Radical treatment for bilateral vertebral artery dissecting aneurysms by reconstruction of the vertebral artery

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OBJECTIVE Bilateral vertebral artery dissecting aneurysms (VADAs) have a poor prognosis because progressive enlargement of the aneurysms compresses the brainstem or causes subarachnoid hemorrhage. The trapping of 1 vertebral artery (VA) places increased hemodynamic stress on the contralateral VA and may lead to enlargement and rupture. Therefore, management strategies are controversial. This study describes a radical treatment for bilateral VADAs using bypass surgery.

METHODS Seven patients with bilateral VADAs were included. Three patients were treated by trapping of 1 VA via coiling or clipping at another hospital; the previously treated VA in 1 patient and the contralateral untreated VA in 2 patients subsequently enlarged. The other 4 patients presented without previous intervention and progressive enlargement of the aneurysms.

RESULTS The post-coil embolization patients underwent V_3 –posterior cerebral artery (PCA) bypass and trapping. The other 4 patients underwent VA reconstruction via V_3 – V_4 or V_4 – V_4 bypass, with contralateral trapping on a separate day in 3 patients and observation in 1 patient. Perioperative complications included 1 case of cerebrospinal fluid leakage for which the patient required an additional operation, 1 case of dysphagia and facial palsy due to sigmoid sinus thrombosis, and 1 case of dysphagia. The long-term outcomes of these patients were favorable.

CONCLUSIONS Patients with bilateral VADAs require treatment on both sides. If VA trapping is performed first, the treatment options for the other side are limited to V_3 –PCA bypass and trapping. This procedure is effective; however, it is also invasive and technically difficult. In cases of bilateral VADAs in which it is feasible to reconstruct 1 side, the best approach is to begin by reconstructing the VA that appears technically easiest, followed by trapping of the contralateral VADA. This strategy allows enough time to suture vessels because contralateral reverse flow is maintained.

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KEY WORDS bilateral vertebral artery dissecting aneurysm; vascular reconstruction; V_3 – V_4 bypass; V_3 –PCA bypass; V_4 – V_4 bypass; vascular disorders

PATIENTS with bilateral vertebral artery dissecting aneurysms (VADAs) have a poor prognosis because progressive enlargement of the aneurysms compresses the brainstem or causes subarachnoid hemorrhage (SAH).^{11,18,33,36} Trapping of the vertebral artery (VA) places increased hemodynamic stress on the contralateral VA and leads to enlargement and possible rupture of that aneurysm.^{11,13,36} Thus, the optimal treatment strategy is controversial. Endovascular treatments, such as stent-assisted coiling, the stent-within-a-stent technique, or

covered stent graft treatment, are becoming increasingly common and have been reported to have relatively good outcomes.^{1,8,19,38,42,44} More recently, flow-diverting devices intended to hemodynamically exclude aneurysms from the parent vessel lumen as the primary treatment have been reported to have good outcomes.^{5,6,24,40} However, the long-term outcomes of such endovascular treatments remain unclear, and they are plagued by issues such as in-stent thrombosis and occlusion of important perforating arteries.^{4,16,25}

ABBREVIATIONS AICA = anterior inferior cerebellar artery; CN = cranial nerve; CTA = CT angiography; mRS = modified Rankin Scale; OA = occipital artery; PCA = posterior cerebral artery; PICA = posterior inferior cerebellar artery; RAG = radial artery graft; SAH = subarachnoid hemorrhage; SCA = superior cerebellar artery; STA = superficial temporal artery; SVG = saphenous vein graft; VA = vertebral artery; VADA = VA dissecting aneurysm.

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Concurrently, there has been a decline in open surgery for VADAs because of the difficulty of treating these aneurysms. However, recent technical and instrumental improvements for vascular reconstruction,^{17,20,21,41} as well as advances in skull base techniques,^{14,15,26,27} have again made open surgery a viable option for treating these complex aneurysms. This study describes the surgical strategy for the radical treatment of bilateral VADAs using bypass surgery.

