The Strategy of Endovascular Treatment for Ruptured Vertebral Artery Dissecting Aneurysm, Based on Its Location Relating to the Position of the Posterior Inferior Cerebellar Artery Origin

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Objective: We evaluated the outcomes of endovascular therapy for ruptured vertebral artery dissecting aneurysm (VADA), focusing on its location relating to the posterior inferior cerebellar artery (PICA) origin.

Materials and Methods: Patients with ruptured VADA, treated in our hospital from January 2007 to July 2015, were divided into four groups with respect to the location of the PICA origin. In seven patients, the dissecting segment involved the origin of the PICA (PICA origin type). In all, 10 patients had dissection distal to the origin of the PICA (PICA distal type). In the remaining two patients, there was no definite PICA (non-PICA type). There were no patients with dissection proximal to the origin of the PICA (PICA proximal type). The postoperative course was retrospectively compared between the groups.

Results: Endovascular parent artery occlusion just proximal to the PICA origin was performed in the PICA origin group, whereas parent artery occlusion involving the whole dissected segment was performed for the other groups. In the PICA origin group, although re-bleeding had occurred in one patient, the modified Rankin scale score 3 months after the surgery, was less than 3 in all patients. Cerebral infarctions occurred in six patients in the PICA distal group and two patients in the non-PICA group. All two patients in the non-PICA group experienced medullary infarction, which occurred in only one patient in the PICA distal group.

Conclusion: Parent artery occlusion just proximal to the PICA in the PICA origin group is effective, but frequent follow-up is necessary to evaluate increase in the blood flow to the residual dissection due to newly developed collaterals. Embolization in the short segment is advised in the PICA distal group to minimize the risk of cerebral infarction due to occlusion of the perforating arteries. Avoiding medullary infarction in treating the non-PICA group remains a challenge.

Keywords: vertebral artery dissection, subarachnoid hemorrhage, endovascular therapy, posterior inferior cerebellar artery

Introduction

Recently, endovascular treatment has become widely accepted as a treatment for ruptured vertebral artery dissecting aneurysm (VADA) due to its low invasiveness.1–7) Although there have been recent reports documenting the effectiveness of stent-assisted coil embolization or flow diverter stent placement,8–10) but parent artery occlusion remains as a safe and effective treatment, particularly in the acute phase of rupture.11,12) To minimize the risk of re-hemorrhage and developing cerebral infarction following parent artery occlusion, it is important to make
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Subjects and Methods

Patients with ruptured VADA who were treated between January 2007 and July 2015 at our institution were retrospectively evaluated by classifying them into four groups according to the relationship between the lesion and PICA origin. In seven patients, the dissecting segment involved the origin of the PICA (PICA origin type). In all, 10 patients had dissection distal to the origin of the PICA (PICA distal type). In the remaining two patients, there was no identifiable PICA (non-PICA type). There were no patients with the dissecting segment proximal to the origin of the PICA (PICA proximal type). The patients in each group were treated according to our treatment strategy as described below. The patient background and postoperative course were evaluated based on the medical records. We also evaluated the relationship of post-treatment cerebral infarction with the ipsilateral origin of the anterior spinal artery (ASA), the distance from the distal end of dissection to the union of the vertebral arteries, and the distance from the union to the PICA origin.

Endovascular treatment

1) PICA origin type

Parent artery occlusion at just proximal to the origin of the PICA is performed to maintain the blood flow to the PICA via the contralateral vertebral artery. A balloon guiding catheter is used if it is feasible to prevent distal embolism during the embolization procedure. Angiography is not performed during embolization to prevent distal embolism.

2) PICA distal type

Occlusion of the entire dissecting portion is generally performed with special attention to the preservation of blood flow to the anterior spinal artery and perforating arteries from the distal vertebral artery. For this purpose, the vertebral artery was occluded in the shortest segment as possible. In addition, a guiding balloon catheter was not used to prevent ischemia of the PICA territory during embolization.

