Objective: To describe the clinical features of patients with occlusive disease of the proximal (V1) segment of the vertebral artery.

Design and Patients: Patients with either occlusion or high-grade stenosis involving the V1 segment were chosen for study from the New England Medical Center Posterior Circulation Registry. The registry is a consecutive series of patients with signs and symptoms of posterior circulation ischemia seen at the New England Medical Center, Boston, Mass, during a 10-year period. Clinical features, radiographic findings, and patient outcome were reviewed.

Results: Of the 407 patients in the registry, 80 (20%) had V1 segment lesions. Patients could be classified into 5 groups: (1) V1 disease and coexistent severe intracranial occlusive disease of the posterior circulation (n=22); (2) V1 disease with evidence of artery-to-artery embolism (n=19); (3) suspected V1 disease with artery-to-artery embolism, but with other potential causes of stroke or less certain vascular diagnosis (n=20); (4) V1 disease associated with hemodynamic transient ischemic attacks (n=13); and (5) proximal vertebral arterial dissection (n=6). Hypertension, cigarette smoking, and coronary artery disease were common risk factors. Clinical features, location of infarct, and outcome differed between groups and reflected the presumed mechanisms of stroke.

Conclusions: Occlusive disease involving the V1 segment of the vertebral artery is common in patients with posterior circulation ischemia, but is often associated with other potential mechanisms of stroke. However, in a series of patients seen at a tertiary referral center, occlusive disease of the V1 segment was the primary mechanism of ischemia in 9% of patients.

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The vertebral artery can be conveniently divided into 4 anatomical segments. The proximal (V1) segment begins at the origin of the vertebral artery from the subclavian artery and ends at the point of entry into the transverse foramen of the vertebral column, typically at C6. The vertebral artery then ascends through the transverse foramina (transverse multiple foramina from C6 to C2), exits at C2, runs posterolaterally around the atlas, and then penetrates the dura mater to become the intracranial vertebral artery (V4 segment).

The origin and the V1 segment of the vertebral artery are a common site for atherosclerotic occlusive disease. Plaque formation often begins in the subclavian artery and extends a few centimeters into the proximal vertebral artery. Hutchinson and Yates found atheroma involving the extracranial vertebral artery (ECVA) in 19 (40%) of 48 autopsy results of patients dying of cerebrovascular disease. A severe stenosis or occlusion was found in 27% of patients and typically involved the V1 segment of the artery. The authors emphasized the relative paucity of data concerning V1 lesions because of the difficulty of studying this portion of the vessel during autopsy. Patients with V1 disease frequently have coexistent extracranial carotid artery disease, and many have extensive atherosclerosis throughout the peripheral vasculature. In the Joint Study of Extracranial Arterial Occlusion, occlusive V1 lesions were shown using angiography in approximately 25% of patients. Lesions of the V1 segment of the vertebral artery were second in frequency only to occlusive disease of the carotid artery origin, which was present in more than 40% of patients. In patients without symptoms of cerebrovascular disease but with vascular risk factors, Hennerici et al found V1 stenosis in 10 (2.3%) of 426 patients and aplasia and/or occlusion of the vertebral artery in 30 (7%) of patients using angiography and duplex ultrasonography.
SUBJECTS AND METHODS

Data from consecutive patients evaluated at the New England Medical Center between 1987 and 1997 for symptoms of posterior circulation ischemia were collected in the Posterior Circulation Registry. Information included demographics, risk factors, clinical description of symptoms, neurologic deficits, and results of diagnostic testing that included a review of all neuroradiological studies.

Hypertension was defined as a history of elevated blood pressure requiring treatment or persistently elevated blood pressure (systolic, >140 mm Hg; diastolic, >90 mm Hg) during follow-up more than 1 month after stroke. Coronary artery disease was defined as a history of angina, myocardial infarction, or documented coronary artery disease using stress testing or cardiac catheterization. Diabetes was defined as a prior clinical diagnosis if the condition required treatment with insulin or oral hypoglycemic agents. Patients with abnormal blood lipid levels had either a documented abnormal lipid profile or were being treated with lipid-lowering agents. We followed criteria of the Stroke Data Bank in defining a high-risk cardiac source of embolism.10 Transient ischemic attacks were limited to those in the vertebrobasilar or posterior cerebral artery territories that occurred 2 years prior to either stroke or diagnostic evaluation at time of entry into the registry. Outcome at the time of hospital discharge was assessed using a modified Rankin scale,11 with good outcome being either no or minor disability (modified Rankin score, 0-2).