Methods

Between April 2010 and April 2014, 7 patients with bilateral VADAs were treated. One patient who had undergone coil embolization performed at another hospital after SAH presented to our institution with progressive enlargement of the contralateral VA. One patient who had undergone coil embolization at an outside facility presented to our service with a recurrent aneurysm. Another patient, who was initially treated at another hospital with VA distal clipping and occlusion, presented to us with enlargement of the aneurysm and enlargement of the contralateral VADA. The 4 other cases presented without previous treatment with progressive enlargement of the aneurysms. Every patient underwent full clinical and neurological evaluations performed by an independent senior consultant neurosurgeon before treatment and at awakening, discharge, and the 6-month follow-up. The modified Rankin Scale (mRS) scores were recorded.

Surgical Intervention

The surgical indications for VADA included SAH, enlargement of the aneurysm, partial aneurysm thrombosis,

and brainstem compression. Our surgical algorithm was as follows. Patients in whom 1 VA was occluded underwent surgical or endovascular V₃–posterior cerebral artery (PCA) anastomosis using a radial artery graft (RAG) or a saphenous vein graft (SVG) with proximal occlusion or trapping of the affected VA. If the posterior inferior cerebellar artery (PICA) arose from the aneurysm or at the trapping site, an occipital artery (OA)–PICA anastomosis was performed. In cases of bilateral VA involvement, a 2-stage operation was performed. In the first operation, trapping of the VA with reconstruction, such as a V₃–V₄ or V₄–V₄ bypass using RAG or SVG, of the VA on 1 side was performed. If reconstruction of the VA was difficult, or dome clipping with preservation of VA anterograde blood flow was easy to perform, dome clipping with preservation of VA anterograde blood flow was selected. Then, proximal occlusion or trapping of the contralateral VA was performed in the second operation (Fig. 1).

Results

The clinical characteristics of the 7 patients are presented in Table 1. There was a predominance of male patients (71.4%). The ages of these patients ranged from 25 to 63 years (mean age 50.2 years). Perioperative complications were encountered in 3 patients during the first operation and in 1 patient during the second operation. The clinical presentation was sudden onset of posterior cervical pain in 4 patients, severe headache in 2 patients, and SAH in 1 patient (Hunt and Kosnik Grade II). The mean clinical follow-up was 19.2 months, and the mean angiographic follow-up was 18.4 months. Transient complications after the first operation were observed in 2 cases: 1 patient experienced facial nerve palsy and dysphagia, and 1 patient had severe dysphagia. It was difficult to discern

FIG. 1. Flowchart of the surgical strategy for bilateral VADAs. *The first interventional side should be determined as follows: for unruptured VADAs, whichever side is easier for reconstruction should be treated first; for ruptured bilateral VADA, the ruptured side should be treated first. **OA-PICA bypass or another bypass should be combined if needed.

TABLE 1. Surgical intervention and outcomes of bilateral VADAs

Case No.	Age (yrs), Sex	Clinical Presentation	Side	1st Op			2nd Op		
				Preop mRS Score	Postop mRS Score	Transient Complications	Transient CN Complications	Time to Op (mos)	Reason for Op
1	62, M	Pst cervical pain	V ₃ -RAG-V ₄ (rt), OA-perforating artery	0	0	CSF leakage, Wallenberg syndrome	None	12	Brainstem compression
2	24, M	Pst cervical pain	V ₃ -RAG-V ₄ (lt), OA-PICA	0	1	Venous infarction due to sigmoid sinus occlusion, dysphagia, facial palsy	VII, X	7	Brainstem compression
3	42, M	SAH (Hunt & Kosnik Grade II)	Endovascular trapping (lt)	0	0	None	None	15	Enlargement
4*	49, M	Pst cervical pain	Distal clipping (lt)	0	0	None	None	8	Enlargement
5	61, F	Pst cervical pain	Clipping w/ securing VA flow (lt)	0	0	None	None	10	Brainstem compression
6†	60, M	Headache	V ₃ -RAG-V ₄ (lt), OA-PICA w/ coil removal	0	3	Wallenberg syndrome	X	—	—
7	53, F	Severe headache	V ₄ -SVG-V ₄ (lt), OA-PICA	0	0	None	None	7	Brainstem compression

