Clinical and Neuroradiological Features of Intracranial Vertebrobasilar Artery Dissection

Takaaki Hosoya, MD; Michito Adachi, MD; Koichi Yamaguchi, MD; Tamami Haku, MD; Takamasa Kayama, MD; Takeo Kato, MD

Background and Purpose—We sought to determine the clinical and neuroradiological features of intracranial vertebrobasilar artery dissection.

Methods—The clinical features and MR findings of 31 patients (20 men and 11 women) with intracranial vertebrobasilar artery dissections confirmed by vertebral angiography were analyzed retrospectively. The vertebral angiography revealed the double lumen sign in 11 patients (13 arteries) and the pearl and string sign in 20 patients (28 arteries).

Results—The patients ranged in age from 25 to 82 years (mean, 54.8 years). Clinical symptoms due to ischemic cerebellar and/or brain stem lesions were common, but in 3 cases the dissections were discovered incidentally while an unrelated disorder was investigated. Headache, which has been emphasized as the only specific clinical sign of vertebrobasilar artery dissection, was found in 55% of the patients. Intramural hematoma on T1-weighted images has been emphasized as a specific MR finding. The positive rate of intramural hematoma was 32%. Double lumen on 3-dimensional (3-D) spoiled gradient-recalled acquisition (SPGR) images after the injection of contrast medium was identified in 87% of the patients. The 3-D SPGR imaging method is considered useful for the screening of vertebrobasilar artery dissection.

Conclusions—Intracranial vertebrobasilar artery dissection is probably much more frequent than previously considered.

Key Words: angiography ■ dissection ■ magnetic resonance imaging ■ vertebrobasilar circulation

Clinical reports, mainly from neurosurgeons, suggest that intracranial vertebrobasilar artery dissection often presents as a subarachnoid hemorrhage due to a dissecting aneurysm.1–6 However, neurologists note that extracranial and intracranial vertebrobasilar artery dissections often cause brain stem ischemia or minor clinical symptoms, such as headache.7,8 The clinical manifestations of intracranial vertebrobasilar artery dissection are still obscure, in part because neurosurgeons and neurologists have treated and described quite different groups of patients. New diagnostic methods for vertebrobasilar artery dissection in which MRI and MR angiography are used have been developed,9–15 but their clinical value has not been studied in patients with intracranial vertebrobasilar artery dissection. This study was conducted to determine the clinical and neuroradiological features of intracranial vertebrobasilar artery dissection.

Subjects and Methods
A total of 31 patients (20 men, 11 women) aged 25 to 82 years (mean, 54.8 years) with intracranial vertebrobasilar artery dissection confirmed by vertebral angiography were studied. Conventional arteriography and/or digital subtraction angiography with selective catheterization of vertebral arteries was performed in all 31 patients. In angiographic findings, the double lumen sign (the presence of a false lumen or an intimal flap)1,2,16,17 and the pearl and string sign1,4,5,18 were used as reliable angiographic findings of vertebrobasilar artery dissection. Of the other reported abnormal findings suggesting vertebrobasilar artery dissection, a string sign,1 tapered narrowing,1,19 total occlusion with proximal distension,2 and reten-

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TABLE 1. Initial Symptoms Due to Intracranial Vertebrobasilar Artery Dissection in 28 Patients

<table>
<thead>
<tr>
<th>Symptom</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Severe headache</td>
<td>11</td>
</tr>
<tr>
<td>Vertigo</td>
<td>11</td>
</tr>
<tr>
<td>Nausea, vomiting</td>
<td>9</td>
</tr>
<tr>
<td>Dysarthria</td>
<td>4</td>
</tr>
<tr>
<td>Tinnitus</td>
<td>4</td>
</tr>
<tr>
<td>Double vision</td>
<td>4</td>
</tr>
<tr>
<td>Dysesthesia</td>
<td>3</td>
</tr>
<tr>
<td>Consciousness disturbance</td>
<td>2</td>
</tr>
<tr>
<td>Hemiparesis</td>
<td>1</td>
</tr>
<tr>
<td>Dysphasia</td>
<td>1</td>
</tr>
</tbody>
</table>

