Ischemic stroke in young adults is rarely caused by a unilateral intracranial arteriopathy. Similar to children, onset of symptoms in young adults is often not abrupt and the arteriopathy may improve over time. Late recurrences were rare. Possibly, a monophasic inflammatory process, as has been suggested for childhood intracranial arteriopathy, also occurs in young adults.

Key Words: etiology, intracranial stenosis, stroke in young adults
Neurology at the University Medical Center Utrecht or investigated at the outpatient clinic between January 1, 1991, and December 31, 2005. Patients were approached for follow-up investigation if: (1) they had had signs or symptoms attributable to anterior circulation AIS; (2) vascular imaging of the intracranial arteries performed within 3 months after stroke was available for review and showed a unilateral arteriopathy of the distal internal carotid artery, proximal anterior cerebral artery, or MCA; and (3) a cardiac source of thromboembolism had been excluded. AIS was defined as focal neurological deficits caused by infarction visible on CT or MRI. Vascular imaging could consist of digital subtraction angiography (DSA), MR angiography, or CT angiography. Arteriopathy was defined as a focal or segmental stenosis or occlusion with regular or irregular abnormalities of the arterial wall. An abrupt occlusion of a major cerebral artery at initial angiography without other abnormalities suggestive of arterial wall disease was not considered an arteriopathy because this may be caused by embolic occlusion.

The following baseline characteristics were collected from the medical charts: mode of onset of stroke symptoms, preceding infections or trauma, migraine before stroke, medical history, medication before and after stroke, known prothrombotic disorders, and risk factors for atherosclerotic disease (smoking, drugs, hypertension, family history of cardiovascular disease, hypercholesterolemia, diabetes mellitus). The mode of onset of stroke symptoms was classified as “abrupt” when neurological symptoms reached maximum severity within 30 minutes. Onset was classified as “progressing” when symptoms gradually progressed and reached maximum severity in >30 minutes. Onset was classified as “stuttering” when presenting symptoms were fluctuating and the patient was not free of symptoms between episodes and as “recurring” when the patient was free of symptoms in between. The severity of stroke at presentation was classified according to the National Institutes of Health Stroke Scale and modified Rankin Scale.

Results of laboratory investigations for atherosclerotic risk factors and prothrombotic disorders, performed during the diagnostic evaluation of stroke, were collected (triglycerides, total cholesterol, high- and low-density lipoprotein cholesterol, homocysteine, thrombocytes, prothrombin time, fibrinogen, antithrombin activity, protein S antigen, protein C activity, activated protein C resistance, prothrombin mutation, factor VIII, lupus anticoagulant, anticardiolipin IgG and IgM, and lipoprotein[a]). At follow-up, 1 of the authors (M.M.M.B.) interviewed patients about recurrence of stroke, transient ischemic attacks, or other vascular events (deep venous thrombosis, pulmonary embolism, peripheral arterial disease, ischemic heart disease) and treatment and patients underwent a clinical examination. Outcome was assessed by means of the modified Rankin Scale. Investigations of triglycerides, total cholesterol, high-density lipoprotein cholesterol, and low-density lipoprotein cholesterol were repeated and prothrombotic disorders were investigated when the investigations in the past had not included all the elements as listed previously. Patients underwent MRI investigation of the brain (T1-, T2-weighted, fluid-attenuated inversion recovery) and MR angiography of the circle of Willis (3-dimensional time of flight with maximum-intensity projection reconstruction) on a 3-T MRI scanner (Achieva; Philips Medical Systems) to study the long-term course of arteriopathy and the occurrence of new ischemic strokes. In 1 patient, a CT and CT angiography scan were performed instead of MRI because the patient had a pacemaker. Based on the comparison of MR angiography with vascular imaging at presentation, the arteriopathy was classified as progressive (increase of stenosis or progression from stenosis to occlusion or new involvement of other intracranial arteries), unchanged, improved (but not normal), or normalized.

This study was approved by the institutional ethical committee and patients gave written informed consent.