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TABLE 1. Surgical intervention and outcomes of bilateral VADAs

Case No.	Side	2nd Op (continued)			Final Op			Permanent CN Morbidity
		Preop mRS Score	Postop mRS Score	Transient Complications	6-mo mRS Score After Op	Clinical FU After Op (mos)	X-Ray FU After Op (mos)	
1	Prox clipping (lt)	1	1	CSF leakage, hydrocephalus (VP shunt)	1	23	23	Sensory disturbance of rt upper & lower limb
2	Prox clipping (rt)	1	1	None	1	17	17	Facial palsy (HB Grade I)
3	V ₃ -RAG-PCA (rt), STA-SCA, OA-AICA	0	0	None	0	21	21	None
4*	Clipping w/ securing VA flow (rt)	0	0	None	0	17	17	None
5	Prox clipping (rt)	0	0	None	0	36	36	None
6†	Under observation	—	—	—	2	12	12	Dysphagia
7	Endovascular trapping (rt)	0	0	None	0	9	3	None

FU = follow-up; HB = House-Brackmann; prox = proximal; pst = posterior; VP = ventriculoperitoneal.

* The first operation was performed at another hospital.

† The first operation (coil embolization and recanalization of the affected side) was performed at another hospital.

whether these 2 complications were a result of cranial nerve (CN) disturbance or brainstem disturbance since the former patient suffered a petrosal vein infarction and the latter patient suffered a lateral medullary infarction. The patient in Case 1 developed Wallenberg syndrome on the reconstructed side 1 month after the operation. There was only 1 transient complication (CSF leakage) after the second operation. There were no cases of mRS score worsening between the first and second operations. The mRS scores at 6 months after the final operation were 0 in 4 patients, 1 in 2 patients, and 2 in 1 patient. Permanent morbidity consisted of 1 case of sensory disturbance due to Wallenberg syndrome, 1 case of mild facial nerve palsy (House-Brackmann Grade I), and 1 case of dysphagia. No recurrence or other complications were identified during the follow-up.

Illustrative Cases

Case 2

A 24-year-old man developed sudden occipital neck pain and presented to our hospital where he was diagnosed with bilateral VADAs. Computed tomography angiography (CTA) showed fusiform aneurysms of the bilateral VAs. The left-side aneurysm was fusiform and partially thrombosed (Fig. 2).

The first operation was performed on the left side because the bilateral VAs deviated to the left side. This meant that the distal V_4 portion of the VA was easy to anastomose. The operation was performed in the park-bench position with a C-shaped skin incision. The suboccipital muscle dissection and transcondylar fossa approach were performed, followed by an OA-PICA bypass (the occlusion time was 25 minutes and 34 seconds). The aneurysm was then trapped and removed. We then proceeded with a RAG- V_4 bypass superior to the CN VII/VIII complex and then a V_3 -RAG anastomosis (Figs. 3 and 4). The total reconstruction time for V_3 -RAG- V_4 bypass was 65 minutes. The antegrade flow of both bypasses was good. Postoperative CTA showed good filling of the antegrade flow in the left VA. There was no immediate postoperative neurological deficit, but 24 hours after surgery the patient became drowsy and developed left CN VII palsy. CT showed obstructive hydrocephalus and hemorrhagic venous infarction in the petrosal vein territory. CT venography showed that the sigmoid sinus and petrosal vein were thrombosed. An external ventricular drain was placed, and the patient was managed medically. The facial palsy and auditory disturbance improved gradually, and the patient was discharged with a mRS score of 1.

