Outcome of Angioplasty for Atherosclerotic Intracranial Stenoses
Michael P. Marks, MD; Mary Marcellus, RN; Alexander M. Norbash, MD; Gary K. Steinberg, MD, PhD; David Tong, MD; Gregory W. Albers, MD

Background and Purpose—We sought to assess the long-term outcome and efficacy of percutaneous transluminal angioplasty in the treatment of symptomatic intracranial atherosclerotic stenoses.

Methods—Twenty-three patients with fixed symptomatic intracranial stenoses were treated over a 5-year period with percutaneous transluminal angioplasty. Patients who underwent successful angioplasty were followed up for 16 to 74 months (mean, 35.4 months).

Results—An angioplasty that resulted in decreased stenosis was performed in 21 of 23 patients (91.3%). In 1 case a stenosis could not be safely crossed, and in another balloon dilatation resulted in vessel rupture. This vessel rupture resulted in the 1 periprocedural death in the series. In follow-up there was 1 stroke in the same vascular territory as the angioplasty and 2 strokes in the series overall. This yielded an annual stroke rate of 3.2% for strokes in the territory appropriate to the site of angioplasty.

Conclusions—Intracranial angioplasty can be performed with a high degree of technical success. The long-term clinical follow-up available in this series suggests that it may reduce the risk of future stroke in patients with symptomatic intracranial stenoses. (Stroke. 1999;30:1065-1069.)

Key Words: angioplasty ■ cerebral ischemia ■ stenosis

Atherosclerotic stenoses have been successfully treated with percutaneous transluminal angioplasty (PTA) in the coronary and peripheral circulations. PTA has been used in a more limited fashion in the cerebrovascular circulation, and its use has predominantly focused on the extracranial cerebrovascular circulation.1–16 PTA has been slower to evolve in the intracranial circulation because of problems of access, concern about distal embolization, the smaller diameter arteries being treated, and concern about the risk of arterial rupture. Published reports have included case reports17–24 and limited series with relatively brief clinical follow-up.25–30 This study was done to evaluate the efficacy and long-term outcome of angioplasty in patients with symptomatic intracranial atherosclerotic stenoses. The report documents the technical results and clinical follow-up of intracranial angioplasty in a group of 23 patients treated over approximately a 5-year period.

Subjects and Methods
A retrospective review of all intracranial angioplasties performed during a 5-year period (March 1992 to March 1997) was performed. Twenty-three patients with fixed symptomatic intracranial stenoses (presumed to be on an atherosclerotic basis) treated solely by elective balloon angioplasty during this time period were included. Approximately 30 patients seen during the same time period undergoing intracranial angioplasty for etiologies other than atherosclerosis or in the setting of acute stroke were excluded. Patients excluded from this study included those treated for vasospasm, pediatric patients with stenoses, and patients with acute stroke undergoing angioplasty and thrombolysis. In addition, those patients with tandem intracranial and extracranial disease undergoing PTA at both sites were excluded. Patients in this study were not observed to have significant extracranial disease.

There were 20 men and 3 women in the treatment group, aged 31 to 84 years (mean age, 62 years). One patient in the series was aged <40 years, 3 were between 40 and 50 years, and the remainder were aged >50 years. Thirteen patients had lesions in the posterior circulation and 10 patients in the anterior circulation. In the anterior circulation, 3 had middle cerebral artery (MCA) stenoses, and 7 had distal internal carotid artery stenoses (for the purposes of this study, intracranial lesions were considered to occur at or above the level of the cavernous carotid artery). In the posterior circulation, 4 patients had basilar artery stenoses, 8 patients had distal vertebral artery stenoses, and 1 had a proximal posterior cerebral artery stenosis. All patients had symptoms that were clearly referable to the region of stenosis documented by digital subtraction angiography. All but 1 patient had hemodynamically significant stenoses (>70%), and 1 patient had a 60% stenosis. Symptoms in 20 patients before angioplasty consisted of 1 or more transient ischemic attacks (TIAs) while on anticoagulant or anticoagulant and antiplatelet therapy. In 3 patients symptoms occurred while on antiplatelet therapy. Ten of the 23 patients (43.5%) also had prior strokes with fixed neurological deficits. Six of these were in the anterior circulation and consisted of hemiparesis and in some cases aphasia. The 4 in the posterior...
circulation had symptoms that included visual impairment, hemiparesis, or ataxia.