The results of imaging studies showing the location of infarcts, and vascular lesions were categorized according to location, severity, and presumed cause. The clinical data were reviewed by experienced stroke neurologists, and probable cause and mechanism of infarction were determined by consensus, using previously described criteria.1 Patients were selected from the registry who had evidence of severe occlusive disease of the V1 segment of the ECVA. Severe occlusive disease was defined as 50% or greater stenosis on angiographic findings or evidence of proximal vertebral artery occlusion using either conventional or magnetic resonance angiography (MRA). In a vessel with the caliber of the vertebral artery, stenosis of 50% or greater is likely to be hemodynamically significant, similar to lesions in intracranial vessels.12 Infarcts in the posterior circulation were grouped into proximal, middle, and distal territories (Figure 1).13 The proximal territory consisted of the medulla and inferior cerebellum in the distribution of the posterior inferior cerebellar artery (PICA). The middle territory consisted of thepons and the distribution of the anterior inferior cerebellar artery. The distal territory consisted of the distribution of the superior cerebellar artery (SCA), midbrain, thalamus, and the occipital and temporal lobes fed by the posterior cerebral artery (PCA).

Patients were classified into 1 of 5 groups. Group 1 consisted of patients with V1 lesions who also had high-grade lesions (>50% stenosis or occlusion) of the intracranial vertebral arteries or the basilar artery. In these patients, the intracranial lesion could explain the ischemia, and the V1 lesion was possibly an incidental finding. Group 2 consisted of patients with V1 lesions and infarcts in the posterior circulation consistent with artery-to-artery embolism.14,15 Patients lacked tandem intracranial occlusive lesions and demonstrated no other potential cause of stroke, such as a cardiac source for embolism. Group 3 patients were similar to those in group 2, except that evidence to implicate the V1 lesion as the cause of ischemia was less certain. Some patients had a coexistent high-risk cardiac source of embolism. Others had clinical and radiographic features consistent with lacunar infarction in the brainstem, so that branch or penetrating artery occlusion was a possible cause. Patients were also included in this group if the evidence for V1 occlusive disease was limited to MRA findings, without confirmation using results from conventional angiography. Magnetic resonance angiography studies were often supplemented by duplex ultrasonography and revealed absence of flow in the ECVA. However, occlusion of the vessel could not be entirely distinguished from a hypoplastic and/or aplastic vessel based on these studies. Group 4 consisted of patients with V1 lesions who had TIAs suggestive of hemodynamic spells involving the posterior circulation. Most patients had bilateral vertebral artery lesions. Group 5 consisted of patients with dissection of the ECVA involving the V1 segment.

Comparisons of risk factors or the use of testing in various groups were made using 2-tailed t tests or analysis of variance where appropriate.

Unlike occlusive disease of the extracranial carotid artery, which can be diagnosed and followed up using ultrasonography, V1 occlusive disease is difficult to demonstrate using noninvasive testing and may require angiography for definitive diagnosis. As a result, the natural history, clinical features, and optimal therapy of V1 lesions are poorly defined. Previous studies of V1 occlusive disease consist primarily of anecdotal reports or autopsy reports, and there are few systematic studies of V1 lesions in patients with posterior circulation ischemia. The New England Medical Center Posterior Circulation Registry, Boston, Mass, consists of a series of consecutive patients evaluated for posterior circulation stroke or transient ischemic attacks (TIAs) at the New England Medical Center in Boston. To describe the clinical features and mechanisms of ischemia associated with V1 occlusive lesions, we reviewed files from the registry of patients who had these lesions. We found that patients with V1 lesions could be categorized into 1 of 5 groups: (1) V1 disease and coexistent severe intracranial occlusive disease of the posterior circulation; (2) V1 disease with evidence of artery-to-artery embolism; (3) V1 disease with suspected artery-to-artery embolism, but the presence of other potential causes of stroke or less secure vascular diagnosis made it difficult to be absolutely certain of the role of the V1 lesion; (4) V1 disease associated with hemodynamic TIAs; and (5) proximal vertebral arterial dissection.

RESULTS

Of 407 patients in the Posterior Circulation Registry, 80 patients (20%) had occlusive lesions involving the V1 segment. There were 60 men and 20 women (mean age, 62.5 years). Eighty-nine percent of patients in this group were
white. Race and age distributions were similar among patients with V1 lesions compared with other patients in the Posterior Circulation Registry, but there was a preponderance of men in the group with V1 lesions (60 [75%] of 80 men vs 196 [60%] of 327 men in the remainder of the registry; P < .05).