The second operation was performed 6 months after the first. Proximal clipping was performed on the right

FIG. 2. Case 2. **A:** Preoperative CT angiogram showing bilateral VADAs and the partial thrombosis of the left-sided aneurysm. **B:** The bilateral VAs deviate strongly to the left side. The left-sided PICA also shows fusiform aneurysmal formation. **C:** Postoperative CT angiogram obtained after the first operation, showing good filling of the reconstructed VA and the OA-PICA anastomosis. **D:** Postoperative CT angiogram obtained after the second operation, showing a diminished left-sided aneurysm and good antegrade flow of the reconstructed left-sided VA. Figure is available in color online only.

FIG. 3. Case 2. Intraoperative images of the left-side transcondylar fossa approach. **A:** The PICA shows fusiform aneurysmal formation (arrowhead). **B:** OA-PICA anastomosis was performed. The anastomosis site of the PICA was not on the pathological wall, but on the normal wall. **C:** The proximal VA is secured caudal to the hypoglossal nerve. **D:** The proximal VA is clipped. **E:** The distal VA is secured in between CN IX, the CN X/XI complex, and the CN VII/VIII complex. The anterior spinal artery is shown (arrowhead). **F:** The distal VA is clipped proximal to the anterior spinal artery. An = aneurysm. Figure is available in color online only.

side. The patient's postoperative course was without complications. The final CTA showed good filling of the left VA with no aneurysm.

Case 3

A 42-year-old man developed an SAH (Hunt and Kosnik Grade II) and was transferred to another hospital where bilateral VADAs with left-sided rupture were diagnosed. Endovascular trapping of the right VA was performed, and he was discharged with an mRS score of 0. However, at his

3-month follow-up, the contralateral aneurysm was noted to be growing, and the patient's care was transferred to our institution (Fig. 5).

A V_3 -RAG-PCA bypass was planned (Figs. 6 and 7). The patient was placed in a left-side park-bench position, and suboccipital muscle dissection was performed with harvesting of the OA. The parietal branch and frontal branch of the superficial temporal artery (STA) were also harvested. Suboccipital craniotomy, temporal craniotomy, and mastoidectomy along with a transcondylar fossa ap-

FIG. 4. Case 2. Intraoperative images of the transcondylar fossa approach on the left side. **A:** After trapping the aneurysm, thrombectomy is performed. **B:** After internal decompression of the aneurysm, the aneurysm is removed. There is a wide space between the CN IX/X/XI complex and CN VII/VIII complex because of the aneurysm mass. **C:** RAG- V_4 end-to-end anastomosis is performed. **D:** Then, V_3 -RAG side-to-end anastomosis is performed. Here, the reconstruction of the VA is established. SS = sigmoid sinus. Figure is available in color online only.

FIG. 5. Case 3. **A:** Preoperative CTA was performed when the patient suffered a subarachnoid hemorrhage. The bilateral VADAs are shown. **B:** Left-side endovascular trapping is performed. **C:** Digital subtraction angiography performed 3 months after trapping shows enlargement of the right-side VADA. Figure is available in color online only.

FIG. 6. Case 3. **A:** The skin incision was designed for just above the parietal branch of the STA, curved to the front midline, and then curved to the posterior neck to include the OA (black line). **B:** Schema of the posterior circulation and aneurysm. **C:** Schema of the final situation: proximal clipping of the right VA and clipping of the origin of the PICA with STA-SCA bypass, OA-PICA bypass, V₃-RAG-PCA bypass, and pressure monitoring from the STA. **D:** Schema for correlation with Fig. 7. The rectangular areas and letters indicate the view of the operative images shown in Fig. 7. JB = jugular bulb; TS = transverse sinus. Copyright Nakao Ota. Published with permission. Figure is available in color online only.