All patients were treated with Stealth angioplasty balloons (Target Therapeutics) varying in size from 2 to 20 mm. These were introduced through 7F or 8F guide catheters placed distally in the cervical cerebrovascular circulation. Wherever possible, this meant that guide catheters were placed at the C1 to C3 level. All catheterizations were performed through the femoral artery, with cannulation of the cervical carotid or vertebral arteries directly by a femorally introduced guide catheter.

Balloons were introduced over 0.14-inch microguidewires and inflated to a maximum pressure of 5.3 atm. Balloon inflation times varied from 30 to 45 seconds. Before angioplasty and introduction of a coaxial system, patients were systemically anticoagulated with intravenous heparin. If residual stenosis was >50% after angioplasty and the vessel wall was found to be smooth, anticoagulation was continued for 24 to 72 hours after angioplasty. When a >50% residual stenosis was demonstrated or the wall showed evidence of irregularity or intimal injury, anticoagulation was continued for at least 2 to 3 months after angioplasty. Most patients were also placed on aspirin or ticlopidine on a long-term basis. Stenosis measurement was based on the ratio of the luminal diameter at the narrowest point on any projection (generally anteroposterior or lateral) versus the luminal diameter in an artery judged to be normal adjacent to the stenosis. This was usually done with software available for stenosis measurement provided with the digital subtraction angiography equipment used for angiography (Siemens Neurostar). Severe pre-occlusive arterial stenoses were generally estimated to be either 90% or 95% stenotic because of the small vessel sizes available for measurement. Follow-up was obtained from return visits to the stroke clinic, visits to the referring physician, or by telephone contact.

Results

The Table shows the angioplasty results and clinical follow-up for the study group. Angioplasty balloons were introduced into the cerebral circulation in all 23 cases, and in all but 1 case the lesion was crossed with an angioplasty balloon. One patient (patient 14) with a basilar artery stenosis could not undergo angioplasty because of proximal tortuosity and small vessel size despite use of the smallest balloons available. In the remaining 22 cases, the lesion was successfully crossed, and angioplasty was performed. One patient (patient 1) with a MCA lesion experienced rupture of the vessel at the time of angioplasty. In all other cases, angioplasty resulted in an improvement in stenosis and a perceived increase in blood flow. An angioplasty with decreased stenosis was therefore performed in 21 of 23 patients (91.3%). One of the patients had successful angioplasty in each of his 2 distal vertebral arteries. Stenoses before angioplasty varied from 60% to 95% (mean, 91.5%). Immediately after angioplasty, stenoses varied from 0% to 75% for the 22 patients (mean, 40.5%). Two patients still had hemodynamically

<table>
<thead>
<tr>
<th>Pt</th>
<th>Lesion Location</th>
<th>Medications Before Treatment</th>
<th>Stenosis Before Treatment, %</th>
<th>Stenosis After Treatment,* %</th>
<th>Medications After Treatment</th>
<th>Clinical Follow-up, mo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MCA W,A</td>
<td>90</td>
<td>†</td>
<td>...</td>
<td>...</td>
<td>...</td>
</tr>
<tr>
<td>2</td>
<td>ICA A</td>
<td>95</td>
<td>50</td>
<td>A</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>VA (R and L) W</td>
<td>90</td>
<td>10</td>
<td>W, A</td>
<td>50</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>VA W</td>
<td>70</td>
<td>50</td>
<td>W, A</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>PCA W</td>
<td>95</td>
<td>60</td>
<td>W, A</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>ICA W</td>
<td>85</td>
<td>45</td>
<td>W, A</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>ICA W</td>
<td>95</td>
<td>60</td>
<td>W, A</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>MCA W, A</td>
<td>90</td>
<td>15</td>
<td>W, A</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>ICA H, A</td>
<td>95</td>
<td>75</td>
<td>A</td>
<td>35</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>VA W, A</td>
<td>75</td>
<td>40</td>
<td>W, A</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>VA W</td>
<td>85</td>
<td>40</td>
<td>T</td>
<td>28</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>BA W</td>
<td>90</td>
<td>75</td>
<td>W, A</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>BA W</td>
<td>95</td>
<td>15</td>
<td>W, A</td>
<td>43</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>BA W</td>
<td>90</td>
<td>†</td>
<td>A</td>
<td>...</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>VA W</td>
<td>95</td>
<td>40</td>
<td>W, A</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>VA W, A</td>
<td>90</td>
<td>50</td>
<td>W, A</td>
<td>74</td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>ICA H</td>
<td>95</td>
<td>50</td>
<td>W, A</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>ICA W, A</td>
<td>95</td>
<td>5</td>
<td>W, A</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>VA W</td>
<td>90</td>
<td>50</td>
<td>W, T</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>MCA W</td>
<td>90</td>
<td>50</td>
<td>W, A</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>21</td>
<td>BA W</td>
<td>80</td>
<td>45</td>
<td>W, T</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>ICA W, A</td>
<td>75</td>
<td>0</td>
<td>W, A</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>VA T</td>
<td>60</td>
<td>50</td>
<td>W, A</td>
<td>18</td>
<td></td>
</tr>
</tbody>
</table>