3) PICA proximal type

Parent artery occlusion of the entire dissecting segment is generally performed, but there was no case of this type in this study.

4) Non-PICA type

The dissecting segment of the parent artery is occluded in the shortest segment as possible to minimize the risk of perforator territory ischemia because a larger number of perforating branches generally originate from the vertebral artery in the non-PICA type.

Results

No marked difference was observed in the patient background among the groups (Table 1). During and after the procedure, treatment-related cerebral infarction occurred in 6 of the 10 PICA distal type patients and 2 of the 2 non-PICA type patients, more frequently than in the PICA origin type group (Tables 2 and 3).
### Table 2  Clinical course of involving the PICA origin group

<table>
<thead>
<tr>
<th>Age/Gender</th>
<th>Side</th>
<th>WFNS grade</th>
<th>Length between the lesion and the union</th>
<th>Length between the union and the PICA origin</th>
<th>Ipsilateral ASA</th>
<th>Cerebral infarction</th>
<th>Rebleeding</th>
<th>mRS after 3 mos.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>41M</td>
<td>Right</td>
<td>4</td>
<td>9.1 mm</td>
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<td>1</td>
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<tr>
<td>2</td>
<td>49F</td>
<td>Left</td>
<td>2</td>
<td>n.d.</td>
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</tr>
<tr>
<td>3</td>
<td>44M</td>
<td>Left</td>
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<td>n.d.</td>
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<tr>
<td>4</td>
<td>56M</td>
<td>Left</td>
<td>1</td>
<td>11.3 mm</td>
<td>+</td>
<td>-</td>
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<td>1</td>
</tr>
<tr>
<td>5</td>
<td>40M</td>
<td>Left</td>
<td>1</td>
<td>2.9 mm</td>
<td>+</td>
<td>-</td>
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<td>1</td>
</tr>
<tr>
<td>6</td>
<td>53M</td>
<td>Right</td>
<td>4</td>
<td>6 mm</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
<tr>
<td>7</td>
<td>47M</td>
<td>Right</td>
<td>2</td>
<td>11.5 mm</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>2</td>
</tr>
</tbody>
</table>

ASA: anterior spinal artery; mRS: modified Rankin Scale; PICA: posterior inferior cerebellar artery; WFNS: World Federation of Neurosurgical Societies

### Table 3  Clinical course of PICA distal group and non-PICA group

<table>
<thead>
<tr>
<th>Age/Gender</th>
<th>Side</th>
<th>WFNS grade</th>
<th>Length between the lesion and the union</th>
<th>Length between the union and the PICA origin</th>
<th>Ipsilateral ASA</th>
<th>Cerebral infarction</th>
<th>Rebleeding</th>
<th>mRS after 3 mos.</th>
</tr>
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<tr>
<td>PICA distal</td>
<td></td>
<td></td>
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<td>2</td>
<td>47M</td>
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<td>n.d.</td>
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<td>4</td>
</tr>
<tr>
<td>3</td>
<td>40F</td>
<td>Left</td>
<td>5</td>
<td>10.5 mm</td>
<td>+</td>
<td>n.d.</td>
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<td>6</td>
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<tr>
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<td>46M</td>
<td>Left</td>
<td>2</td>
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<td>-</td>
<td>+</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>51M</td>
<td>Left</td>
<td>2</td>
<td>8.8 mm</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>1</td>
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<tr>
<td>6</td>
<td>52M</td>
<td>Left</td>
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<td>6.2 mm</td>
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<td>1</td>
</tr>
<tr>
<td>7</td>
<td>49M</td>
<td>Right</td>
<td>1</td>
<td>12 mm</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>36M</td>
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<td>1</td>
</tr>
<tr>
<td>9</td>
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<td>11.5 mm</td>
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<td>1</td>
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<td>10</td>
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<td>Left</td>
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<td>1.5 mm</td>
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<td>1</td>
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<tr>
<td>Non-PICA</td>
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<tr>
<td>1</td>
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<td>5.1 mm</td>
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<td>+</td>
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<td>3</td>
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<tr>
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<td>46F</td>
<td>Right</td>
<td>4</td>
<td>7.8 mm</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>5</td>
</tr>
</tbody>
</table>