FIG. 7. Case 3. Intraoperative images of the approach on the right side. **A:** Aneurysm and PICA are determined from the retrosigmoid field. **B:** OA-PICA end-to-side anastomosis is performed. **C:** The SCA on the right is determined from the presigmoid space. **D:** STA-SCA anastomosis is performed. **E:** The right P₂ portion of the PCA is determined from the presigmoid space. The PCA is present more in the cranial direction than the SCA. Then, RAG-PCA end-to-side anastomosis is performed. **F:** The V₃ portion of the VA is determined. **G:** V₃-RAG side-to-end anastomosis is performed. **H:** The RAG is running from the retrosigmoid space to the presigmoid space. SC = semicircular canal. Figure is available in color online only.

proach were performed. First, OA-PICA bypass was performed (the occlusion time was 24 minutes and 2 seconds), and then STA-SCA bypass was performed as a backup during VA occlusion (the occlusion time was 32 minutes and 3 seconds). Next, a V₃-RAG-PCA bypass was performed. The occlusion time of the RAG-PCA anastomosis was 45 minutes and 17 seconds, and that of V₃-RAG anastomosis was 12 minutes and 9 seconds. Pressure monitoring performed on the other branch of the STA-SCA bypass showed a decreased pressure wave when the V₃ portion of the VA was temporarily occluded. After establishing V₃-RAG-PCA bypass, the pressure improved, thus indicating that the V₃-PCA bypass was completely achieved. Finally, proximal clipping of the right VA and the origin of the PICA was performed. Postoperative CTA showed good filling of the V₃-RAG-PCA, STA-SCA, and OA-PICA

anastomoses without any aneurysm filling (Fig. 8). The patient was discharged with an mRS score of 0.

Case 4

A 49-year-old man developed sudden headache and was diagnosed with bilateral VADAs. He was initially followed conservatively. During this period of observation, the VADA on the left side grew and was treated by distal VA clipping/occlusion at another institution (Fig. 9). Follow-up at 1 year later showed that the contralateral VA was growing. He then came to our hospital.

A V₃-RAG-PCA bypass with VA proximal occlusion was planned. First, the transcondylar fossa approach was performed, and the aneurysm and parent artery were identified. The aneurysm dome was easily identified, making clipping of the aneurysm while securing VA blood flow technically feasible (Fig. 10). The patient was discharged with an mRS score of 0 and is undergoing periodic follow-up by CTA.

Discussion

The best treatment for unilateral VADA remains parent artery occlusion,^{10,12,22,34} but it is not feasible for bilateral VADAs. Trapping the VA places increased hemodynamic stress on the contralateral VA and leads to enlargement and possibly rupture.^{11,13,36} The same findings were seen in this series.

Although endovascular treatment for bilateral VADAs, such as stent-assisted coiling, the stent-within-a-stent technique, and covered stent graft, have been reported to have good outcomes,^{1,8,19,38,42,44} there are still concerns regarding their widespread use. First, the mass effect of the aneurysm cannot be decreased, especially in the early phase. Though Halbach et al.⁷ reported on the efficacy of endovascular embolization of intracranial aneurysms in patients presenting with a mass effect, many reports suggest that aneurysm enlargement occurs after endovascular trapping.^{2,3,9,23,39} This means that compression of the brainstem may increase and neurological symptoms may worsen. Second, the long-term outcomes are unclear. Iihara et al.⁹ reported the continued enlargement of a thrombosed VA aneurysm after complete endovascular trapping. They reported that adventitial neovascularization by the vasa vasorum may play a key role in enlargement, and surgical clip placement and aneurysmectomy should be considered. Thus, patients who were treated with endovascular trapping with a well-developed vasa vasorum require long-term follow-up. If recurrence or enlargement occurs, surgical trapping and aneurysmectomy are needed.^{30,37} Third, patients who undergo stenting need continued antiplatelet agents and strict follow-up using digital subtraction angiography. Lastly, the covered stent should avoid the orifice of the PICA, even when it is involved in the aneurysm. Thus, the aneurysmal wall with the involved vasa vasorum may not be completely occluded, and there may be a risk of recurrence and regrowth.

