Angiography of Nonhemorrhagic Cerebral Infarction in Young Adults

Wendy R.K. Smoker, MD, José Biller, MD, William L. Hingtgen, MD, Harold P. Adams Jr., MD, and Gilbert J. Toffol, DO

The radiographic examinations and hospital records of 93 young adult patients (15–45 years of age) with nonhemorrhagic cerebral infarction evaluated at our institution during the past 9 years were reviewed. The angiographic examinations were abnormal in 76% of patients. The most common abnormalities were embolic disease and atherothrombotic disease. Forty-seven patients underwent angiography within 7 days of their event. There were no major neurologic or systemic complications related to early angiography. We believe that angiography performed early in the course of the illness is a high-yield, safe procedure that may significantly alter the management of acute stroke in young adults. (Stroke 1987;18:708–711)

In the past, patients with acute cerebral infarctions seldom underwent cerebral angiography during the acute phase of their disease. Since complication rates related to angiography were reported to be higher in patients with cerebrovascular disease, most patients had their studies delayed for variable times ranging from 4 to 6 weeks after their event. More recently, we have performed cerebral angiography earlier in the course of the ischemic event. To assess the importance of early angiography and the complication rate in this group of patients, the current retrospective study was undertaken.

Subjects and Methods

We reviewed our experience in 144 patients aged 15–45 years hospitalized at the University of Iowa for nonhemorrhagic cerebral infarction between July 1977 and February 1986. All patients had noncontrast computed tomography (CT) examinations that established the diagnosis of nonhemorrhagic cerebral infarction. Ninety-three of these patients underwent cerebral angiography; and they form the study population for this communication. Examinations obtained on all patients included complete blood count, platelet count, prothrombin time, partial thromboplastin time, fibrinogen, serum chemistries, urinalysis, chest radiographs, electrocardiograms, and CT scans. Most patients had echocardiograms, and a few patients had contrast echocardiography. When blood disorders were suspected to be the cause of infarction, platelet function studies and determinations of Antithrombin III, Protein C, and Protein S were also obtained. The presumed etiology for infarction, history, physical examination findings, and CT scan results were analyzed for all patients.

All catheterizations were performed by the percutaneous femoral approach. Conventional or intraarterial digital subtraction arch aortograms and selective common carotid or vertebral artery angiograms were obtained in all patients. The time between the onset of the ischemic event and angiography was recorded, as was the catheter size, volume of contrast media injected, and any neurologic or systemic complications that occurred during or within 48 hours after angiography.

All angiograms were reviewed by 2 staff neuroradiologists, and the angiographic findings were divided into 9 categories (Table 1). Branch occlusions included all suspected etiologies, whether secondary to an embolus, thrombus, or atherosclerosis. This category included vessel occlusions distal to the terminal bifurcations of the internal carotid or basilar arteries.

Results

There were 50 men and 43 women ranging from 15 to 45 years of age with a mean age of 34 years (Table 2). Forty-seven of the 93 patients, or 51%, underwent angiography within 1 week of their ischemic event (Table 3). A total of 3 transient complications occurred among the 93 patients studied, 2 neurologic and 1 systemic. There were no permanent complications. The first neurologic complication, blurred vision lasting <24 hours, occurred in a 24-year-old man who underwent intra-arterial digital arch and bilateral common carotid angiography using a 5 French catheter 3 days after infarction. The other neurologic complication consisted of an episode of possible worsening aphasia in a 28-year-old woman who underwent arch and bilateral common carotid angiography 8 days after her event. Angiography had been performed with a 5 French catheter in this case as well. The single systemic complication occurred in a 39-year-old woman following arch and bilateral common carotid angiography with a 5 French catheter 4 months after cerebral infarction and consisted of transient atypical chest pain requiring no treatment.

The correlation between the time to angiography and the percent of abnormal angiographic examina-
Angiographic abnormalities were present in 71 of the 93 patients (76%). Table 1 shows the distribution of patients in each category. Distal branch occlusions were the most common angiographic abnormalities, occurring in 25 patients (27%). Attempts to subdivide this group based on both clinical and angiographic findings revealed 16 of these cases to be probably embolic in origin, 8 to be of probable atherothrombotic origin, and 1 unknown. Of the 25 branch occlusions, 19 (76%) involved the distribution of the MCA, 3 of the PCA, 1 of the ACA, and 1 of the basilar artery (BA). Thirteen of the 19 MCA occlusions were believed to be embolic.