TABLE 2. Clinical Diagnoses of 31 Patients With Intracranial Vertebrobasilar Artery Dissection

<table>
<thead>
<tr>
<th>Diagnosis</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Subarachnoid hemorrhage</td>
<td>3</td>
</tr>
<tr>
<td>Infarction</td>
<td>15</td>
</tr>
<tr>
<td>Wallenberg syndrome</td>
<td>7</td>
</tr>
<tr>
<td>Other brain stem infarction</td>
<td>5</td>
</tr>
<tr>
<td>Cerebellar infarction</td>
<td>1</td>
</tr>
<tr>
<td>Cerebral infarction*</td>
<td>2</td>
</tr>
<tr>
<td>Others</td>
<td>13</td>
</tr>
<tr>
<td>Aneurysm</td>
<td>4</td>
</tr>
<tr>
<td>Vertebrobasilar insufficiency</td>
<td>4</td>
</tr>
<tr>
<td>Sudden deafness</td>
<td>1</td>
</tr>
<tr>
<td>Headache</td>
<td>1</td>
</tr>
<tr>
<td>No abnormality</td>
<td>3</td>
</tr>
</tbody>
</table>

Numbers indicate the number of patients.
*Two patients presented with infarction in the middle cerebral artery territory.
The prognosis of vertebrobasilar artery dissection was relatively good. Twenty-five patients were followed up with only medication such as drug therapy for hypertension or anticoagulant therapy, 3 patients had balloon and/or coil embolization, and 3 patients had trapping or clipping operations. There were 8 patients with a complete remission of symptoms, 15 with good recovery, and 5 without remarkable change. The remaining 3 patients had no symptom of vertebrobasilar artery dissection, which was detected incidentally. There were no deaths in this patient series.

**Angiographic Findings**

All 31 patients showed positive angiographic findings (double lumen sign and/or pearl and string sign) in 41 arteries. Four patients had both the double lumen sign and pearl and string sign, 7 had the double lumen sign only, and 20 had the pearl and string sign only. Of the 41 dissected arteries, 18 were left vertebral arteries, 11 were right vertebral arteries, and 12 were basilar arteries. The right vertebral artery dissection was extended to an extracranial portion in only 1 case.

The initial arteriograms had been made from 6 hours to 8 months after the onset of symptoms in 28 patients, and diagnoses of vertebrobasilar artery dissection were obtained in 26 patients; 2 patients were diagnosed by follow-up angiography. The initial angiography was performed in 9 patients within 7 days after onset, 6 within a month, 9 within 3 months, and 5 after 3 months. The times of onset of dissection in 3 patients were not determined because their vertebrobasilar artery dissections were detected incidentally during investigation of other disorders.

Seven patients had follow-up angiography. There were 2 patients with progressive angiographic findings (Figure 1), 3 with regressive angiographic findings (Figure 2), and 2 with unchanged findings. In the 2 patients with progressive findings, evidence of vertebral or basilar artery dissection was not obtained by initial angiography. In 1 patient, although the initial angiography performed 3 days after onset showed localized stenosis of the intracranial segment of the right vertebral artery, the pearl and string sign was visible on follow-up angiography on day 96 (Figure 1). In another patient, the initial angiography performed on the day of onset showed mild wall irregularity of the basilar artery and occlusion of the right posterior cerebral artery. We suspected that these findings were the result of a basilar artery dissection, but these findings were not considered diagnostic. A follow-up angiography on day 8 revealed the pearl and string sign of the left vertebral artery to basilar artery. In 3 patients with regressive findings, initial angiography was performed on days 2, 7, and 20 after the onset of the symptoms. A follow-up angiography performed 36 days after onset in the first patient showed that the pearl and string sign of the left vertebral artery became regressive but was still evident. Reliable angiographic findings were not obtained by follow-up angiography of the remaining 2 of the 3 patients performed at 27 days and 5 months after onset, respectively.