Brain imaging was performed on all patients, with 57 (71%) of 80 patients undergoing computed tomography (CT) and 69 (86%) of 80 patients undergoing magnetic resonance imaging (MRI). Evaluation for a cardiac source of embolism included the findings from Holter monitor studies (24 [30%] of patients), transthoracic echocardiography (43 [54%] of 80 patients), and transesophageal echocardiography (11 [14%] of 80 patients). Vascular imaging included carotid and vertebral artery duplex ultrasonographic studies (55 [69%] of 80 patients), transcranial Doppler ultrasonography (66 [83%] of 80 patients), MRA (41 [51%] of 80 patients), and conventional angiography (67 [84%] of 80 patients). Use of diagnostic tests in patients with V1 lesions was similar to that of other patients in the registry, with the exception of cerebral angiography, which was obtained in 221 (54%) of 407 patients in the registry as a whole. The use of cerebral angiography was determined on an individual basis after review of noninvasive testing. Only 21 (21%) of 98 patients in the registry with a high-risk cardiac source of embolism, for example, underwent cerebral angiography since, in many cases, invasive testing would not have altered therapy. Patients in the registry who had cerebral angiography tended to be younger (57.2 vs 64.4 years; P < .001) and were less likely to have coronary artery disease (64 [29%] of 221 patients vs 79 [42%] of 186 patients; P < .01), but otherwise were similar to the remaining patients in the registry with respect to race, sex, and other risk factors. Of the 221 patients in the registry who underwent angiography, 80 (36%) of 221 patients had V1 occlusive lesions.

In the 80 patients with V1 lesions, 37 had occlusions, 34 had stenoses, and 12 had bilateral lesions (3 with bilateral occlusions, 2 with bilateral stenoses, and 7 with mixed occlusion and/or stenosis). Patients with V1 occlusion or stenosis had similar demographics, risk factors, and clinical features, and both groups were analyzed together. The contralateral vertebral artery was abnormal at some anatomical level in 42 (52.5%) of 80 patients. The contralateral lesion involved the contralateral vertebral artery in 21 patients (12 with stenosis, 5 with occlusion, and 4 with hypoplasia with the contralateral vertebral artery ending in a PICA) and the ECVA in 21 patients (11 with stenosis, 5 with occlusion, and 5 with hypoplasia). Patients with bilateral vertebral artery abnormalities were similar to other patients in terms of demographics and risk factors, except that patients with bilateral lesions were more likely to have coronary artery disease (59.5% vs 34.2%; P < .05) and prior TIAs (59.5% vs 36.8%; P < .05). Bilateral vertebral artery abnormalities were particularly common in groups 1 and 4 (Table 1).

Of 67 patients who underwent cerebral angiography, 16 were noted to have prominent collateral circulation to the distal ECVA via deep cervical arteries, and in patients with V1 occlusion, these collaterals reconstituted the distal ECVA and potentially the intracranial cerebrovascular artery (ICVA) on that side. Patients with cervical collaterals tended to be younger (55.5 vs 62.3 years; P < .01) and were more likely white (100% vs 88%; P < .01) compared with patients without collaterals. Deep cervical collaterals were more common in patients with V1 occlusion (13 [37%] of the 35 patients) compared with those with V1 stenosis (3 [9%] of the 32 patients) (P < .01). Interestingly, patients with bilateral vertebral artery abnormalities were not more likely to have deep cervical collaterals; the percentage of patients with collaterals was actually smaller among those with bilateral vertebral artery abnormalities compared with others, but this difference was not statistically significant (18% vs 28%; P = .32). All 16 patients with cervical collaterals had a good clinical outcome (minor or no disability), whereas 8 (20%) of the 41 patients without collaterals had a moderate neurologic deficit or worse (P = .001).

### Table 1. Patients With V1 Occlusive Lesions

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>No. (%) of Patients</th>
<th>Patients With Bilateral Vertebral Artery Abnormalities, %†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coexistent intracranial disease (group 1)</td>
<td>22 (27.5)</td>
<td>77</td>
</tr>
<tr>
<td>Artery-to-artery embolism (group 2)</td>
<td>19 (24)</td>
<td>26</td>
</tr>
<tr>
<td>Possible artery-to-artery embolism (group 3)</td>
<td>20 (25)</td>
<td>25</td>
</tr>
<tr>
<td>Hemodynamic TIAs (group 4)</td>
<td>13 (16)</td>
<td>92</td>
</tr>
<tr>
<td>Dissection (group 5)</td>
<td>6 (7.5)</td>
<td>50</td>
</tr>
</tbody>
</table>

*V1 indicates the proximal segment of the vertebral artery; TIA, transient ischemic attack.
†Stenosis, occlusion, or hypoplasia involving either the contralateral extracranial vertebral artery or the intracranial vertebral artery.
Patients with V1 lesions were classified into 1 of 5 groups, depending on the presumed mechanism of stroke or TIA (Table 1). Patients with atherosclerotic V1 lesions with coexistent intracranial occlusive disease comprised the largest group, whereas V1 dissections were the least common. Vascular risk factors are shown in Table 2. Mean age was similar between groups, except that patients with dissection were younger than other patients (mean age, 43.8 years; mean age for other groups combined, 64.0 years) (P < .05). There were no significant differences in the distribution of race or sex between groups. Coronary artery disease was common in groups 1, 3, and 4, but uncommon in groups 2 and 5 (P < .001). A high-risk cardiac source for embolism was, by definition, not seen in patients in group 2. Coexistent carotid artery lesions were found in 14 (17%) of 80 patients. Other risk factors were similar among the groups.