Results

Of 490 patients with AIS, 356 had an anterior circulation AIS (Figure 1). In 17 (5%) of them, a unilateral intracranial large-artery arteriopathy was documented. One patient died 4 days after stroke and 2 patients refused participation in the study. Fourteen patients underwent follow-up investigations. Characteristics of the 14 patients are summarized in Table 1. Median age at the time of stroke was 34 years (range, 27–49 years) and 7 patients were male. The onset of symptoms was abrupt in 3 patients, whereas 11 patients (79%) had a nonabrupt onset with gradual progression in 2, a stuttering course in 6, and recurring symptoms in 3 patients. Two patients presented with severe headache in the week before stroke. Four patients had no risk factors for atherosclerosis, 9 were smokers, and 7 had a family member with cardio-or cerebrovascular disease. None of the patients had had a trauma before stroke.

Radiological Characteristics at the Time of Stroke

The extent of infarction and the severity of arteriopathy are summarized in Table 2. In 7 patients the infarct involved both the basal ganglia and cortex and in 1 patient the infarct was limited to the basal ganglia. In 4 patients, only DSA was performed at the time of stroke; in 5 patients only MR angiography time of flight and 5 patients underwent both DSA and MR angiography. In 13 patients, the MCA was abnormal. The other patient had arterial disease in the distal internal carotid artery only. In 1 of the 13 patients with MCA involvement, the ipsilateral anterior cerebral artery was affected as well, and in 4, the arteriopathy involved distal internal carotid artery, MCA, and anterior cerebral artery. Eight patients (57%) had a tapering occlusion of ≥1 affected intracranial arteries.

Radiological Characteristics at Follow-Up

The median duration of follow-up was 8.8 years (range, 1.7–12.8 years). Imaging of the brain revealed a new infarction in 1 patient (Patient 9). In none of the patients did repeated vascular imaging reveal progression of arteriopathy. In 8 patients (57%) the arteriopathy had improved: complete normalization in 5 and evident but incomplete improvement in 3. In the other 6, the severity of the arteriopathy remained unchanged (Figure 2A–C).

Clinical Outcome

Two patients (14%) had recurrent ischemic symptoms from the hemisphere ipsilateral to the arteriopathy during follow-up. Patient 9 had a recurrent stroke after 4 years, which increased the severe paresis of her left arm but did not change her modified Rankin Scale of 2. Patient 6 had a transient ischemic attack that did not change his modified Rankin Scale of 1. No other vascular events were reported. Functional outcome at the time of follow-up was good (modified Rankin Scale ≤2) in 10 of 14 patients.

Presumed Cause of AIS

Normalizing Arteriopathy

Of the 5 patients with normalized vascular imaging, 1 patient (Patient 2) most likely had postpartum angiopathy. Patient 1 had herpes zoster ophthalmicus in the year before stroke on the side of the affected MCA but a connection between stroke

...
and herpes zoster ophthalmicus was never suspected at that time. Lumbar puncture showed an increased cerebrospinal fluid protein (0.87 g/L) but no other abnormalities. Investigations for viral infections were not performed. In Patients 3, 4, and 5, the cause of arteriopathy could not be determined, although an increased lipoprotein(a) (Patients 3 and 5) and an increased factor VIII activity (Patients 3, 4, and 5) may have contributed to their risk of stroke. In Patient 4, cerebrospinal fluid pleocytosis was found, but the underlying cause was never found and a lumbar puncture was not repeated. Despite the presence of several risk factors for atherosclerosis, we considered it unlikely that atherosclerosis caused the arteriopathies because then we would not have expected complete normalization. Furthermore, these patients did not have symptoms of the heart or peripheral arteries indicating generalized vascular disease during follow-up.