**MR Findings**

An intramural hematoma on T1-weighted images emphasized as a specific MR finding was detected in 10 of the 31 patients (32%) and in 11 of the 41 arteries (27%). The initial MR images of these 10 patients had been made from 7 to 61 days after the onset of symptoms, except for 1 patient whose MR examination was done 6 months after onset. None of the 7
patients who had MR examinations within a week after onset showed an intramural hematoma. Three of the 4 patients examined in the second week showed an intramural hematoma, as did 0 of 2 in the third week, 1 of 1 in the fourth week, 5 of 14 in the second month, and 0 of 5 in the third month. In 1 patient, T1-weighted images obtained 7 days after onset did not show an intramural hematoma, which was identified by examination on day 21. In another patient, T1-weighted images obtained 45 days after onset did not show the intramural hematoma, which was confirmed by the examination on day 162 (Figure 1). Nine of the 10 patients with an intramural hematoma underwent follow-up MR examinations. The intramural hematoma completely disappeared in 4 patients (Figure 2) whose follow-up MR examinations were done from 75 days to 8 months after onset. In 2 patients who underwent MR examinations 9 and 11 months after onset, the size of the intramural hematoma was reduced. In another 2 patients, the intramural hematoma disappeared, but follow-up T1-weighted images performed 3 or 4 months later showed a new intramural hematoma at a different site. In 1 patient, the intramural hematoma did not change for 4 months. A patient with an intramural hematoma discovered on day 162 underwent surgery on day 169. Four arteries showed an intramural hematoma on T1-weighted images but no positive angiographic finding.

A double lumen on 3-D SPGR images after an injection of contrast medium was identified in 27 of the 31 patients (87%) and 27 of the 41 arteries (66%). This finding was observed in approximately half of the patients who underwent MR examinations more than a year after onset. Twelve patients with a double lumen underwent follow-up MR examinations. The double lumen disappeared in 3 patients, was present but limited in 1 (Figure 3), and did not change in 7. In 1 patient the double lumen became more clear (Figure 1). Eleven arteries showed a double lumen on 3-D SPGR but no positive angiographic finding.

MR findings of 2 of the 3 patients with subarachnoid hemorrhage are shown in Figures 1 and 2. In 1 patient whose CT revealed the spread of a high-density clot in the subarachnoid space, the intramural hematoma was not clear because of a high-intensity clot within the cistern, but MR angiography clearly showed the pearl and string sign. The double lumen was partly demonstrated at the junction between pearl and string.

**Extension of Vertebrobasilar Artery Dissection**

We evaluated the extension of the arterial dissection in each patient on the basis of both angiographic and MR findings. In 10 of 31 patients (32%), arterial dissection was limited to 1 vessel. Nine patients showed unilateral vertebral artery dissection, and only 1 patient showed basilar artery dissection. In the other 21 of 31 patients (68%), arterial dissection extended into 2 or 3 vessels. Bilateral vertebral arteries were involved in 7 patients, unilateral vertebral artery and basilar artery were involved in 7 patients, and bilateral vertebral arteries and basilar artery were involved in 7 patients.

**Discussion**

**Demography and Risk Factors**

Our series includes 31 patients with intracranial vertebrobasilar artery dissection documented by vertebral angiography and who had MR examinations. Although extracranial verte-
bral artery dissection has been reported to be more common than intracranial vertebrobasilar artery dissection.\textsuperscript{7,8,14,15,22} we found only 1 patient with extracranial vertebral artery dissection. Intracranial vertebrobasilar artery dissection is probably much more frequent than previously considered and is at least not a rare condition compared with extracranial vertebral artery dissection.

