Noninvasive Detection of Vertebral Artery Dissection

Michael Hoffmann, MD; Ralph L. Sacco, MD; Stephen Chan, MD; and J.P. Mohr, MD

Background and Purpose: We sought to identify the use of duplex and transcranial Doppler sonography in the noninvasive diagnosis of vertebral dissection.

Methods: Ten patients with a diagnosis of symptomatic vertebral artery dissection confirmed by cerebral angiography were retrospectively analyzed.

Results: Computed tomographic scanning and magnetic resonance imaging together delineated lateral medullary or cerebellar infarcts in 7 patients. Angiography documented a total of 21 vertebral artery lesions (16 stenoses and 5 occlusions), with 7 of 10 patients having multiple sites of vertebral artery dissection. Vertebral Doppler was abnormal in 8 of the 10 patients. A high resistance signal in the relevant vertebral artery was found in 6 patients, no flow in a well-imaged vertebral artery in 1, and bilateral retrograde vertebral artery flow in 1 patient. Transcranial Doppler was abnormal in only 2 patients, with reduced pulsatility index in 1 and high resistance vertebral signal in another. A hyperintense intramural signal of the affected vertebral artery by magnetic resonance imaging was documented in 1 patient in whom Doppler sonography was nondiagnostic.

Conclusions: Vertebral artery dissection can be detected and monitored by noninvasive vertebral Doppler and magnetic resonance imaging in the setting of a clinically suggestive presentation. (Stroke 1993;24:815–819)

KEY WORDS • magnetic resonance imaging • ultrasonics • vertebral artery

Dissection of the cervicocephalic vessels increasingly is being recognized as a treatable cause of stroke.1 An appreciation of internal carotid artery dissection preceded that of the vertebral arteries, but during the last decade approximately 100 cases of vertebral artery dissection cases have been documented in the English language medical literature.2-5 Vertebral artery dissection more commonly afflicts young and middle-aged adults; it has a remarkably good prognosis with rare recurrence and usual resolution in 63% to 88% after a period of 2 to 3 months, as documented by cerebral angiography.2-6

The favorable natural history of vertebral artery dissection emphasizes the need for a noninvasive approach to the detection, monitoring, and follow-up of this condition. Angiography of the vertebrobasilar system is associated with a higher morbidity and mortality rate compared with the carotid circulation.7 Furthermore, angiography alone is not always definitive in the diagnosis of vertebral dissection.2 Rather, a constellation of plausible antecedent events, appropriate symptomatology, and the findings of a lateral medullary syndrome or fragments thereof set the stage within which the angiogram is interpreted. A characteristic high-resistance Doppler flow pattern has already been described in patients with carotid artery dissection.8

Doppler scanning of normal vertebral arteries is well described,9,10 and its comparison with angiography has been reported.11 The useful application of duplex Doppler in vertebral artery dissection has also been reported.12 We present a retrospective descriptive case series of 10 patients with vertebral artery dissection, all of whom had cerebral angiography and Doppler investigations.

Subjects and Methods

We retrospectively reviewed 10 consecutive patients with vertebral artery dissection for a 4-year (1987 to 1991) period. In these patients, cerebral arteriography, duplex Doppler (Diasonic), and transcranial Doppler (TCD; 2-MHz probe and EME TC-264-B) sonography were performed, as well as head computed tomography (CT) scan or magnetic resonance imaging (MRI). The inclusion criteria for this series were based on angiographic documentation of dissection. This case series represents patients admitted acutely as well as those transferred after ictus to our stroke service. All CT, MRI, and duplex Doppler studies were performed within the first 2 weeks of presentation. In all cases, the initial vertebral artery Doppler study was done before arteriography, and therefore the technician was unaware of the diagnosis of dissection.