In patients with V1 lesions, the qualifying event for inclusion in the registry was stroke in 50%, TIA followed by stroke in 26%, and TIA only in 24%. Transient ischemic attacks were present in half of the patients overall (Table 3), and the frequency of TIA was similar among groups, except that by definition all patients in group 4 had TIAs. Thirty-four percent of patients had multiple TIAs. Patients with recurrent TIAs frequently had stereotypical spells of dizziness and ataxia, although new symptoms often developed at some point (eg, diplopia or weakness), which prompted further medical evaluation.

Compared with other patients in the registry, patients with V1 lesions were overall more likely to have coronary artery disease (48% vs 33%; P < .05), hypertension (77% vs 58%; P < .05), and to smoke cigarettes (50% vs 32%; P < .05). Patients with V1 lesions were less likely to have a high-risk cardiac source for embolism (11% vs 27%; P < .05). Overall outcome for patients with V1 lesions was good (minor or no deficit) in 85% of patients, compared with good outcome in 76% of the remaining patients in the registry (P = .10).

GROUP 1: V1 LESION AND COEXISTENT INTRACRANIAL OCCLUSIVE LESION

Twenty-two patients had a V1 lesion with coexistent intracranial occlusive disease in the posterior circulation that was demonstrated using angiography (n = 20) or MRA (n = 2). Seven had unilateral V1 occlusive lesions, 8 had V1 stenosis, and 7 patients had bilateral ECVA lesions (3 with bilateral occlusions, 1 with bilateral stenosis, 1 with a combination of occlusion and stenosis, 1 with a combination of occlusion and hypoplasia, and 1 with a combination of stenosis and hypoplasia). Intracranial lesions involved the basilar artery (n = 8), intracranial vertebral artery (n = 6), or both (n = 8). Of the 14 patients who showed evidence of ICVA lesions, 3 had unilateral occlusion, 7 had unilateral stenosis, and 4 had bilateral ICVA lesions (2 patients had bilateral obstructions, 1 had a combination of occlusion and stenosis, and 1 had a combination of occlusion and hypoplasia). Of the 16 patients who had basilar artery lesions, 9 had basilar occlusions and 7 had basilar stenosis. In these patients, the intracranial lesion could explain the ischemic symptoms, and the V1 lesion was possibly an incidental finding. The mechanism for stroke in these patients was thought to be due to intracranial thrombosis or hypoperfusion related to the intracranial lesion, but the role of the V1 lesion in terms of blood flow or a possible source of embolism remains uncertain.

Infarctions tended to be distributed within the proximal and middle segments of the posterior circulation. Lesions typically involved the PICA cerebellar territory (8 of the 22 patients) and the pons (10 of the 22 patients). Approximately half the patients had multiple areas of infarction. Fifty percent of patients had TIAs, half of which were recurrent. Transient ischemic attacks were often

### Table 2. Vascular Risk Factors in Patients With V1 Occlusive Lesions*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>1 (n = 22)</th>
<th>2 (n = 19)</th>
<th>3 (n = 20)</th>
<th>4 (n = 13)</th>
<th>5 (n = 6)</th>
<th>All Patients (N = 80)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean age, y‡</td>
<td>65.0</td>
<td>58.1</td>
<td>69.4</td>
<td>62.8</td>
<td>43.9</td>
<td>62.5</td>
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<tr>
<td>Hypertension, %</td>
<td>77</td>
<td>63</td>
<td>80</td>
<td>85</td>
<td>50</td>
<td>74</td>
</tr>
<tr>
<td>Smoking, %</td>
<td>36</td>
<td>58</td>
<td>50</td>
<td>77</td>
<td>17</td>
<td>50</td>
</tr>
<tr>
<td>Coronary artery disease, %‡</td>
<td>59</td>
<td>16</td>
<td>60</td>
<td>77</td>
<td>0</td>
<td>48</td>
</tr>
<tr>
<td>Diabetes mellitus, %</td>
<td>41</td>
<td>5</td>
<td>30</td>
<td>39</td>
<td>17</td>
<td>28</td>
</tr>
<tr>
<td>Abnormal blood lipid levels, %</td>
<td>36</td>
<td>16</td>
<td>30</td>
<td>23</td>
<td>0</td>
<td>25</td>
</tr>
<tr>
<td>High-risk cardiac source for embolism, %*</td>
<td>14</td>
<td>0</td>
<td>15</td>
<td>15</td>
<td>17</td>
<td>11</td>
</tr>
<tr>
<td>Previous stroke, %</td>
<td>36</td>
<td>16</td>
<td>10</td>
<td>8</td>
<td>17</td>
<td>19</td>
</tr>
</tbody>
</table>

* V1 indicates proximal segment of the vertebral artery.
† Analysis of variance P < .001 for differences among V1 groups.
‡ See Table 1 for an explanation of the V1 groups.