Pt indicates patient; ICA, internal carotid artery; VA, vertebral artery; PCA, posterior cerebral artery; BA, basilar artery; W, warfarin; and A, aspirin; H, heparin; T, ticlopidine.

*Represents measurement made immediately after angioplasty.
†See text for explanation.
significant stenosis (>70%) after angioplasty. However, in both of these cases the degree of stenoses before angioplasty was ≥90%, and improvement in blood flow was observed on the basis of the degree of filling of the vasculature distal to the stenoses. We therefore grouped these as technically successful angioplasties. The Figure shows an example from the group of successful angioplasties.

Two complications occurred at the time of angioplasty. The first resulted in rupture of the MCA artery at the site of angioplasty. This represented the single patient death at the time of the procedure. The second complication was thrombosis at the site of angioplasty that occurred in the supraclinoid carotid approximately 1 hour after angioplasty. This thrombus was successfully lysed with intra-arterial tissue plasminogen activator, and the patient experienced no sequelae from this event.

Twenty-one of the initial 23 patients were available for follow-up. Patient 14, who had a basilar stenosis that could...
Intracranial Angioplasty

not be angioplastied, died in the immediate perioperative period after undergoing attempted surgical revascularization. The 21 patients were followed up for 16 to 74 months (mean, 35.4 months). Two deaths occurred in the follow-up group. One patient died 25 months after angioplasty after a myocardial infarction, and 1 died 29 months after angioplasty with lung cancer that was first diagnosed 23 months after angioplasty. There were 2 strokes in the 21 patients being followed up. One occurred in a territory appropriate to the artery that underwent angioplasty, and the other occurred in a territory remote from the vascular distribution of the angioplastied vessel. Patient 16 developed a left homonymous hemianopsia due to a right occipital infarct 37 months after successful angioplasty of a distal vertebral artery. Patient 5 had a documented MCA stroke 32 months after angioplasty of the proximal posterior cerebral artery. Therefore (including patient 1, who died at the time of MCA angioplasty), there were 2 strokes in a territory appropriate to the angioplasty and 3 strokes overall in the series. These data yield an annual stroke rate of 3.2% for strokes in the territory of the angioplasty and 4.8% for all strokes.

Discussion

This series reports the longest clinical follow-up after PTA of intracranial atherosclerotic stenosis of which we are aware, with a mean follow-up time of approximately 3 years. During that time, there was 1 stroke appropriate to the territory of angioplasty in the 21 patients followed, giving an annual stroke rate of 3.2%. The purpose of this study was to report clinical outcome and follow-up stroke rates after intracranial angioplasty. Routine angiographic follow-up is generally not performed on asymptomatic patients at our center. We therefore did not have extensive radiological follow-up available on most patients in the series.

It is difficult to know how our clinical follow-up compares with the natural history of these lesions or the stroke rate with medical therapy alone. The limited data that are available suggest that intracranial angioplasty may significantly reduce the rate of future stroke compared with medical therapy alone. Prospective data regarding the anterior circulation (carotid siphon or MCA lesions) are provided by the EC/IC Bypass Study. In this study with medical treatment had an annual stroke rate of 8% to 10% with stenoses in these regions. A recently published report from the Warfarin-Aspirin Symptomatic Intracranial Atherosclerotic Disease study group documents the prognosis of patients with stenoses of the intracranial vertebral and basilar artery treated with medical therapy. Annual stroke rates in the same territory of the stenotic artery were 7.8% and 10.7% for the vertebral artery and basilar artery, respectively. The 3.2% per year stroke rate in the territory of the artery of angioplasty in our series therefore compares favorably with data obtained on similar patients undergoing medical therapy. Moreover, it should be pointed out that the patients in this series may well be at a higher risk for stroke since they are a select group of patients who continue to have symptoms despite antiplatelet therapy and/or angioplasty. The angioplasty in and of itself does not, however, obviate the need for continuing medical therapy. Most of the patients in this series received anticoagulation for 2 to 3 months after angioplasty, and all remained on antiplatelet therapy on a long-term basis.

