:** Writing - review & editing. **Takashi Sasayama:** Writing - review & editing. **Eiji Kohmura:** Supervision.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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