Sixteen patients (17%), 10 men and 6 women with a mean age of 37 years, had large-vessel atherosclerotic cerebrovascular disease (ASCVD). Fourteen of these patients had isolated disease and exhibited stenoses or plaques of the internal carotid artery (ICA) or vertebral artery (VA) origins. A single case of VA occlusion was included in both the ASCVD and dissection categories, as the etiology remained in question. A second case, that of a diffusely narrowed cervical ICA with proximal atherosclerotic plaquing and stenosis, was included in both the ASCVD and fibromuscular dysplasia (FMD) categories.

Intraluminal clots were identified in 11 patients (12%), 5 men and 6 women with a mean age of 30 years. All intraluminal clots were presumed to be on the basis of embolic phenomena, an assumption that was supported clinically. Five cases involved the distribution of the MCA, 2 of the PCA, 1 of the ACA, and 3 of the supraclinoid ICA. All of the MCA clots were identified in the left hemisphere.

Vascular dissections were encountered in 12 patients (13%), 8 men and 4 women with a mean age of 36 years. Three patients (25%) had a history of antecedent trauma. The ICA was involved in 8 cases, the left and right ICAs being equally affected. Five of the ICA dissections were localized to the C2-C3 level, while the remaining 3 involved the entire ICA, beginning 2–3 cm distal to its origin and extending to the carotid canal entrance. The remaining 4 dissections involved the VA, 2 at the level of the C6 foramen transversarium and 2 at the level of the C1.

Findings consistent with Moyamoya disease were present in 5 patients (5%), all women, ranging from 24 to 40 years of age. Only the anterior circulations were involved in all patients. Multiple areas of infarction were identified on CT scans of all patients obtained before angiography.

Table 1. Angiographic Findings in 93 Young Adults With Nonhemorrhagic Cerebral Infarction

<table>
<thead>
<tr>
<th>Category</th>
<th>Number</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Branch occlusions</td>
<td>25</td>
<td>27</td>
</tr>
<tr>
<td>Normal</td>
<td>22</td>
<td>24</td>
</tr>
<tr>
<td>Atherosclerotic cerebrovascular disease</td>
<td>16</td>
<td>17</td>
</tr>
<tr>
<td>Intraluminal clots</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>Vascular dissections</td>
<td>12</td>
<td>13</td>
</tr>
<tr>
<td>Moyamoya disease</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Cerebral aneurysms</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Fibromuscular dysplasia</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Miscellaneous</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Seven patients were included in 2 categories.

Table 2. Age Distribution of Patients With Nonhemorrhagic Cerebral Infarction

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Men</th>
<th>Women</th>
</tr>
</thead>
<tbody>
<tr>
<td>15–19</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>20–24</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>25–29</td>
<td>9</td>
<td>5</td>
</tr>
<tr>
<td>30–34</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>35–39</td>
<td>9</td>
<td>8</td>
</tr>
<tr>
<td>40–45</td>
<td>16</td>
<td>15</td>
</tr>
</tbody>
</table>

Table 3. Angiographic Findings by Time to Angiography

<table>
<thead>
<tr>
<th>Days</th>
<th>Number</th>
<th>Percent</th>
<th>Normal</th>
<th>Abnormal</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–2</td>
<td>24</td>
<td>26</td>
<td>3</td>
<td>21</td>
<td>88</td>
</tr>
<tr>
<td>3–7</td>
<td>23</td>
<td>25</td>
<td>4</td>
<td>19</td>
<td>83</td>
</tr>
<tr>
<td>8–10</td>
<td>10</td>
<td>11</td>
<td>1</td>
<td>9</td>
<td>90</td>
</tr>
<tr>
<td>11–14</td>
<td>8</td>
<td>8</td>
<td>2</td>
<td>6</td>
<td>75</td>
</tr>
<tr>
<td>15–30</td>
<td>12</td>
<td>13</td>
<td>4</td>
<td>8</td>
<td>67</td>
</tr>
<tr>
<td>30–1 yr</td>
<td>16</td>
<td>17</td>
<td>8</td>
<td>8</td>
<td>50</td>
</tr>
</tbody>
</table>

with proximal atherosclerotic plaquing and stenosis, was included in both the ASCVD and fibromuscular dysplasia (FMD) categories.
scan at that time demonstrated diffuse cerebral edema without evidence of hemorrhage. Angiography revealed severe narrowing of the supraclinoid ICA, the ACA, and MCA, believed to represent arterial spasm.