We adopted strict criteria for evaluating angiograms. Among abnormal angiographic findings suggesting vertebrobasilar artery dissection, the double lumen sign (the presence of a true and false lumen or an intimal flap)\textsuperscript{1,2,16,17} is considered the only pathognomonic finding of an arterial dissection, but this has rarely been confirmed. The pearl and string sign\textsuperscript{1,18} is not pathognomonic but is considered a reliable finding of an arterial dissection. Many authors described the pearl and string sign as a reliable finding of arterial dissection,\textsuperscript{1,2,4,5,16–18} and we concur. The string sign\textsuperscript{1,19} and tapered narrowing\textsuperscript{1,19} may also be reliable findings; however, an intracranial arterial stenosis without dilatation is often difficult to distinguish from arteriosclerotic changes or vasospasm due to subarachnoid hemorrhage. Total occlusion with proximal distension\textsuperscript{1} and retention of contrast medium\textsuperscript{1,3} may be important angiographic findings as results of an arterial dissection. We did not consider these findings to be arterial dissection in the present study.

Our patients with dissection are older than those in other reports. The mean age in other reports was nearly 45 years and ranged from 21 to 63 years.\textsuperscript{2–7,18,20,22} In our series the mean age was 54.8 years. Our series included 13 patients older than 60 years, whereas previous reports included only a few such patients. The peak age of onset in our patients was in the 40s, and the mean age of 54.8 years is younger than that observed for arteriosclerotic stroke. We emphasize that vertebrobasilar artery dissection occurs not only in young adults but also in older adults. In contrast to a female predominance or no gender dominance in extracranial vertebral artery dissection,\textsuperscript{8,20} intracranial vertebrobasilar artery dissection has shown a male predominance in many reports\textsuperscript{2–6,8} but a female predominance in 1 report.\textsuperscript{7} In the present study the male/female ratio was 20/11.

Hypertension is suggested as one of the risk factors for vertebrobasilar artery dissection.\textsuperscript{7,20} The incidence of previously documented hypertension varies between 25% and 50%.\textsuperscript{4,7} In our patients, hypertension was recorded in 7 of 31 patients (23%). We agree with Berger and Wilson,\textsuperscript{5} who stated that hypertension and atherosclerosis were rare in dissecting aneurysm of the vertebral artery.

Precipitants and Activities, Including Trauma
Minor or trivial trauma preceding dissection is found in many patients with extracranial vertebral artery dissection.\textsuperscript{22} Common events reported to cause such traumas are as follows: sports activities (eg, jogging), daily activities (eg, sneezing, head turning, sleeping with unusual head position), and potentially excessive torsion of the cervical spine (eg, during chiropractic manipulation, resuscitation, intubation, tonic-clonic seizure). In this study such events were reported by 9 of the 20 patients. Minor or trivial trauma is probably also related to intracranial vertebrobasilar artery dissection. Movement may directly injure the vertebral artery or often stretch it. Stretching of the extracranial vertebral artery may result in a tear at the boundary between the third (V3) and fourth (V4) segments, which are fixed around the dura matter. Vertebral artery dissection, which occurs at the craniocervical junction, may extend both proximally and distally.
Clinical Symptoms and Signs
Unilateral occipital headache and/or posterior neck pain has been emphasized as one of the most important clinical symptoms of spontaneous vertebral artery dissection.\textsuperscript{1–7,20–22} The frequency of headache in the present series was 55\%, which is relatively low compared with that in other studies.\textsuperscript{11} The true incidence of headache is probably higher, because this result was obtained from review of patients’ records. Some physicians may not have mentioned the presence of headache. Some patients did not complain of any symptom, including headache.

