Vertebral Artery-to-Vertebral Artery Bypass with Interposed Radial Artery or Occipital Artery Grafts: Surgical Technique and Report of Three Cases

Hisashi Kubota[1], Rokuya Tanikawa[1], Makoto Katsuno[1], Naoto Izumi[1], Kosumo Noda[1], Nakao Ota[1], Yohei Ishishita[1], Takanori Miyazaki[1], Shinichi Okabe[2], Sumio Endo[3], Mika Niemelä[4], Masaaki Hashimoto[1]

Key words
- Everting technique
- Intracranial vertebral artery reconstruction
- Occipital artery graft
- Radial artery graft
- Vertebral artery-to-vertebral artery bypass

Abbreviations and Acronyms
ECA: External carotid artery
PCA: Posterior cerebral artery
PCOM: Posterior communicating artery
PICA: Posterior inferior cerebellar artery
RAG: Radial artery graft
STA: Superficial temporal artery
SVG: Saphenous vein graft
VA: Vertebral artery
VA-VA: Extracranial vertebral artery-to-intracranial vertebral artery

From the [1]Far East Neurosurgical Institute Abashiri Neurological Hospital, Hokkaido, Japan; [2]Department of Neurosurgery, Seirei Memorial Hospital, Ibaraki, Japan; [3]Department of Neurosurgery, Yokohama Shin-midori General Hospital, Kanagawa, Japan; and [4]Department of Neurosurgery, Helsinki University Central Hospital, Helsinki, Finland

To whom correspondence should be addressed: Rokuya Tanikawa, M.D. [E-mail: taniroku@gmail.com]

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BACKGROUND: **The treatment of unclippable vertebral artery (VA) aneurysms incorporating the posterior inferior cerebellar artery with parent artery preservation is among one of the most formidable challenges for cerebrovascular microsurgery and endovascular surgery. We propose that intracranial VA reconstruction using an extracranial VA-to-intracranial VA (VA-VA) bypass with a radial artery graft or an occipital artery graft may be an additional technique in the armamentarium to treat these formidable lesions. The rationale, surgical technique, and complications are discussed.**

METHODS: **Three illustrative cases are described, in which the lesions were a VA dissecting aneurysm with ischemic lesions, bilateral asymptomatic unruptured VA aneurysms, and a VA giant aneurysm with subarachnoid hemorrhage.**

RESULTS: **The partial extreme lateral infrajugular transcondylar approach was used. Computed tomographic angiography was useful for preoperative evaluation of the depth of the distal aneurysmal neck. A VA-VA bypass was performed in two patients. Because there was another ipsilateral aneurysm at the V2 segment in one patient, an external carotid artery–VA bypass was performed. Although two patients were discharged with good clinical results, one patient with subarachnoid hemorrhage died because of brainstem infarction.**

CONCLUSIONS: **The VA-VA bypass using a radial artery graft or an occipital artery graft is an option that can be considered in the strategy for treating VA aneurysms to preserve the normal anatomic vascular configuration in the posterior circulation.**

INTRODUCTION

Vertebral artery (VA) resection by microsurgical or endovascular trapping with posterior inferior cerebellar artery (PICA) revascularization is critical for treating PICA-involved unclippable VA aneurysms if the contralateral VA is patent. PICA can be revascularized using one of the methods described in previous reports, such as occipital artery (OA)–PICA bypass, PICA-PICA in situ bypass, PICA reimplantation, or VA-PICA bypass with radial artery graft (RAG) (2, 3, 7, 9, 13, 18).

The treatment of a VA aneurysm without a contralateral patent VA is technically challenging because of the difficulty in maintaining adequate blood supply to the entire posterior circulation. External carotid artery (ECA)–posterior cerebral artery (PCA) or VA-PCA bypass with RAG or saphenous vein graft (SVG) is required in these patients (5, 15, 19, 20).

Although endovascular therapy has emerged as an alternative means of treatment (1, 14, 16, 17), there is a subset of these lesions that have failed endovascular treatment. These lesions are extremely complex. This rare subset of lesions requires an uncommon treatment: specifically, reconstruction of the intracranial VA using an extracranial VA-to-intracranial VA (VA-VA) bypass after resection of a VA aneurysm. In this paper, we describe our technique of intracranial VA reconstruction using a VA-VA bypass with an RAG or an OA graft and present three representative cases. A VA-VA bypass can be an option for the complete exclusion of VA aneurysms and preservation of normal anatomical vascular structure.

Surgical Technique

The patient is placed in the park bench position. The head is fixed flexed to avoid venous congestion and rotated to the side opposite the site of the lesion. The mastoid body is the highest point in the surgical field. The partial extreme lateral infrajugular transcondylar exposure approach, which the authors always use for aneurysm treatment in the posterior fossa, is performed (6). A C-shaped skin incision is made from near the midline, 1 cm above the superior nuchal line, to near the C2 spinal process. Suboccipital muscles are reflected layer by layer; during this

procedure, the OA is safely dissected between the splenius capitis muscle and the semispinalis capitis muscle. The V3 segment is exposed in the suboccipital triangle, and the vertebral venous plexus is treated without inducing bleeding. A burr hole is created using a 5-mm extra-coarse drill burr; subsequently, sigmoid sinus skeletonization and suboccipital groove drilling is performed. After the craniotomy, the superior medial third of the occipital condyle is removed to expose the hypoglossal canal, through which the posterior part of a jugular tubercle is epidurally removed (Figure 1A). The lateral removal of bone is important for preparing a wide intradural space for anastomosis.