**Discussion**

In their series of 1,082 patients, Mani et al reported an overall complication rate associated with catheter cerebral angiography of 3.9% in training institutions and 0.9% in nontraining institutions. Their study also revealed the complication rate to be 2.5 times greater in patients > 60 years of age being evaluated for cerebrovascular disease; they encountered only 1 complication in patients < 40 years of age. Highest complication rates were in patients with cerebrovascular occlusive disease, posttraumatic or postoperative states, and in patients with subarachnoid hemorrhage. Overall, complications increased when patients were > 40 years of age or when catheter time exceeded 80 minutes. Patterson et al reported no permanent complications in 86 patients under the age of 50 being evaluated for cerebrovascular disease. Earnest et al reported a higher incidence of complications in patients with recent transient ischemic events and infarctions, although the difference was not statistically significant. Among 202 examinations in patients < 50 years of age who underwent angiography, there were no permanent complications.

It has been shown by a number of authors that the use of smaller, softer catheters is associated with a decreased rate of neurologic complications. We attribute the lack of permanent neurologic complications in our series to the use, whenever possible, of smaller catheters. Larger, 7 French, complex curved catheters were used only when selective catheterization of a vessel was not possible with the smaller, 5 French, simple curved catheters.

Although all of our patients were < 45 years of age, half of them underwent angiography during the acute phase of their illness (within 7 days of the ischemic event). Our complication rate is very similar to those reported in other recent studies and is in keeping with the complication rate intrinsic to cerebral angiography described by Mani et al. These rates are significantly less than several previous reports listed in the study by Mani et al, probably related to the transfemoral approach, decreased catheter time, and improved (smaller) catheters. We believe that cerebral angiography in young stroke patients is a safe procedure, without increased risk of complication, even when performed early in the course of the disease.

Twenty-four percent of patients in our series had normal arteriograms. These patients most likely had small-vessel occlusive disease involving small perforating branches of the MCA not visualized on angiography. Our percent is similar to that described by Janaki et al, who reported a 30% incidence of normal arteriograms in patients with cerebral infarction. However, our figure is lower than that reported by Chopra and Prabhaker (45% normal studies), and by Hilton-Jones and Warlow (42% normal examinations). The majority of the patients in the aforementioned studies underwent angiography at various times after their ischemic event. It is likely that our higher positive rate is related to earlier angiography, as well as to magnification technique.

We encountered 15 cases of typical ICA and VA atherothrombotic disease. If we combine these with our 8 cases of distal branch occlusions felt to be secondary to atherothrombotic disease, we have a total of 24 patients in whom infarction was due to atherothrombotic disease. If we also combine the 16 patients in whom branch occlusions were felt to be on the basis of embolic disease with the 11 patients who had intraluminal clots identified angiographically, there are a total of 27 patients in whom embolic disease was responsible for their infarctions. Details concerning the sources of emboli in these 27 patients are presented in Table 4. There are, therefore, almost equal percents of patients with atherothrombotic (24%) and embolic (27%) disease (predominantly cardiac in origin). This correlates well with the findings of Hart and Miller, who reported the cause of cerebral infarction in patients < 40 years of age to be on the basis of emboli in 20% and on the basis of atherosclerosis in 20%. Klein and Seland attributed 16% of cerebral infarctions in their series to atherosclerotic disease and 29% to emboli. Chopra and Prabhaker attributed 63% of infarctions in their series to nonembolic occlusive disease, whereas Snyder and Ramirez-Lassepas reported a 47% incidence of atherosclerotic disease. The most common source of emboli in all series reported was cardiac. In our series, angiographic demonstration of intraluminal clot was found to be embolic in all cases, the majority of which were cardiac in origin (see Table 4).