The clinical presentation of vertebral artery dissection is quite varied.\textsuperscript{7,8,20–22} Subarachnoid hemorrhage was shown in only 3 patients in the present study, and 2 of them were confirmed by lumbar puncture (Figures 1 and 2). This incidence of subarachnoid hemorrhage is lower than that in reports from neurosurgical departments.\textsuperscript{2–5} Brain stem stroke was common, in agreement with reports from neurological departments.\textsuperscript{7,20–22} More than 50\% of patients with intracranial vertebral artery dissection demonstrate symptoms related to brain stem ischemia. Wallenberg syndrome is the most frequent clinical syndrome in patients with brain stem stroke due to intracranial verteobasilar artery dissection. The reported incidence of Wallenberg syndrome in patients with vertebral artery dissection ranges from 26\% to 43\%.\textsuperscript{3,7,20,22} In addition, reports have indicated a probable association between intracranial vertebral artery dissection and Wallenberg syndrome.\textsuperscript{13,23} In the present study, 7 patients showed Wallenberg syndrome (23\%). This incidence is less than in other reports, but Wallenberg syndrome is the most frequent brain stem infarction and occurred more frequently than subarachnoid hemorrhage in our patients with intracranial verteobasilar artery dissection. The dissection decreases blood flow to branches that supply the lateral medulla.

Some patients had only mild symptoms such as headache, vertigo, or tinnitus, and in 3 patients verteobasilar artery dissection was detected incidentally. No symptom relating to verteobasilar artery dissection was observed in these 3 patients.

MR Imaging
Intramural hematoma\textsuperscript{9–12,14,15} on T1-weighted images, intimal flap\textsuperscript{11} on T2-weighted images, and double lumen and enhancement of the wall and septum on contrast-enhanced 3-D SPGR\textsuperscript{13} are MR findings that suggest arterial dissection. Of these MR findings, intimal flap on T2-weighted images was not evaluated in the present study. Enhancement of the wall and septum on contrast-enhanced 3-D SPGR was also not evaluated because this finding was shown only in occluded arteries and there was only 1 patient with this finding in this study. Therefore, we evaluated the findings of intramural hematoma on T1-weighted images using a spin-echo sequence and double lumen on contrast-enhanced 3-D SPGR. To avoid flow artifacts, a high-intensity signal lesion seen in the lowest slice was not considered an abnormal finding. We also rejected a finding of linear high-intensity signal lesion along the arterial wall, which could not be differentiated from flow-related enhancement.

The positive rate of intramural hematoma was 32\% in the present series, which was much lower than previously reported. According to Kitanaka et al,\textsuperscript{12} intramural hematoma of intracranial dissected vertebral artery was best revealed in the subacute to early chronic stage, but after 2 months, intramural hematoma could not be seen on MR images. On the basis of a review of patients with thoracic aortic dissections, Murray et al\textsuperscript{24} found a moderately strong correlation between the number of days after symptom onset and the signal intensity of the intramural hematoma, and they showed that T1-weighted images obtained within a week after onset rarely revealed high signal intensity. In our 7 patients who had MR examinations within a week after onset, we did not observe an intramural hematoma with a high signal. Our observations revealed a relatively high incidence of intramural hematoma in the subacute to early chronic stage. Among the 19 patients who had MR examinations after 1 week to 2 months, 9 patients with intramural hematoma were observed (47\%). This low rate may be explained by the presence of a pseudolumen without thrombosis, in which case there is blood flow in the pseudolumen, as is also frequently seen in aortic dissections. We studied a patient whose intramural hematoma was depicted on day 162 but was unclear on day 45 (Figure 1). In this patient, we suggest that rethrombosis of the pseudolumen occurred, which presented as an aneurysm on the follow-up angiogram obtained on day 95 because of thrombolysis of the thrombosed pseudolumen observed on the first angiogram. Several authors note the high sensitivity of intramural hematoma in arterial dissection,\textsuperscript{11,23} but they may have missed the diagnoses of arterial dissection in many patients without intramural hematoma.