### Table 3. Transient Ischemic Attacks (TIAs) in Patients With V1 Occlusive Lesions*

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>No. of Patients</th>
<th>Any TIA</th>
<th>Multiple TIAs</th>
<th>Only TIAs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coexistent intracranial disease (group 1)</td>
<td>22</td>
<td>50</td>
<td>25</td>
<td>14</td>
</tr>
<tr>
<td>Artery-to-artery embolism (group 2)</td>
<td>19</td>
<td>26</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>Possible artery-to-artery embolism (group 3)</td>
<td>20</td>
<td>45</td>
<td>25</td>
<td>15</td>
</tr>
<tr>
<td>Hemodynamic TIAs (group 4)</td>
<td>13</td>
<td>100</td>
<td>100</td>
<td>92</td>
</tr>
<tr>
<td>Dissection (group 5)</td>
<td>6</td>
<td>33</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>All patients</td>
<td>80</td>
<td>50</td>
<td>34</td>
<td>24</td>
</tr>
</tbody>
</table>

* V1 indicates proximal segment of the vertebral artery. Unless otherwise indicated, values are expressed as percentages.
complex in nature and consisted of symptoms such as vertigo, perioral paresthesias, generalized weakness, diplopia, visual field defects, and syncope. Outcome was relatively poor in group 1 patients, with 7 (32%) of the 22 patients either dying or having major neurologic deficits and more than two thirds having some degree of neurologic deficit by the time of discharge.

REPORT OF A CASE

A 63-year-old man with diabetes and coronary artery disease developed nausea, vomiting, and an unsteady gait when he arose from bed one morning. On admission 3 days later, he had increasing nausea with diplopia, dysarthria, vertigo, and bilateral hearing loss. Examination showed upbeat and rotatory nystagmus, decreased facial sensation on the right side, and marked gait ataxia. Magnetic resonance imaging scans showed a right PICA territory cerebellar infarct with possible involvement of the medulla. Cerebral angiography revealed occlusion of the right vertebral artery at its origin with distal reconstitution by deep muscular branches, and a second occlusion in the intracranial segment at the level of the PICA. The distal left vertebral artery was hypoplastic (Figure 2). The midbasilar artery was occluded at the level of the anterior inferior cerebellar artery, with retrograde flow into the distal basilar artery on carotid artery injection (Figure 2).

The angiogram suggested tandem lesions at the vertebral artery origin, the intracranial vertebral artery segment, and in the midbasilar artery. Symptoms and findings were consistent with thrombosis of the intracranial vertebral and basilar arteries. The possibility of either embolism from the vertebral artery origin or a hemodynamic contribution from the V1 lesion cannot be excluded. Despite anticoagulation with heparin therapy, the patient developed further neurologic deficits 6 days later, with a new left pontine infarct seen on repeated MRI scans.

GROUP 2: V1 LESION WITH ARTERY-TO-ARTERY EMBOLISM

Nineteen patients had V1 lesions with clinical and radiographic features suggestive of artery-to-artery embolism from the proximal vertebral artery. By definition, no patient had a cardiac source for embolism and all patients underwent conventional angiography. (Nine of these patients were described previously). Nine patients had V1 unilateral occlusions and 6 had high-grade unilateral stenosis at or within a few centimeters of the ECVA’s origin (Figure 3). Of the 3 patients with bilateral lesions, bilateral vertebral origin stenoses were seen in one patient, and another patient had V1 occlusion on one side, with vertebral origin stenosis on the other. In 1 patient with V1 occlusion, the contralateral vertebral artery was hypoplastic and ended in a PICA. A single patient had a vertebral artery origin aneurysm with intraluminal thrombus. Three patients had ICVA occlusions, all ipsilateral to the V1 lesion, and presumed secondary to artery-to-artery embolus.

Strokes typically involved either the proximal posterior circulation territory alone (6 [32%] of 19 patients) or a combination of proximal and distal territories (7 [37%] of 19 patients). The most common sites of infarction were the PICA cerebellum (10 [53%] of 19 patients), the SCA territory cerebellum (7 [37%] of 19 patients), and the occipital and temporal lobes (6 [32%] of 19 patients). Presumably, patients with V1 thrombosis had either propagation of clot or embolism to the intracranial segment of the ipsilateral vertebral artery with infarction of the PICA territory cerebellum and often the lateral medulla. Six patients had both PICA and SCA and/or PCA infarctions, suggesting that the clot mi-

Figure 2. Top. Intracranial, anteroposterior view after left vertebral artery injection. The left vertebral artery supplies a large posterior-inferior cerebellar artery, but the distal communication with the basilar artery is hypoplastic. The midbasilar artery is occluded. Bottom. Intracranial, lateral view after carotid injection. The distal basilar artery fills in a retrograde manner via the posterior communicating artery.
grated from the intracranial vertebral artery to the SCA and/or PCA. Transient ischemic attacks were the least common in this group of patients and tended to be 1 or 2 episodes of dizziness or visual blurring. At the time of discharge, 2 patients (11%) had major neurologic deficits, 14 patients (74%) were left with minor deficits, and 13 patients (16%) had complete resolution of their symptoms.