ASA: anterior spinal artery; mRS: modified Rankin Scale; PICA: posterior inferior cerebellar artery; WFNS: World Federation of Neurosurgical Societies
Table 2 shows the clinical course of the PICA origin group patients. Re-bleeding and treatment-related cerebral infarction occurred in one patient each, the modified Rankin Scale (mRS) score 3 months after the onset was one or two in all patients, demonstrating favorable outcome. Table 3 shows the clinical course of the PICA distal and non-PICA group patients. No re-bleeding occurred after treatment in these two groups, but treatment-related cerebral infarction occurred in six patients in the PICA distal group, including one medullary infarction. Occurrence of the cerebral infarction was related to neither the ipsilateral origin of the ASA, the distance from the distal end of dissection to the union, nor the distance between the union and the origin of the PICA. On the other hand, medullary infarction occurred in both patients in the non-PICA group (Fig. 1). In both patients, the length of dissection was approximately 10 mm, the distance from the distal end of dissection to the union was short, being 8 mm or less, and the mRS score after 3 months was ≥3 (Table 3).

Illustrative Cases

1) Involving the PICA origin type, case 6 (re-rupture after embolization)

A 53-year-old male suddenly onset of an occipital headache, vomiting, and disturbance of consciousness, and he was emergently transported to our hospital. On arrival, the level of consciousness was Glasgow Come Scale (GCS) E4V2M4. Head CT and 3D-CTA showed subarachnoid hemorrhage predominantly involving the posterior fossa and right VADA. A diagnosis of World Federation of Neurosurgical Societies (WFNS) grade IV and Fisher group 3 subarachnoid hemorrhage was made (Fig. 2A).

Endovascular treatment was performed on the same day. Angiography performed by navigating an 8 Fr Optimo 90 cm (Tokai Medical Products, Aichi, Japan) placed in the right vertebral artery showed VADA with the PICA originating near the center of the dissection (Fig. 2B). A Headway 17 (Terumo, Tokyo, Japan) and an Excelsior SL-10 (Stryker, Kalamazoo, MI, USA) were advanced to the dissected area, and embolization was performed using the double catheter technique. After placing 12 coils (Fig. 2C), angiography confirmed disappearance of the blood flow through the ipsilateral vertebral artery (Fig. 2D).

Although the postoperative course was generally uneventful, re-deterioration of consciousness appeared on the 14th hospital day. Cerebral angiography was performed on the same day as head CT suggested minor re-bleeding (Fig. 2E). Angiography of the left vertebral artery showed faint visualization of the residual part of the dissecting aneurysm with no visualization of the right PICA (Fig. 2F), suggesting washout of contrast material by the collateral blood flow from somewhere else. The decision was made to perform additional embolization through the left vertebral artery to further occlude the dissected segment of the vertebral artery.

A 6 Fr FUBUKI (Asahi Intec, Aichi, Japan) was placed in the left vertebral artery. Since navigation of a wire-guided catheter was considered difficult because of the acute angle of the union of the vertebral arteries, the Marathion microcatheter (eV3, Covidien, Irvine, CA, USA) was turned around at the basilar apex along with a Traxcess 14 (Terumo) and advanced into the dissected segment. The excess of the microcatheter in the basilar artery was reduced by withdrawing it. Additional embolization was performed using 5 ED coils (Kanaka Medix, Osaka, Japan) (Fig. 2G) until disappearance of the residual dissecting aneurysm was confirmed by the left vertebral angiography (Fig. 2H).