Improving Arteriopathy
In these 3 patients the cause remained unclear. Two had no risk factors for atherosclerosis at all. Patient 6 had ulcerative colitis. An increased risk of thromboembolic events and cerebral vasculitis in patients with inflammatory bowel disease has been described. In this patient, DSA showed tapering occlusion of M2 branches and not abrupt occlusion suggestive of an embolus. There were no signs of small-vessel abnormalities consistent with small-vessel vasculitis. A brain biopsy was not performed.

Stabilizing Arteriopathy
In 1 patient, polyarteritis nodosa had been considered in the past but could never be confirmed. A large-artery vasculitis was assumed to be the cause of stroke and DSA did not show small-vessel abnormalities. He was treated with prednisone for 6 years. A few years later, he was diagnosed with sarcoidosis. In the other 5 patients, no definite cause of stroke was found, although several possibly contributing factors were identified (Table 1). In these patients, atherosclerosis as the cause of the arteriopathy cannot be excluded, but no new vascular events suggestive of generalized atherosclerosis occurred during follow-up.

Discussion
This study shows that unilateral intracranial arteriopathy, according to the childhood AIS standardized classification and diagnostic evaluation criteria classified as focal cerebral arteriopathy, is a rare cause of AIS in young adults. None of our patients had a progressive arteriopathy and the arteriopathy improved or normalized over time in 57%. In the

Figure 1. Overview of 773 young patients with stroke from the Utrecht Stroke Database. In a group of 773 young patients with stroke, we identified 17 patients with unilateral intracranial large-artery arteriopathy. Other (*) indicates sinovenous thrombosis, intracranial hemorrhage, and acute focal neurological deficits without parenchymal pathology on CT or MRI. EC indicates extracranial; IC, intracranial.
majority, onset of symptoms was not abrupt. Late recurrences were rare and clinical outcome was good in 71% of patients.

When unilateral focal cerebral arteriopathy is diagnosed in children without risk factors for stroke, only 6% have progressive arterial disease over time, whereas in 94%, TCA can be diagnosed. The nonabrupt mode of onset of symptoms and the nonprogressive nature of the arteriopathies that we found in young adults are comparable to what has been observed in children with TCA. In children with TCA, follow-up vascular imaging shows complete normalization in 23%, stabilization in 32%, and improvement in 45%. Late recurrences are rare and clinical outcome is good in 41% of patients. In our small series of young adults, late recurrent stroke occurred in only 1 of the 14 patients. Based on the similarities in clinical presentation, and radiological characteristics, we suggest that TCA can cause ischemic stroke also in young adults. The design of our study does not allow a reliable estimation of the frequency of TCA in young adults with AIS. If a monophasic inflammatory process is the underlying cause of arteriopathy in at least a subset of these adult patients, as has been suggested in children with TCA, further studies are needed to determine whether immunosuppressive treatment can improve outcome. Other causes of intracranial arteriopathies that may improve over time are the "reversible cerebral vasoconstriction syndromes," characterized by thunderclap headache (94%), often with seizures, a

Table 1. Clinical Characteristics of 14 Patients With Unilateral Intracranial Large-Artery Arteriopathy