REPORT OF A CASE

A 74-year-old man with a history of hypertension, diabetes, and coronary artery disease developed a sudden staggering gait with a tendency to fall to the right. For several hours he vomited and was confused. Examination showed rotatory nystagmus on left gaze, slight ataxia of his right arm, and marked rightward lateropulsion when sitting or attempting to stand.

Magnetic resonance imaging scans showed a complete right PICA territory cerebellar infarct (Figure 4). Angiographic evidence revealed occlusion of the right vertebral artery at the origin, with reconstitution via deep muscular branches in the neck (Figure 4). The right PICA did not fill, but the left PICA and the anterior-inferior cerebellar arteries were well visualized. No cardiac source for embolism was found. The patient was thought to have had an atherosclerotic stenosis of the right vertebral artery origin that recently occluded, resulting in artery-to-artery embolism to the right PICA.
GROUP 3: V1 LESION WITH POSSIBLE ARTERY-TO-ARTERY EMBOLISM

Twenty patients had V1 lesions and posterior circulation strokes, but artery-to-artery embolism was only a possible cause of stroke for a variety of reasons. Nine patients had V1 occlusions, 7 had unilateral V1 stenosis, and 4 had bilateral V1 lesions (2 with a combination of occlusion and stenosis, 1 with occlusion and hypoplasia, and 1 with stenosis and hypoplasia). Four patients had ICVA occlusion (3 with occlusion ipsilateral to V1 lesion, and 1 with a bilateral ICVA occlusion, and 1 patient had basilar artery occlusion). Ten patients with V1 lesions also had potential cardiac sources for embolism. Six of these patients showed evidence of a hypokinetic or akinetic left ventricular segment, 2 had valvular disease, 1 had atrial fibrillation, and 1 had a stroke during cardiac catheterization. Two patients who underwent angiography had lesions on MRI scans suggestive of penetrating artery territory infarcts. One patient had dizziness and an internuclear ophthalmoplegia, with a small lesion in the pontine tegmentum. The second patient had hemisensory deficits, with a small lesion in the thalamus. In both cases, the infarct could have been secondary to either embolism from the V1 lesion or intrinsic small vessel disease.

Eleven patients had V1 lesions that were discovered using MRA scans, but did not have confirmatory findings on angiography. Three patients had a potential cardiac source of embolism, and 1 patient developed symptoms shortly after cardiac catheterization. In the remaining 6 patients, however, no other cause of stroke was found, and V1 occlusive disease with artery-to-artery embolism was considered the likely cause.

Infarct distribution in this group of patients was heterogeneous but typically of distal intracranial territory in location (12 [60%] of the 20 patients), particularly involving the occipital and temporal lobes. Outcome was relatively good, with 15 patients having either minor neurologic deficits (11 [55%] of the 20 patients) or no deficit (6 [30%] of the 20 patients) at the time of discharge.

GROUP 4: V1 LESION WITH HEMODYNAMIC SPELLS

Thirteen patients had V1 lesions and TIAs suggestive of hemodynamic spells involving the posterior circulation.

Eight patients had V1 occlusion, and 5 had V1 stenosis. Twelve patients underwent cerebral angiography, and 1 had evidence of proximal vertebral artery occlusion demonstrated using both MRA and duplex ultrasonography. The contralateral vertebral artery had occlusive lesions in 12 patients, involving the ECVA in 6 and the ICVA in 6. In patients with contralateral ECVA lesions, 2 patients had V1 stenosis, 3 patients had stenosis in the V2 segment (2 with atherosclerotic stenosis and 1 with positional spondylotic compression), and 1 patient had ECVA hypoplasia. Of the 6 patients who had ICVA lesions, 2 showed evidence of stenosis, 1 had an ICVA occlusion, and 1 had a hypoplastic ICVA. The only patient with posterior circulation TIAs in the absence of bivertebral disease was found to have occlusion of both internal carotid arteries. Three other patients in this group also had coexistent carotid artery occlusive disease (1 patient with bilateral and 2 patients with unilateral lesions).

Two patients had evidence of previous strokes based on the results from imaging, one involving the occipital lobe and the other involving the cerebellum and temporal lobe. All patients had TIAs that were typically recurrent for a period of 1 week to several months. The most common symptom was dizziness (9 of the 13 patients), often associated with either gait or limb ataxia, and recurring in a stereotypical pattern. Other symptoms included visual blurring (n=6), perioral paresthesias (n=5), and diplopia (n=2). Three patients had single episodes of syncope. Two patients reported a ringing or roaring sound in the ears during their TIAs.