Vertebral angiography was performed with attention paid to the entire length of the vertebrobasilar system using fluoroscopy, digital imaging, and rapid cut-film imaging. Test injections were made to assess patency and flow pattern of the proximal vertebral arteries, with digital images obtained when necessary. After demonstration of the patency of the vessel, the catheter tip was placed into the proximal vertebral artery, and the entire
length of the cervical portion of the vertebral artery was studied under fluoroscopy and digital imaging. If satisfactory flow of contrast from the vertebral artery up to the basilar artery and posterior cerebral arteries was demonstrated, a cut-film series of the vertebral artery was then performed for complete documentation. This series was usually obtained in the Caldwell position for optimal depiction of the distal vertebral arteries where the majority of the dissections were found. Both vertebral arteries were studied in this manner, with an additional view obtained if necessary for further evaluation. Subtracted views of selected images were obtained. Positive findings indicating presumptive vertebral artery dissection included at least one of the following: (1) stenosis (usually irregular), (2) occlusion, (3) pseudoaneurysm, and (4) intraluminal defect (thrombus). A single stenosis without irregularity was considered suspicious for, but not definitely indicative of, dissection.

A standard duplex Doppler examination recorded flow velocity and direction and waveform characteristics in the vertebral, common, external, and internal carotid arteries. A high resistance signal in the vertebral artery was diagnosed when no diastolic flow was evident in the Doppler signal, combined with the characteristic acoustic quality of the signal. Standard TCD investigation measured flow velocity, direction, and pulsatility in the middle, anterior, and posterior cerebral arteries and in the vertebral and basilar arteries. Follow-up sonologic data were available in four patients.

Results

Among the 10 patients with vertebral artery dissection, the mean age was 36 years (age range, 24 to 58 years) in the 8 men and 2 women. Six were white, 2 Hispanic, and 2 Asian. Some form of trivial injury occurred in 8 patients; neck manipulation or exercises were a likely precipitant in 5, and a motor vehicle accident, jogging, and jumping preceded the onset of neurological symptoms in 3 other patients. Seven patients had neck pain. Among the 10 patients, 6 presented with a lateral medullary syndrome, the remainder with elements thereof or brain stem deficits. Six of the 10 patients had an excellent outcome at 6-month follow-up. Four patients were left with mild residual symptoms.

CT was positive in 6 of 10 patients. MRI was performed in 7 patients and was superior to CT for imaging the relevant infarct, being positive in 2 patients in whom CT was negative. Cerebellar infaracts were found in 6 and lateral medullary infarcts in 3 patients. Two patients had a normal CT and MRI.

The findings on duplex Doppler and TCD and the angiographic sites of dissection are presented in Table 1. Overall, duplex Doppler abnormalities were found in 8 of the 10 patients. Of the 10 patients, 6 had a high resistance signal in the vertebral artery in question (Fig 1), 1 had no flow detected in a well-imaged vertebral artery, and 1 patient had reversed flow in both vertebral arteries. Two patients had an initially normal study. Follow-up Doppler was limited to 4 patients. In 2 patients the signal normalized from a high resistance signal at the first examination, and in 2 patients the high resistance signal persisted, but in 1 of the 2 the resistivity index (systolic velocity minus diastolic velocity divided by the systolic velocity) improved.

TCD data in this series were largely normal. Only two patients had an abnormal result; a low pulsatility index in the basilar artery was found in one patient, and increased velocity in the dissected vertebral artery in another (Table 1). The latter patient had diffuse narrowing of the right vertebral artery, as well as involvement of the vertebrobasilar junction on angiography.