Flow-diverting stents have recently been introduced (these devices are not approved in Japan as of March 2015), and the reported periprocedural and midterm follow-up results to date have been impressive^{5,6,24,40} and

FIG. 8. Case 3. Pre- and postoperative CTA images. **A:** Preoperative CT angiogram showing the right-side VADA. The bilateral VAs deviate strongly to the left side. **B:** Preoperative CT angiogram. **C:** Postoperative CT angiogram showing good filling of the V₃-RAG-PCA bypass, STA-SCA bypass, and OA-PICA bypass. Figure is available in color online only.

marked by high rates of curative parent artery reconstruction with a reasonable level of treatment-associated morbidity and mortality. However, these studies include not only VADAs but also other aneurysm locations. Moreover, few studies focused on VADA;⁴³ especially in terms of bilateral VADAs, there has been only 1 case report.²⁸ In addition, flow-diverting stents are not approved for clinical application in Japan, and, as a very new technology, there are still few long-term follow-up results.⁴³ The previously mentioned concerns about other endovascular devices also exist for flow-diverting stents. Fiorella et al.⁴ and Klisch et al.¹⁶ reported very late thrombosis and occlusion of the VA and basilar artery after stopping clopidogrel because they could not achieve complete aneurysm obliteration, and the aneurysmal mass was not decreased. Presently, it is unclear if the intima covered by the stent retains its normal function, and patients may have to continue antiplatelet agents almost permanently. Martin et al.²⁵ reported delayed aneurysm rupture from thrombus-associated autolysis of the aneurysmal wall. Another important consideration is the maintenance of the patency of the branch vessels or perforators from the parent vessel. This is theoretically possible due to the presence of interstices between the stent strands, but the results have been mixed with cases of branch artery occlusion being reported.²⁵ Hence, direct surgical treatment using bypass, while highly technically demanding, may confer several advantages over endovascular therapies. First, there is no need to continue dual antiplatelet therapy because the reconstructed VA is covered by the normal intima. Second, complete obliteration of the aneurysm by trapping can be performed, and mass reduction by aneurysmectomy and thrombectomy can be achieved. If aneurysmectomy can be accomplished, the risk of recurrence or regrowth is eliminated. Third, OA-PICA anastomosis is easily added if PICA is involved in the lesion. Finally, if one side of the bilateral VADAs is treated by VA reconstruction, the treatment of the contralateral VADA is only parent artery occlusion, which is known to provide reliable outcomes.^{10,12,22,34}

Vascular reconstruction of the VA,^{20,21} such as V₃-RAG-V₄ anastomosis as the initial operation, is the most useful microsurgical method of treating bilateral VADAs. Favor-

able outcomes can be achieved if performed by a skilled neurosurgeon. Because the contralateral VA compensates for the blood flow of the basilar artery during anastomosis, there is sufficient time for temporary occlusion and reconstruction. After one VA is reconstructed, the treatment of the other side involves only parent artery occlusion. There are several essential components to this complex surgery. Determination of the initial operative side is key. Many cases of bilateral VADAs have serpentine-like VAs that deviate significantly laterally. The side to be reconstructed must be the one that is technically easier to reconstruct, even if the aneurysm on that side is smaller than the other. Dome clipping while securing VA blood flow is another option for these aneurysms if dome clipping appears feasible or VA reconstruction proves difficult. This may reduce lower CN injuries during the operation. However, this method also has problems, similar to endovascular stenting or trapping, and the pathologically abnormal vessel wall involving the vasa vasorum remains. This means that

FIG. 9. Case 4. Pre- and postoperative CTA images of the first operation. **A:** Before the first operation, the CT angiogram shows bilateral VADAs. The left side shows fusiform dilation, and the right side shows the string sign with a thrombosed aneurysm. **B:** After the first operation on the left side, CTA shows enlargement of the right-side aneurysm. Figure is available in color online only.