Angiography of the right vertebral artery demonstrated the right PICA opacified via the lateral spinal artery from the intradural part of the vertebral artery along with faint visualization of the residual dissecting aneurysm (Fig. 2I). Since the blood flow to the aneurysm was significantly stagnated, it was decided to not to perform additional embolization. He was referred to a rehabilitation hospital after placing a ventriculoperitoneal shunt for hydrocephalus. Angiography performed 3 months after the last treatment showed visualization of the right PICA via the right lateral spinal artery without opacification of the dissected part (Fig. 2J). The mRS score improved to 2 after 3 months and to 1 after 6 months, and the patient is currently followed up on an outpatient basis.
Endovascular treatment was performed on the same day. The dissected area was present distal to the PICA, and the distance between the distal end of dissection and the union was 1.5 mm (Fig. 3B). The ASA originated from the right vertebral artery. An 8 Fr Optimo (Tokai Medical Products) was navigated to the left vertebral artery, and a Headway 17 (Terumo) and an Excelsior SL-10 (Stryker) were advanced to the dissected area, which was then densely

2) PICA distal type, case 10

A 50-year-old female who suddenly noted occipital pain was emergently transported to our hospital. On arrival, GCS was E4V5M6 without focal neurological deficit. Head CT and 3D-CTA showed subarachnoid hemorrhage primarily in the posterior fossa and left VADA. A diagnosis of WFNS grade I and Fisher group 3 subarachnoid hemorrhage was made (Fig. 3A).
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reducing the risk of re-bleeding; 4) and 5) are preferable in preserving the parent artery; 1), 3), 4), and 5) can preserve the blood flow to the PICA; and 1) is the simplest among all.

The risk of re-bleeding after proximal occlusion of the parent artery alone varies in each report. Yasui et al. reported, by combining their own cases and those in the literature, that five of the nine patients (55.6%) who suffered re-bleeding died. Nonaka et al. on the other hand, reported no re-bleeding in eight patients after proximal occlusion of the parent artery. To date, to our knowledge, there have been no explicit data on the incidence of re-bleeding after proximal occlusion of the parent artery. In the present report, re-bleeding was observed in one (14.3%) of the seven patients, which did not markedly affect the outcome. Previous reports ascribed re-bleeding to the retrograde blood flow from the contralateral vertebral artery, and this possibility cannot be excluded in our cases of re-bleeding presented above. However, the right PICA was not visualized on angiography of the left vertebral artery at the time of re-treatment, suggesting the possibility that the anterograde blood flow from the newly developed collateral circulation was dominant over the retrograde blood flow from the contralateral vertebral artery, which we consider more likely to have been responsible for re-bleeding.

According to Lasjaunias et al., the lateral spinal artery is an intradural intersegmental anastomosis that latently connects the anterior inferior cerebellar artery (AICA), PICA, and cervical segmental arteries, and normal variations such as AICA-PICA, C1-PICA, and C2-PICA can occur depending on the persistence pattern of blood vessels. Therefore, restitution of the blood flow to the lesion through the latent anastomoses via the lateral spinal artery can occur sometime after occlusion of the parent artery. Although proximal occlusion of the parent artery is favorable in its technical simplicity and securing of the blood flow to the PICA, periodic assessment of the state of occlusion is necessary because of the potential of re-establishment of the flow to the dissection through the various latent anastomoses at the craniocervical junction. Since re-bleeding of the PICA origin type lesions occurs frequently within 2 weeks of the initial hemorrhage according to a previous report, cerebral angiography should be performed at least within 2 weeks after proximal occlusion of the parent artery to consider additional endovascular or surgical treatments as necessary. We consider that the appropriate timing of repeat angiography is in 10–14 days after the onset, considering the effects of cerebral vasospasm on the blood flow and the development of collateral circulations.