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex; Age, Y</th>
<th>Ischemic Event(s)</th>
<th>Onset of Symptoms</th>
<th>NIHSS</th>
<th>mRS*</th>
<th>Atherosclerotic Risk Factors</th>
<th>Relevant History</th>
<th>Relevant Laboratory Findings</th>
<th>Presumed Cause of AIS at Follow-Up</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M; 28</td>
<td>Minor stroke; preceding TIAs</td>
<td>Recurring</td>
<td>4</td>
<td>1/0</td>
<td>None</td>
<td>HZO</td>
<td>ANA +; CSF protein 0.87 g/L</td>
<td>HZO arteriopathy</td>
</tr>
<tr>
<td>2</td>
<td>F; 28</td>
<td>Minor stroke</td>
<td>Abrupt</td>
<td>6</td>
<td>2/1</td>
<td>FH</td>
<td>Puerperium</td>
<td>Fibrinogen 5.7 g/L; normal at follow-up</td>
<td>Postpartum arteriopathy</td>
</tr>
<tr>
<td>3</td>
<td>F; 29</td>
<td>Major stroke</td>
<td>Stuttering</td>
<td>7</td>
<td>3/2</td>
<td>Smoking; FH; hypercholesterolemia</td>
<td>Migraine</td>
<td>Cholesterol 6.7 mmol/L; fibrinogen 6.2 g/L; factor VIII 254%; Lp(a) 834 mg/L</td>
<td>Unknown</td>
</tr>
<tr>
<td>4</td>
<td>F; 38</td>
<td>Minor stroke</td>
<td>Stuttering</td>
<td>2</td>
<td>2/1</td>
<td>Smoking; FH; hypertension</td>
<td>CSF WBC 43.10^6/L; factor VIII 201%</td>
<td>Fibrinogen 7.5 g/L; later 4.4 g/L; factor VIII 168%; Lp(a) 1040 mg/L; CSF protein 0.64 g/L</td>
<td>Vasculitis</td>
</tr>
<tr>
<td>5</td>
<td>M; 49</td>
<td>Major stroke</td>
<td>Progressing</td>
<td>15</td>
<td>4/3</td>
<td>Smoking</td>
<td>Unknown</td>
<td>Fibrinogen 1.8 g/L; factor VIII 184%</td>
<td>Vasculitis</td>
</tr>
<tr>
<td>6</td>
<td>M; 27</td>
<td>Minor strokes; preceding TIAs</td>
<td>Recurring</td>
<td>2</td>
<td>2/1</td>
<td>None</td>
<td>Ulcerative colitis; lacunar infarct 5 y before</td>
<td>Fibrinogen 5.3 g/L; heterozygous for factor V mutation</td>
<td>Unknown</td>
</tr>
<tr>
<td>7</td>
<td>M; 34</td>
<td>Major stroke</td>
<td>Abrupt</td>
<td>16</td>
<td>4/3</td>
<td>None</td>
<td>Unknown</td>
<td>Factor VIII 196%</td>
<td>Unknown</td>
</tr>
<tr>
<td>8</td>
<td>F; 36</td>
<td>Minor stroke; preceding TIAs</td>
<td>Stuttering</td>
<td>2</td>
<td>2/2</td>
<td>Smoking; hypertension</td>
<td>Unknown</td>
<td>Fibrinogen 5.0 g/L; heterozygous for factor II mutation</td>
<td>Unknown</td>
</tr>
<tr>
<td>9</td>
<td>F; 30</td>
<td>Major stroke; preceding TIAs</td>
<td>Stuttering</td>
<td>9</td>
<td>3/2</td>
<td>Smoking; FH; hypertension</td>
<td>Unknown</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>F; 31</td>
<td>Major stroke</td>
<td>Progressing</td>
<td>5</td>
<td>3/2</td>
<td>Smoking; FH</td>
<td>Celiac trunk stenosis</td>
<td>Fibrinogen 5.0 g/L</td>
<td>Unknown</td>
</tr>
<tr>
<td>11</td>
<td>M; 34</td>
<td>Major stroke; preceding TIAs</td>
<td>Abrupt</td>
<td>14</td>
<td>4/4</td>
<td>Smoking</td>
<td>Lp(a) 443 mg/L</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>M; 42</td>
<td>Minor stroke; preceding TIAs</td>
<td>Stuttering</td>
<td>3</td>
<td>2/1</td>
<td>Alcohol; smoking; FH; hypercholesterolemia</td>
<td>Cholesterol 7.7 mmol/L; ANA +; factor VIII 200%</td>
<td>Unknown</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>M; 46</td>
<td>Major stroke; preceding TIAs</td>
<td>Recurring</td>
<td>11</td>
<td>4/3</td>
<td>None</td>
<td>PAN; lacunar infarct 2 y before</td>
<td>ANA +; protein S Ag 54%; protein C Ag 57%; factor VIII 192%; CSF protein 0.94 g/L</td>
<td>Vasculitis (sarcoidosis)</td>
</tr>
<tr>
<td>14</td>
<td>F; 49</td>
<td>Minor stroke</td>
<td>Stuttering</td>
<td>2</td>
<td>2/1</td>
<td>Smoking; FH; hypertension</td>
<td>Fibrinogen 4.4 g/L; factor VIII 189%</td>
<td>Unknown</td>
<td></td>
</tr>
</tbody>
</table>