Next, an OA-PICA bypass is performed. The cuff of the recipient vessel is cut in a fish-mouth shape (Figure 1B). For reliable patency of the anastomosis, the cuffs between the recipient and donor vessels were opposed in an everting fashion to ensure that both endothelial layers were attached together (Figure 1C-F). The everting suture method reduces the formation of a thromboembolic source and makes the suturing safer and more accurate during the anastomotic procedure. The occlusion time during the OA-PICA bypass is less than 30 minutes. Patency was confirmed using Doppler sonography and an electromagnetic blood flowmeter.

The RAG or OA graft is prepared in an albumin-containing heparinized saline solution to check for leaks. One end of the graft is closed using a temporary clip, and the solution is injected into the other end. Leakage from tiny branches is confirmed by the pressure distention technique (15, 19).

Before performing the anastomosis between the V4 segment and the graft, the V4 is stabilized and surrounded with Gelfoam®, and a continuous drainage suction tube is put in place (Figure 1G). This manipulation is very important to ensure that there is a suitable and dry field for the bypass procedure. The VA-VA bypass is not associated with any limitations in occlusion time during anastomosis; therefore, suturing was carried out with meticulous care to avoid harming the lower cranial nerves. During end-to-end anastomosis using 9-0 nylon sutures, the cuffs of the donor and recipient vessels were cut in the fish-mouth configuration, using the same procedure as OA-PICA end-to-side anastomosis, in order to obtain a large orifice for the anastomotic part of the vessel (Figure 1B and Figure 1H). Importantly, heparinized saline solution was used to check for leakage at the anastomotic site. The proximal bypass was then performed using 8-0 nylon sutures in an end-to-side fashion. The cuff of the donor vessel was cut in a teardrop shape for V3-RAG, V3-OA graft, and ECA-RAG bypasses (Figure 1I).

Case Illustrations

Patient 1. A 44-year-old man was admitted to hospital with neck pain of 7 days' duration. Computed tomographic angiography (CTA) showed the pearl-and-string sign on the left VA (Figure 2A). The right posterior communicating artery (PCOM) was fetal type. A silent cerebellar infarction was detected on magnetic resonance imaging at 10 and 25 days. The aneurysm was surgically excised with an OA-PICA bypass at day 45. Intraoperative findings showed that the dissection reached PICA (Figure 2B). After an OA-PICA bypass was performed and resection of the aneurysm was achieved, we performed a bypass between the V3 and the V4 using an interposed OA graft (Figure 2C-E). The OA was long enough to reconstruct the resected part of the VA aneurysm. After the operation, the patient had transit dysphasia and was finally discharged without permanent neurologic deficits (Figure 2F).

Patient 2. A 41-year-old man was operated on for bilateral asymptomatic unruptured VA aneurysms (Figure 3A). The larger aneurysm on the left side was treated with OA-PICA and VA-VA bypasses with an RAG. Although the right PCOM was fetal type, the P1 segment of the right PCA was hypoplastic. Before aneurysmal resection, OA-PICA anastomosis was performed (Figure 3B). Next, a VA-VA bypass with an RAG was performed to reconstruct the intracranial left VA (Figure 3C-F). The proximal OA was occluded during the operation, because a thromboembolism occurred in the proximal portion of the OA. The proximal OA was transposed to the RAG (Figure 3D-F). The patient's condition improved without neurologic deficits (Figure 3G). The contralateral VA aneurysm was trapped after revascularization of the PICA by the OA 3 months later. The patient had no neurological deficits and was discharged within 4 weeks after the second procedure.

Patient 3. A 35-year-old man suffered from a subarachnoid hemorrhage with World Federation of Neurological Surgeons Committee grade IV and was transferred to our hospital. Although this patient presented with a poor-grade subarachnoid hemorrhage, surgical treatment was selected because of his young age. Angiography demonstrated a giant aneurysm on the right VA, in which there was another ipsilateral aneurysm at the V2 segment (Figure 4A). The left VA and both PCOMs were hypoplastic. To avoid ischemia of the posterior circulation, superficial temporal artery (STA)—superior cerebellar artery and OA—anterior inferior cerebellar artery bypasses were prepared before aneurysmal resection (Figure 4B). In this patient, the subtemporal approach was required for STA—superior cerebellar artery bypass, in addition to the partial extreme lateral infrajugular transcondylar exposure approach. An ECA-VA bypass with an RAG was performed to achieve intracranial VA reconstruction (Figure 4C-F). Proximal ECA-RAG bypass was accomplished first, to shorten the occlusion time of the VA and avoid long-term ischemia of the brainstem and cerebellum. This was different from the normal procedure, in which the distal bypass is performed first. The RAG was anastomosed to the ECA, because the V3 segment was not available because of V2 dissecting aneurysm. The aneurysm was consequently resected, after an end-to-end anastomosis between the RAG and the distal V4 portion (Figure 4C). Postoperative angiography and MR images showed good patency of the bypasses and no ischemic lesion, respectively (Figure 4E and Figure 4G). Although the patient's condition was improving, an epidural hemorrhage occurred 9 days after the operation. As a result, the patient died of brainstem infarction.

DISCUSSION

Type of Bypass Surgery

Drake et al. reported the results of a large series of VA aneurysms without revascularization (4). Although the decision for revascularization takes into account both the caliber and the dominancy of the VA, PICA,