FIG. 10. Case 4. Pre- and postoperative CTA images of the second operation. **A:** Anterior to posterior CTA images before the second operation. **B:** Lateral view from left side before the second operation. **C:** Anteroposterior view after the second operation, showing how dome clipping with securing of the VA antegrade blood flow was performed. **D:** Lateral view from the left side after the second operation. Figure is available in color online only.

there is a risk of recurrence or regrowth of the aneurysm, and such cases require strict observation.

Though there are some case reports of favorable outcomes with trapping the ruptured side and waiting for the spontaneous resolution of the contralateral unruptured dissecting aneurysm^{31,32} or using bilateral conservative treatment,²⁹ long-term outcomes are still unknown and patients should be followed carefully. Staged bilateral occlusion for vertebrobasilar VADAs has been reported^{11,35} as having a favorable outcome, but it cannot be tolerated in many cases of bilateral VADAs if the patients do not have sufficient flow from the posterior communicating artery. Thus, there is a high risk of residual VA occlusion if the posterior communicating artery is not well developed. Hence, in cases where one side of the VA is occluded and the other side grows or ruptures (Case 3 in the present series), a V₃-PCA bypass must be performed before VA trapping. However, V₃-PCA bypass in this situation carries some risk because the blood flow of the basilar artery is stopped during anas-

tomosis of the V₃ portion of the VA; the contralateral VA is occluded and cannot compensate for the blood flow of the basilar artery. Thus, before performing V₃-PCA bypass, a backup bypass—such as STA–superior cerebellar artery (SCA), STA–anterior inferior cerebellar artery (AICA), or OA–AICA bypass—is needed to provide adequate blood flow during anastomosis. Since malfunction of the V₃-PCA is fatal, pressure monitoring from the other branch of these backup bypasses should be performed (Case 3 in the present series).

The position for this approach is the park-bench position, and suboccipital muscle dissection is necessary. Suboccipital muscle dissection allows easy harvesting of the occipital artery and securing of the V₃ portion of the VA. The most important merit of suboccipital muscle dissection is that the operative field becomes shallower and wider than the 1-layer approach,¹⁴ which facilitates less cumbersome suturing of the V₃-V₄ anastomosis.

A transcondylar fossa approach^{15,26,27} is needed for a V₃-V₄ bypass, or a combined presigmoid approach with mastoidectomy is needed for V₃-PCA bypass.⁴¹ With the transcondylar fossa approach, one can look up the operative field and use eggshell drilling to expose the sigmoid sinus and, thus, make a wide operative field on the lateral side.

The suturing location of V₄ anastomosis should be inferior to the CN VII/VIII complex, in between the CN VII/VIII complex and CN IX, or below CN X. The site of the end-to-end anastomosis between RAG and the distal end of the V₄ segment of the VA may be determined after removing the aneurysm. This may be especially true for cases of large aneurysms where removal provides an appropriate space to perform the end-to-end anastomosis with RAG. If the distal side of the V₄ segment could be mobilized superficially, end-to-end anastomosis becomes easier on the lower CNs.

Conclusions

Bilateral VADAs are treatable with favorable outcomes if direct VA reconstruction by RAG is performed with the correct operative strategy by a skilled neurosurgeon. A lateral suboccipital craniotomy provides sufficient exposure to perform the procedure. Suboccipital muscular dissection makes the operative field shallow and the operation easier to perform. Meticulous sigmoid sinus skeletonization and condylar fossa drilling are also important in order to widen the surgical field and perform the anastomosis in a deep surgical corridor in a layer-by-layer fashion.

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Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Ota. Acquisition of data: Ota. Analysis and interpretation of data: Ota. Drafting the article: Ota. Reviewed submitted version of manuscript: Tanikawa. Approved the final version of the manuscript on behalf of all authors: Ota. Administrative/technical/material support: Eda, Matsumoto, Miyazaki, Matsukawa, Yanagisawa, Suzuki, Miyata, Oda, Noda, Tsuboi, Takeda, Kamiyama, Tokuda. Study supervision: Tanikawa, Takeda, Kamiyama, Tokuda.

Supplemental Information

Previous Presentations

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