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**Table 1. Vascular Imaging Results Among 10 Patients With Symptomatic Vertebral Artery Dissection**

<table>
<thead>
<tr>
<th>Duplex Doppler</th>
<th>Transcranial Doppler</th>
<th>Artery</th>
<th>Abnormal segments</th>
<th>Follow-up duplex Doppler</th>
</tr>
</thead>
<tbody>
<tr>
<td>HRS in LVA</td>
<td>Normal</td>
<td>LVA</td>
<td>V1, V3</td>
<td>Normal (6 mo)</td>
</tr>
<tr>
<td>HRS in LVA</td>
<td>Normal</td>
<td>LVA</td>
<td>V3</td>
<td>Normal (6 mo)</td>
</tr>
<tr>
<td>HRS in RVA</td>
<td>Normal</td>
<td>RVA</td>
<td>V1, V3*</td>
<td>HRS (6 mo)</td>
</tr>
<tr>
<td>HRS in LVA</td>
<td>Normal</td>
<td>RVA</td>
<td>V2</td>
<td>HRS (5 mo)</td>
</tr>
<tr>
<td>HRS in RVA</td>
<td>Normal</td>
<td>LVA</td>
<td>V1*</td>
<td>Not done</td>
</tr>
<tr>
<td>No flow</td>
<td>High flow</td>
<td>LVA</td>
<td>V2*</td>
<td>Not done</td>
</tr>
<tr>
<td>in LVA</td>
<td>in RVA</td>
<td>RVA</td>
<td>V3</td>
<td>Not done</td>
</tr>
<tr>
<td>Retrograde flow in RVA and LVA</td>
<td>Normal</td>
<td>LVA</td>
<td>V1*</td>
<td>Not done</td>
</tr>
<tr>
<td>Normal</td>
<td>Low PI in BA</td>
<td>LVA</td>
<td>V2</td>
<td>Not done</td>
</tr>
<tr>
<td>Normal</td>
<td>Normal</td>
<td>RVA</td>
<td>V2</td>
<td>Not done</td>
</tr>
</tbody>
</table>

HRS, high resistance signal; LVA, left vertebral artery; RVA, right vertebral artery; PI, Pulsatility index; BA, basilar artery; V1, Proximal vertebral artery; origin to transverse foramen and intraforaminal C6 to C2; V2, C1-C2 articulation; V3, distal vertebral artery; C1 to base of skull; V4, intradural segment of vertebrobasilar junction.

*Oclusion of these arterial segments.
Among the 10 patients, 21 sites of dissection were found by angiography (Table 1). These were frequently found at the proximal (7/21), C1-C2 (7/21), and distal (6/21) vertebral artery segments. Only 1 patient had intradural dissection of the vertebral artery, and no dissections were found in the middle segment. Stenoses were the most frequent angiographic finding (16/21), and arterial occlusion was found in 5 of 21 (Table 2). No pseudoaneurysm or intraluminal clot was noted in the angiograms in our series. Dissections were frequently multiple (7/10) and often bilateral (5/10). Diffuse narrowing (3/21) was not common in our series, and concomitant cervical internal carotid artery dissection was found in only 1 patient.

Although brain MRI was performed in 7 of the 10 patients, cervical MRI was done in only 1 patient, and magnetic resonance angiography was not available during the conduct of this study. In this patient the clinical and angiographic findings were suspicious but not definitely diagnostic of vertebral artery dissection. An MRI scan of the cervical region clearly demonstrated a hyperintense signal within the vertebral artery wall, a finding consistent with dissection of that artery (Fig 2).

**Discussion**

The list of relatively benign and often mundane activities temporally linked to vertebral artery dissection continues to increase. Recently, tonic-clonic sei-
Maneuvers have been added to the list of yoga, chiropractic manipulation, calisthenics, aerobic exercises, ceiling painting, and trampoline exercises.\textsuperscript{2,13-15} Chiropractic manipulation seems to be particularly notorious etiologically, having been the subject of numerous publications.\textsuperscript{16-21} In addition, deficits from vertebral artery dissection are variable and include partial brain stem syndromes, Wallenberg's lateral medullary syndrome, isolated amnesia,\textsuperscript{22} and a locked-in syndrome.\textsuperscript{23} As documented by our series and others, a high index of suspicion is required in any young person presenting with posterior circulation symptomatology and possible antecedent trauma, however trivial.