REPORT OF A CASE

A 58-year-old man with a history of diabetes, coronary artery disease, and smoking was admitted with recurrent spells of diplopia, dizziness, and loss of balance with an unsteady gait. The spells typically lasted 30 to 60 seconds and almost always occurred when the patient was standing. He reported approximately 25 spells during a period of 1½ months. The most recent spells before admission included a new symptom of dysarthria and transient confusion.

The results of 4-vessel angiography revealed high-grade (>75%) stenosis at the left internal carotid artery’s origin and high-grade stenosis of the left vertebral artery at its origin (Figure 5). The right vertebral artery was normal in caliber but ended in PICA, without substantial filling of the basilar artery (Figure 5). His spells were considered to be hemodynamic in origin, secondary to vertebral artery origin stenosis in the setting of “basilarization” of the vertebral artery.23 The contribution of the internal carotid artery stenosis to his symptoms was uncertain. He underwent left carotid endarterectomy, ligation of the proximal left vertebral artery, and end-to-side anastomosis of the vertebral artery to the left common carotid artery. After surgery, he had no further spells.
GROUP 5: PROXIMAL VERTEBRAL ARTERY DISSECTION

Six patients had vertebral artery dissections originating in the V1 segment, demonstrated using angiography. Three patients had bilateral vertebral artery dissections. Dissections of the V1 segment of the vertebral artery made up 23% of all dissections in the registry. Patients in this group were younger, and none had coronary artery disease. One patient developed transient atrial fibrillation after his stroke.

In 4 patients, the infarct involved the ipsilateral PICA cerebellum, with a lateral medullary infarct in one, and infarcts in the pons and SCA territory in another. One patient had a lateral medullary infarct alone, and one had infarcts in the thalamus and occipital lobe. The mechanism of infarction was presumed artery-to-artery embolism from the region of dissection. Four patients experienced minor disabilities at discharge, and 2 experienced no neurologic deficits.

The clinical spectrum of carotid artery origin disease is well described, in part because of the availability of noninvasive techniques to record an image of the internal carotid artery’s origin and the accessibility of this segment of the artery to the surgeon. While the proximal vertebral artery is also accessible to surgical intervention, the incidence, clinical manifestations, and prognosis of V1 occlusive disease are, in contrast, poorly understood. Mechanisms of ischemia are similar in the anterior and posterior circulations.1,15,17 Occlusive lesions cause strokes or TIAs by hemodynamic compromise, embolism of platelet and/or thrombin fragments from atherosclerotic lesions, or propagation of thrombus from a recent occlusion.6,17,18

Anatomical differences and the patterns of collateral circulation, however, result in unique circumstances in the posterior circulation. Since the vertebral arteries converge to supply the basilar artery, interruption of one vessel may be compensated by flow from the other. On the other hand, asymmetry of size between vertebral arteries is the rule, and a marked size difference may be present in up to 15% of healthy subjects.19 The distal vertebral artery may be hypoplastic on 1 side (typically terminating in PICA), resulting in basilarization of the contralateral vertebral artery. Occlusive lesions in the V1 segment often result in development of collaterals from deep cervical branches that may reconstitute the distal ECVA and preserve blood flow.7,16,20

In our series, we found that most patients with V1 lesions share common risk factors for stroke, including hypertension, diabetes, coronary artery disease, and cigarette smoking. Patients could be subdivided into 5 groups based on the presumed mechanism of ischemia. The largest group consisted of patients with V1 lesions associated with coexistent occlusive lesions of the intracranial vertebral and basilar arteries (group 1). The symptoms and pattern of neurologic deficits in these patients were complex, and infarcts were often multifocal. Transient ischemic attacks were common, with more than one third of patients having had TIAs before their stroke. Ischemia could be due to thrombosis or hemodynamic effects of the intracranial lesions, but the potential contribution of the V1 lesion to either diminished blood flow or artery-to-artery embolization is uncertain.

Ischemia due to artery-to-artery embolism followed a more distinct pattern (group 2).14,15 Onset of symptoms was usually abrupt, although some patients had preceding TIAs of dizziness and visual disturbance. Strokes typically involved the PICA cerebellum and the PCA territory, as these are the most common recipient sites for embolism. Dizziness and ataxia were the most common symptoms. Some patients with emboli to the PCAs presented with only hemianopia and had no brainstem symptoms.