Discussion

1) Treatment for the PICA origin type

There are five modality of endovascular treatments for ruptured VADA in the acute phase: 1) proximal occlusion of the parent artery, 2) occlusion of the aneurysm along with the parent artery, 3) occlusion of the aneurysm along with the parent artery with bypass surgery, 4) stent-assisted coil embolization, or 5) flow diverter stent placement. Of these treatment option, 2) and 3) are superior to the others in
2) Treatment for the PICA distal type

Since the distance from the lesion to the vertebrobasilar junction is short in the PICA distal type, it is necessary to avoid damaging the perforating branches to the brainstem including the ASA during embolization.

According to the results of 11 autopsies by Akar et al., the ASA originated distally to the PICA in all subjects, and the mean distance from the vertebrobasilar junction was 6.5 mm (5–11 mm) on the right side and 8.5 mm (6–17 mm) on the left side. Additionally, they also reported that the perforating branches to the brainstem arising from the vertebral artery were located 7.8 mm (0–20 mm) and 7.0 mm (1–22 mm) from the vertebrobasilar junction on the right and left sides, respectively.17) In the PICA distal group at our hospital, the mean distance from the distal end of the lesion to the vertebrobasilar junction was 9.0 mm (1.5–12 mm). Nevertheless, no cerebral infarction affecting the outcome was observed. We performed parent artery occlusion avoiding occlusion of the ASA and the perforating branches to the brainstem identified by cerebral angiography, as a result of which, we experienced only one treatment-related medullary infarction.

Mercier et al.18) investigated 25 brain samples and reported that there were plenty of pial anastomoses on the anterior aspect of the medula oblongata and the surface of olivary nucleus in almost half the specimens, indicating that these important sites have some ischemic tolerance. Therefore, it could be possible to prevent major cerebral infarction by preserving the ASA and perforating branches identified by high-quality preprocedural angiography. If a large perforating branch is identified in the dissected area, it should be preserved by performing parent artery occlusion just proximal to it, even if some risk of re-bleeding may persists.

3) Treatments for the PICA proximal and non-PICA types

In the present study, there were no patients with PICA proximal type. Mercier et al. studied 50 vertebral arteries in 25 patients and reported that there were no perforating branches to the brainstem originating from the vertebral artery between the dural penetration and the origin of the PICA in 48 vertebral arteries.18) According to this result, the risk of perforator infarction by parent artery occlusion should be less in the PICA proximal type than in other types. On the other hand, Ikeda et al.19) reported that a longer segment of parent artery occlusion, particularly proximal to the dissection, results in more frequent medullary infarction. Therefore, even for the PICA proximal type, the length of parent artery occlusion should be as short as possible.

Concerning the non-PICA type, Mercier et al.18) reported that no perforating branches to the medulla oblongata originated from the PICA in AICA-PICA or C1-PICA type patients, perforating branches to the medulla oblongata originated from the intradural vertebral artery in all patients, and the mean number of such branches was 2.6. The risk of medullary infarction by parent artery occlusion for the non-PICA type is considered high, not only because the blood flow to the medulla oblongata cannot be expected from the PICA, but also because the origins of perforating branches from the vertebral artery are difficult to predict. Actually, both patients in the non-PICA group in our series postprocedurally developed medullary infarction, despite careful short-segment embolization. How to avoid brainstem infarction in non-PICA type dissection is to be addressed in the future.

| Conclusion |

Proximal occlusion of the parent artery seems to be effective for the treatment of the PICA origin type, but frequent follow-up by MRI or angiography is necessary because flow to the dissected segment can be restituted secondary to the development of the collaterals. For the PICA distal type, the risk of medullary infarction can be minimized by performing the shortest possible parent artery occlusion to avoid occlusion of the perforating branches. For the non-PICA type, the risk of medullary infarction by parent artery occlusion is high, and the best treatment method is to be elucidated in the future.

| Disclosure Statement |

There are no conflicts of interest to disclose regarding this paper.

| References |

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