Dissection of the ICA is caused by numerous factors including direct trauma (blunt or sharp), mechanical compression or stretching, spontaneous, or sec-

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**Table 4. Sources of Emboli in 27 Patients With Embolic Disease**

<table>
<thead>
<tr>
<th>Angiographic finding/source</th>
<th>Patients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Intraluminal clot</strong></td>
<td></td>
</tr>
<tr>
<td>Arterial source</td>
<td>3</td>
</tr>
<tr>
<td>Paradoxical embolism</td>
<td>2</td>
</tr>
<tr>
<td>Mitral valve prolapse</td>
<td>1</td>
</tr>
<tr>
<td>Hypercoagulable state</td>
<td></td>
</tr>
<tr>
<td>Oral contraceptives</td>
<td>2</td>
</tr>
<tr>
<td>Acute alcohol intoxication</td>
<td>1</td>
</tr>
<tr>
<td>Undetermined</td>
<td>2</td>
</tr>
<tr>
<td><strong>Distal branch occlusion</strong></td>
<td></td>
</tr>
<tr>
<td>Paradoxical embolism</td>
<td>4</td>
</tr>
<tr>
<td>Rheumatic valvar heart disease</td>
<td>2</td>
</tr>
<tr>
<td>Mitral valve prolapse</td>
<td>2</td>
</tr>
<tr>
<td>Infective endocarditis</td>
<td>2</td>
</tr>
<tr>
<td>Atrial myxoma</td>
<td>1</td>
</tr>
<tr>
<td>Left atrial enlargement with impaired</td>
<td></td>
</tr>
<tr>
<td>ventricular function</td>
<td>1</td>
</tr>
<tr>
<td>Undetermined</td>
<td>4</td>
</tr>
</tbody>
</table>
FMD. Traumatic and spontaneous dissections oc-

ondary to underlying vascular disease such as
FMD. Traumatic and spontaneous dissections oc-
cur most frequently at the C2-C3 level and may propa-
gate proximally or distally. Vertebral dissections also
commonly occur at the C6 level where the artery enters
the foramen transversarium. We had 12 patients with
vascular dissection, only 3 of whom had a history of
trauma. Four of the ICA and 2 of the VA dissections
were localized to the C2-C3 level. All of the angiogra-
phy appearances described above were represented in
our series.

Moyamoya is a disease of unknown etiology that
involves progressive narrowing of the supraclinoid
ICA and the proximal MCA and ACA. It commonly
affects both carotid circulations, often asymmetrically,
and is most often seen in young women. We en-
countered 5 cases of Moyamoya, all in young wom-
en. This is a slightly greater incidence than that report-
ed by Klein and Seland, who reported only 1 case in
76 patients examined. Although a relatively infrequent
cause of nonhemorrhagic cerebral infarction, angiog-
graphy is essential to establish the diagnosis.

We identified 4 patients with intracranial aneu-
rysms, similar to the 5% incidence reported in the
series by Klein and Seland. In our single case of
myotic aneurysm, the most likely cause of the pa-
tient’s infarct was septic embolism; however, at the
time of angiography, no branch occlusions or intralu-
minal clots could be identified. This case was there-
fore included in the category of aneurysms.

Three appearances of FMD involving the ICA have
been described. Our 3 cases of FMD had the
classical (Type I) form while the other 2 had the Type
II variety. One of our Type II patients was felt to have a
carotid dissection with underlying FMD since the nar-
rowing extended intracranially. In numerous previous
reports, FMD is not included as a cause of cerebral
infarction in young adults.11-16,26-29 Although encoun-
tered in only 3 of our 93 patients, FMD should cer-
tainly be considered as a possible cause of stroke in young
women.

Atherothrombotic disease and emboli, specifically
cardiac, are the most common causes of cerebral in-
farction in young adults. Other etiologies that must be
considered include nonarteriosclerotic vasculopathies
such as dissections, Moyamoya disease, FMD, and
cerebral aneurysms. We believe early angiography is
indicated in young patients with nonhemorrhagic cere-
bral infarction, having found no increased incidence of
complications. Early angiography is more likely to
provide diagnostic information, assists in planning fu-
ture treatment, and provides valuable prognostic infor-
mation.

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