We found that hemodynamic TIAs due to bilateral vertebral artery disease (group 4) was a less common presentation of V1 disease. Fisher16 described 5 patients with bilateral occlusion of the proximal vertebral arteries who had transient symptoms of faintness, blurred vision, dizziness, and weakness. His patients had collateral circulation with reconstitution of the distal segment of the vertebral artery via deep muscular branches. Fisher concluded that permanent neurologic deficit after V1 occlusion was uncommon and emphasized the benign nature of the condition. Seventeen percent of our patients with V1 lesions fit this pattern (group 4), but the majority of our patients with V1 lesions had posterior circulation strokes, resulting in some degree of disability. Bilateral V1 disease with hemodynamic spells may be underdiagnosed because of transient and non-specific symptoms (typically dizziness), and because it is difficult to detect V1 stenosis without the benefit of conventional angiography. In only 1 patient, bilateral carotid artery occlusion was believed to play a causal role, although coexistent carotid artery disease was common.

Dissection of the proximal segment of the vertebral artery (group 5) was uncommon. In patients in the registry with arterial dissection, 23% of patients had involvement of the V1 segment. In a review of 61 patients described in the literature with vertebral artery dissection, 12% of patients had dissections that involved the V1 segment.17 Except for younger age and fewer vascular risk factors, the clinical findings were similar to those of patients in group 2, implying artery-to-artery embolism as the primary mechanism.

Several potential biases in our selection of patients may limit comparison with other studies and populations of patients. The use of cerebral angiography in 54% of patients in the registry may have introduced a selection bias, since the results of angiography represent the most sensitive and reliable means of detecting V1 lesions. In addition, the New England Medical Center is a referral center for patients with stroke, with a known interest in posterior circulation stroke. Hence, patients in the registry may have a larger percentage of diagnostically complex or unusual conditions compared with typical patients admitted to the hospital for stroke. While these limitations may affect the relative percentages of patients with V1 lesions or within V1 groups, the clinical characteristics of patients within these groups are likely valid and representative. Despite these limitations, we found that 20% of our patients with symptoms of posterior circulation ischemia had evidence of V1 occlusive
Patients with V1 lesions often have other potential causes of stroke (eg, intracranial disease in group 1 or cardiac source of embolism in group 3). However, in 38 patients (9% of patients in the registry), the V1 lesion was the only detected cause of stroke. These findings suggest that in patients without a defined cause of posterior circulation stroke or TIA, angiography should be considered to assess the proximal vertebral artery.

Duplex ultrasonography of the vertebral artery can determine patency of the vessel and direction of blood flow. It is most useful in the diagnosis of subclavian steal syndrome, where reversal of blood flow shown on ultrasonography closely matches findings of angiography.19,20 Hennerici et al7 found that ultrasonographic evidence of absence or marked asymmetry of blood flow in the ECVA was frequently associated with either occlusion, hypoplasia, or proximal stenosis of the artery using angiography, but 16% of abnormalities were false positives. Duplex ultrasonography could not distinguish between proximal stenosis or hypoplasia of the vessel, and some patients with angiographically confirmed vertebral artery abnormalities had such findings missed with ultrasonography. In patients with V1 occlusion, Kimura et al21 found absence of blood flow in the cervical vertebral artery using ultrasonography in all 11 patients. Patients with V1 stenosis were not described. There are few data concerning the accuracy of MRA scans in V1 stenosis or occlusion, although a few studies suggest that correlation of MRA scans compare favorably with cerebral angiography for intracranial lesions in the posterior circulation.22,23 In our experience, MRA scans suggest V1 occlusive disease when the ECVA is either absent or poorly visualized and the infarcts are in typical recipient sites for artery-to-artery embolism (eg, PICA cerebellum and PCA territory), but results of contrast angiography are required for definitive diagnosis.

There are few data on long-term outcome in patients with V1 lesions. Moufarrij et al24 described clinical follow-up in 96 patients with angiographically proven severe occlusive disease of the vertebral artery, in most cases involving the proximal V1 segment.25 For an average follow-up of 4.6 years, 2 patients had brainstem strokes (both with coexistent basilar artery stenosis), and no patient had a definite posterior circulation TIA. However, only a minority of patients in this series (19%) had symptoms of posterior circulation ischemia at onset of the study, and in most cases the vertebral artery lesion was an incidental finding. In contrast, all our patients had symptoms of posterior circulation ischemia prompting diagnostic evaluation. The presence of cervical collaterals reconstituting the distal ECVA appeared to be associated with better short-term clinical outcome (assessed at the time of hospital discharge) in our series. Unfortunately, long-term follow-up data in terms of outcome and recurrent stroke risk were not available in a sufficient number of patients for analysis.

Treatment of V1 lesions remains empirical and includes the use of antiplatelet agents and anticoagulants. Patients with evidence of artery-to-artery embolism are often given anticoagulants for a period of time to reduce the incidence of recurrent events.17 Patients with hemo-dynamic spells may benefit from higher blood pressure, increase in blood volume, and avoidance of orthostatic hypotension. Despite medical therapy, patients with continued symptoms have been treated with surgical bypass or endarterectomy26 or angioplasty via a transmural approach.27 Increasing recognition of V1 lesions and a better understanding of the natural history of these lesions are needed before these therapies can be adequately evaluated.

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