Surgical revascularization may be another therapeutic option for symptomatic intracranial stenosis. However, surgical revascularization using extracranial to intracranial anastomosis for symptomatic anterior intracranial stenosis does not have proven efficacy compared with medical therapy. The EC/IC Bypass Study found that patients undergoing surgery for MCA stenosis fared substantially worse than those receiving medical therapy. In addition, surgical revascularization may carry significant risks in some cases.

Previous series have been more limited in terms of the amount of clinical follow-up data available. The most extensively followed group of patients was described by Clark et al, who reported mean long-term follow-up of 22±16 months in 17 intracranial angioplasty patients. In this series there were 2 strokes associated with PTA, giving a stroke rate of 12% for the initial procedure, but no patient experienced a stroke in longer-term follow-up.

Others series have generally reported shorter follow-up times and/or treatment of smaller numbers of patients. Touho reported a mean follow-up time of 8.7±1.9 months in 13 patients who underwent PTA, and in this group 1 patient had repetitive TIA, but no new strokes were reported. Mckenzie et al reported a series of intracranial angioplasties that included 8 patients with atherosclerotic stenoses. At 12-month follow-up, they reported that all but 1 of the patients were improved clinically. Terada et al described 11 patients with a mean follow-up time of 24 months, and in this group 1 patient had recurrent TIAs. Takis et al reported a mean follow-up time of 8.4 months in a series of 10 patients, with no clinical strokes reported in this group. Mori et al reported a somewhat larger series of patients undergoing angioplasty with 35 patients with attempted and 27 with successful dilatations. This group, however, did frequent serial angiography regardless of symptoms to determine restenosis rate, and in 8 patients with severe stenosis within the first 3 to 6 months, repeated PTA was performed. Two of these patients were reported to have neurological symptoms in the first 90 days after PTA.

The procedure of intracranial angioplasty can be performed with a high degree of technical success, usually resulting in immediate improvement in the observed stenosis and improved blood flow. In this series we were able to perform angioplasty in 21 of 23 subjects (91.3%). Two patients who underwent angioplasty continued to have hemodynamically significant stenosis (>70%), but improvement in blood flow was observed, and both of these patients remained asymptomatic after angioplasty. Eleven of the procedures were associated with stenoses ≥50% immediately after angioplasty. In this series this did not appear to be associated with a significant rate of complication after the procedure. The 1 patient in this series who did have late infarct in a territory appropriate to angioplasty had a 50% stenosis; however, follow-up imaging of the artery was not available to determine the degree of stenosis at the time of infarct. No other patient in this group had TIAs or infarcts. Stents may be used in the future to improve residual stenosis in settings such as...
this; however, they are not commonly used now in the intracranial circulation.

The 1 patient death that occurred in this series was early in our experience. This patient had an eccentric-appearing MCA stenosis that did not respond well to a 2.5-mm balloon dilatation. The vessel proximal to this lesion measured 3 mm, and a 3-mm balloon was therefore introduced into the circulation and dilated, resulting in the vessel rupture. This has led us to consistently slightly undersize the angioplasty balloon compared with the measured size of the adjacent artery. The 1 additional complication that occurred in this series was a TIA in a patient who also was treated rather early in our experience. This patient experienced a TIA approximately 1 hour after angioplasty, which was the result of a thrombus that was successfully lysed with tissue plasminogen activator. Our procedure up until this time was to discontinue systemic heparin at the end of the procedure and restart anticoagulant therapy several hours after angioplasty to remove the femoral artery sheath and obtain hemostasis. Systemic anticoagulation is now maintained through the period of sheath removal.

While intracranial angioplasty can be performed with a high degree of technical success, as this series demonstrates, there is still a risk associated with this procedure. We therefore generally reserve intracranial angioplasty for patients who continue to be symptomatic while on appropriate medical therapy. It is likely that the majority of patients with symptomatic stenosis will respond to medical therapy; however, this series suggests that outcome may be improved with the use of angioplasty in those patients who have continued symptoms despite medical therapy. These data suggest that a controlled randomized trial should be planned to compare the efficacy of angioplasty with medical therapy alone in this setting.

References
Outcome of Angioplasty for Atherosclerotic Intracranial Stenosis
Michael P. Marks, Mary Marcellus, Alexander M. Norbash, Gary K. Steinberg, David Tong and Gregory W. Albers

Stroke. 1999;30:1065-1069
doi: 10.1161/01.STR.30.5.1065

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://stroke.ahajournals.org/content/30/5/1065

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org/subscriptions/