NIHSS indicates National Institutes of Health Stroke Scale; mRS, modified Rankin Scale; AIS, arterial ischemic stroke; M, male; F, female; TIA, transient ischemic attack; FH, family history of cardiovascular disease; HZO, herpes zoster ophthalmicus; PAN, polyarteritis nodosa; ANA, antinuclear antibody; CSF, cerebrospinal fluid; WBC, white blood cell count; Lp(a), lipoprotein A.

*mRS at the time of presentation/at time of follow-up.
“string of beads” appearance of cerebral arteries, and intracranial hemorrhage. Ischemic stroke is a rare complication of this syndrome (1%–31%). Postpartum angiopathy is described as part of reversible cerebral vasoconstriction syndromes. Patient 2 with postpartum angiopathy never had headache before her stroke. Patients 10 and 14 presented with severe headache in the week before stroke onset. However, both patients had a stable arteriopathy after a follow-up duration of 12 years and therefore did not have “reversible vasoconstriction.” Apart from reversible cerebral vasoconstriction syndromes, the differential diagnosis of AIS associated with unilateral intracranial arteriopathies in young adults also includes dissection, unilateral moyamoya disease, postradiation vasculopathy, fibromuscular dysplasia, primary angiitis of the central nervous system, drug-induced vasoconstriction, Sneddon syndrome, and recanalization of a thromboembolic occlusion. Although none of these conditions could be diagnosed in the described patients, we cannot exclude these with certainty because pathological studies of the vessel wall were not performed. A recent study showed that dissection of the intracranial internal carotid artery may mimic TCA. Possibly, dedicated vessel wall imaging may help to establish the underlying cause of intracranial arteriopathies in the future.

The strength of our study is that we were able to collect young adults with AIS from a prospective database over a
long period of time. In these patients we performed extensive diagnostic investigations, including vascular imaging at the time of follow-up and clinical evaluation in person to evaluate recurrence of vascular events.

Our study also has limitations. We may have missed the diagnosis of unilateral nonprogressive intracranial arteriopathy, because not in all patients in the Utrecht Stroke Database were the intracranial arteries visualized. Therefore, our study cannot reliably estimate the frequency of TCA in young adults with AIS.

Another limitation is that investigations for inflammatory causes of stroke including cerebrospinal fluid analysis were not routinely assessed in young adults with an unknown cause of stroke. Furthermore, in 4 patients, the MR angiogram at follow-up had to be compared with DSA because MR angiography was not performed at the time or presentation. However, because MR angiography may overestimate arterial stenosis compared with DSA, it is unlikely that this has affected the observation that the arteriopathy improved or stabilized in the majority of patients.

**Summary and Conclusions**

This study shows that in none of the described patients was unilateral intracranial arteriopathy progressive. A nonpro-ressive, inflammatory arteriopathy may cause AIS in young adults, similar to the entity that has been found in children, and a high index of suspicion may reveal more cases in the future. Intracranial vascular imaging should be performed in young adults with AIS when the cause of stroke is not found in the heart or the extracranial arteries. When vascular imaging shows nonatherosclerotic unilateral focal cerebral arteriopathy, the risk of late recurrences is small and clinical outcome is good in the majority of patients. It is important to search for inflammatory causes and to repeat intracranial vascular imaging, differentiating between a nonprogressive or possibly reversible arteriopathy and progressive arteriopathies as in atherosclerosis, vasculitis, or moyamoya disease.

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**Disclosures**

None.

**References**


The Course of Unilateral Intracranial Arteriopathy in Young Adults With Arterial Ischemic Stroke

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