Findings on cerebral angiography are helpful but not always diagnostic of vertebral artery dissection. When specific radiographic signs such as pseudoaneurysm or intraluminal clot are found, the diagnosis is usually assured. As documented in our series, these features are infrequent. More often, irregular stenoses or occlusions are found, which are less specific for artery dissection and may be observed in atherosclerotic or partially recanalized embolic occlusions of the vertebral artery. The diagnosis may be suspect unless the angiographic findings are interpreted in conjunction with the clinical presentation, as was true for all of our 10 cases.

Functional noninvasive imaging with duplex Doppler and TCD seems particularly suited in this clinically dynamic condition. The patency and state of the dissected vessel may alter over days to weeks,\textsuperscript{5,6} making this a suitable condition for repeated ultrasonic measurement of blood velocity, resistance to flow, and resolution to normal. A high resistance signal was the most frequent finding in our series and has been described by others.\textsuperscript{8,11,12} This abnormality is not specific for vertebral artery dissection but is a reflection of an impediment to normal arterial flow that could also exist in atherosclerotic or embolic occlusion of the distal vertebral artery. In addition to a high resistance signal, studies with duplex Doppler of the extracranial vertebral artery\textsuperscript{11,12} have described a localized increase in diameter with decreased pulsatility in that segment and the occasional intravascular echoes.\textsuperscript{12} Our findings were confined to the reporting of high resistance signals for the sake of reproducibility. Experience is required for optimum insonation of the vertebral artery, as alluded to by other investigators in this field.\textsuperscript{9-11} No doubt the inclusion of more extensive parameters might well have increased sonologic sensitivity of vertebral artery dissection in our series.

In our series, routine TCD was not so diagnostic. However, the intracranial or fourth part of the vertebral artery was less frequently involved in our series, and it was not routinely insonated. We would advocate insonation of the intracranial portion of the vertebral artery by TCD in patients with suspected vertebral artery dissection. Vertebral artery dissection may involve solely the intracranial portion, with more dire clinical consequences secondary to the frequent presentation of subarachnoid hemorrhage, thus requiring a cerebrospinal fluid analysis for definitive diagnosis.\textsuperscript{24} At times it is possible to insonate the posterior inferior cerebellar artery (PICA), to see if this is dominant or functions as a collateral vessel in cases of dissection with occlusion of the intracranial vertebral artery segment. Patency, waveform characteristics, resistivity index, and collateral vessel assessment (eg, PICA) all yield corroborating noninvasive data useful in detecting vertebral artery dissection.
Two initially normal Doppler examinations were recorded. Possible explanations include technical difficulties secondary to operator dependence, routing of blood flow through patent PICA's with masking of the characteristic high resistance signals, and finally, normal asymmetry of the vertebral arteries, thus complicating interpretation. A more comprehensive evaluation of the vessels apart from only seeking high resistance signals may increase the yield of positive cases.

MRI of the vertebral artery has been proposed by others as the imaging modality of choice for diagnosis of vertebral artery dissection.25 This usually requires imaging more inferiorly than the conventional brain and brain stem slices to include the cervical segments of the vertebral artery. We applied this technique to one patient in whom the angiogram was suspicious but not definitely diagnostic of dissection, and in whom the Doppler findings were unhelpful. The characteristic hyperintense signal within the wall of the vertebral artery was found on T1-weighted spin-echo imaging, as shown in Fig 2. More recent studies have demonstrated the use of magnetic resonance angiography in the detection of dissection of the carotid artery,26 which also may be useful in the evaluation of vertebral artery dissection.

The favorable natural history of vertebral artery dissection in the majority of patients, its preponderance in the young and middle-aged, and the preferred treatment with antiplatelets or anticoagulation27-30 make noninvasive detection and monitoring all the more desirable. We propose that both duplex Doppler sonography and MRI of the cervicocephalic vessels offer such an option.

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References

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