Arterial dissection is probably a dynamic condition. Several authors described spontaneous improvement of the angiographic or MR angiographic findings.\textsuperscript{3,14,18,20,21} In addition, we observed progression of the angiographic findings in 2 patients, as previously observed.\textsuperscript{7,14,15} In these patients, the initial angiograms performed within a week after onset revealed a localized stenosis or a mild arterial wall irregularity. The occurrence of spontaneous thrombosis or spontaneous thrombolysis of the pseudolumen may not be rare. If spontaneous thrombolysis occurs, an intramural hematoma will not be detectable, because high signal intensity due to the thrombosed clot is observed in the subacute phase. In contrast, evidence of arterial dissection in the chronic phase may be obtained if the thrombosis occurs later. We emphasize that the duration between the onset and the examination is very important. It is possible that angiographic evidence of the arterial dissection or a finding of intramural hematoma on T1-weighted images cannot be obtained when the duration between the onset and the examination is within a week or >1 month. Accordingly, intracranial verteobasilar artery dissection should be considered a cause of vascular disease in the posterior fossa, even if T1-weighted images do not show an intramural hematoma.

Vascular Imaging
Contrast-enhanced 3-D SPGR is a useful method for screening of intracranial verteobasilar artery dissection; however, there have been few reports\textsuperscript{13} concerning contrast-enhanced
3-D SPGR. The positive rate of double lumen observed with this method was 87% in the present study, although the false-positive rate is unknown. We always observe the intracranial vertebral and basilar arteries using real-time reformation with planes perpendicular to the arteries. This has offered high-quality images on MR angiotomography with good spatial resolution. In normal subjects, some flow artifacts are observed. Central low signal intensity is frequently seen, and a semilunar hypointense lesion is often visible with a bending artery, which is clearly found on a section along the artery. We defined a double lumen as the existence of a definite low-intensity boundary between a high-intensity lumen (true lumen) and a moderate-intensity lumen (pseudolumen), which may represent a thrombosed clot or slow blood flow. If dilatation of the arterial lumen is also noted (Figures 1 and 2), we make the diagnosis of arterial dissection by MR images only. In such cases, we performed angiography to demonstrate abnormal findings indicating double lumen on SPGR and made careful observations, a protocol that may increase the number of patients with a correct diagnosis of vertebrobasilar artery dissection. In our experience, approximately 50% of such patients had angiographic and arterial dissection was confirmed in one third of them by angiography. We hypothesize that we can obtain a correct diagnosis in only a small number of cases with intracranial vertebrobasilar artery dissection because the diagnosis of arterial dissection cannot be made if evidence of it is not obtained by neuroradiological examinations.

Although previous reports have described that arterial dissection in the posterior circulation frequently involved 2 or 3 vessels on the basis of pathological studies or MR findings, its incidence is obscure. In the majority of reported cases, arterial dissections were limited to 1 vessel. Because of the limitation of each neuroradiological examination or field of view of the operation, the extension of arterial dissection might be an underestimation. In our present study we evaluated the extension of the arterial dissection on the basis of both MR and angiographic findings. An arterial dissection limited to a unilateral vertebral artery or basilar artery was rather rare (32%). However, there may also be many arterial dissections without positive neuroradiological findings. We consider that the vertebral artery dissection occurring at the third segment (V3) has a tendency to extend to the basilar artery and/or contralateral vertebral artery, since an aortic dissection often extends to its branches and/or the iliac arteries.

No case of subarachnoid hemorrhage due to intracranial vertebral artery dissection studied with MRI has been reported until now, to our knowledge. In the present study we described MR findings of 3 patients with subarachnoid hemorrhage. Intramural hematoma on T1-weighted images was clearly visible, except in 1 case with spread of a high-intensity clot within the cistern. A double lumen on 3-D SPGR was detected in all 3 cases. We did not find any specific MR finding or a specific angiographic finding for subarachnoid hemorrhage.

Some recent studies indicate the possibility of establishing the diagnosis of extracranial arterial dissection with the use of ultrasound, helical CT, and MR angiography. How-
tory and the reliability of the finding of double lumen on 3-D SPGR has not been determined.

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References
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