Percutaneous intracranial stent placement for aneurysms

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Object. Intracranial stent placement combined with coil embolization is an emerging procedure for the treatment of intracranial aneurysms. The authors report their results using intracranial stents for the treatment of intracranial aneurysms.

Methods. A prospectively maintained database was reviewed to identify all patients with intracranial aneurysms that were treated with intracranial stents. Ten lesions, including eight broad-based aneurysms and two dissecting aneurysms, were treated in 10 patients. Four lesions were located in the cavernous segment of the internal carotid artery, two at the verteobasilar junction, two at the basilar trunk, one at the basilar apex, and one in the intracranial vertebral artery. Attempts were made to place stents in 13 patients, but in three the stents could not be delivered. Altogether, intracranial stents were placed in 10 patients for 10 lesions.

Results that were determined to be satisfactory angiographically were achieved in all 10 lesions. Two patients suffered permanent neurological deterioration related to stent placement. In two patients, the aneurysm recurred after stent-assisted coil embolization. In one case of recurrence a second attempt at coil embolization was successful, whereas in the second case a recurrence parent vessel occlusion was required and well tolerated.

Conclusions. Intracranial stents can be a useful addition to coil embolization by providing mechanical, hemodynamic, and visual benefits in the treatment of complex, broad-based aneurysms.

KEY WORDS • intracranial stent • aneurysm • embolization

Intracranial stent placement is an emerging procedure for the treatment of cerebrovascular disease. To date few reports on the technique and results of stent placement for nonatherosclerotic intracranial cerebrovascular disease have been published. Gruber, et al., described outcomes in the embolization of 31 very large (2 cm) or giant aneurysms with GDCs, without the addition of a stent. Only five of 25 aneurysms originally deemed more than 90% occluded displayed a stable degree of occlusion on angiograms. Thus, angiographic verification of the stability of large or giant aneurysms with GDCs alone appears poor. In this paper we report the results of our experience in the development of intracranial stents for the treatment of complex intracranial aneurysms.

Clinical Material and Methods

From a prospectively maintained database, 13 patients (10 women and three men with a mean age of 56 years [range 29–77 years]) harboring intracranial aneurysms that were treated with intracranial stents were identified. Indications for the procedure, the anatomical location and type of the aneurysm, the type of treatment (that is, GDCs), anatomical results, and clinical and angiographic follow-up data were reviewed (Tables 1–3). All cases were reviewed by the cerebrovascular team, which included a microsurgical cerebrovascular surgeon and an endovascular neurosurgeon.

Indications for Stent Placement

This series was composed mostly of large, giant, and recurrent broad-based aneurysms. The consistent anatomical factor was the broad base of all aneurysms (Table 2), which was the basis of the decision to add a stent to prevent coil herniation and possibly to achieve more durable outcomes. The natural history of symptomatic giant aneurysms is grim. Mortality rates 2 and 5 years after conservative management are 62 and 80%, respectively. Recurrent aneurysms pose significant challenges related to the presence of scar tissue and surgical clips, which can increase the associated risks of complications if reoperation is necessary. Eight aneurysms were symptomatic: three were associated with SAH; four created a mass effect causing cranial nerve deficits; and one produced embolic stroke. Three aneurysms had recurred after earlier clip application. One lesion was an enlarging pseudoaneurysm that developed after tumor resection. A large, broad-based PCoA aneurysm was discovered incidentally. After a review of the patients’ clinical presentation and cerebral angiograms, the team consid-
ered treatment to be indicated based on the presence of SAH, a cranial nerve deficit, or a recurrent aneurysm.

Attempts were made to place stents in 13 patients; in three the stents could not be delivered. Consequently, intracranial stents were placed in 10 patients (three men and seven women) to treat eight broad-based aneurysms and two dissecting aneurysms. Four stents were placed in the cavernous segment of the ICA, two at the VBJ, two in the basilar trunk, one at the basilar apex, and one in the intracranial VA. All aneurysms were treated with stent-assisted coil embolization either immediately after stent placement or in a delayed fashion during a separate second procedure. Technical success for aneurysms treated with stent and coil placement was defined as greater than 90% aneurysm occlusion, as demonstrated by immediate and, in some cases, follow-up angiography.

All procedures were performed with induced general endotracheal anesthesia accompanied by monitoring of somatosensory evoked potentials. A baseline activated clotting time was obtained after initial access. Anticoagulation therapy was administered with a heparin bolus to achieve an activated clotting time that was 2 to 2.5 times slower than baseline or longer than 250 seconds. The patient was then given half the loading dose every hour to maintain an anticoagulated state. If possible, all patients were given enteric-coated aspirin (650 mg/day) and clopidogrel (75 mg twice a day) for 3 days before treatment. Patients continued to receive clopidogrel and aspirin therapy for 3 weeks after stent placement, after which they switched to a single antiplatelet agent. If a patient could not be treated with antiplatelet agents before the procedure, a bolus of abciximab (c7E3 Fab; ReoPro, Eli Lilly & Co., Indianapolis, IN) was given during the procedure to prevent embolic complications.

### Results

Of the 13 patients, the stent could not be navigated to the base of the aneurysm for its implantation in three patients. One patient had a broad-based aneurysm involving the PCoA, and the other two patients had complex aneurysms located at the ICA bifurcation. In these three cases, the stents could not be navigated beyond the distal siphon at the level of the OphA. No patient suffered a neurological complication as a result of failed stent placement.

Technical success was achieved in the 10 patients in whom stents were placed. Initially, a dissecting aneurysm of the V4 segment, which had been treated with stent-assisted coil embolization, was occluded, but the aneurysm later recanalized. Subsequently, the parent vessel was sacrificed using coil embolization without complications. Angiography demonstrated that more than 90% of the aneurysm was occluded in all 10 patients. Five patients underwent angiographic follow up at a mean of 9 months (Table 3). Occlusion was stable or improved in three of these five patients. Coils became compacted in two patients and

### Table 1

**Clinical characteristics of 13 patients with aneurysms who underwent percutaneous intracranial stent placement**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Age (yrs), Sex</th>
<th>Indication for Surgery</th>
<th>Type of Aneurysm†</th>
<th>Location</th>
<th>Treatment Successful</th>
<th>Technical Complications</th>
<th>Neurological Sequelae</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>72, F</td>
<td>recurrence of aneurysm previously treated w/ GDCs &amp; clip application</td>
<td>large recurrent</td>
<td>basilar trunk</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>2</td>
<td>49, F</td>
<td>recurrent aneurysm after clip application</td>
<td>giant</td>
<td>ICA bifurcation</td>
<td>stent not placed</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>3</td>
<td>36, M</td>
<td>SAH</td>
<td>pseudoaneurysm</td>
<td>lt V4</td>
<td>aneurysm recurred</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>4</td>
<td>51, F</td>
<td>incidental aneurysm</td>
<td>aneurysm</td>
<td>rt PCoA</td>
<td>stent not placed</td>
<td>dissection</td>
<td>none</td>
</tr>
<tr>
<td>5</td>
<td>59, F</td>
<td>SAH</td>
<td>aneurysm</td>
<td>lt ICA bif/M1</td>
<td>stent not placed</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>6</td>
<td>73, F</td>
<td>diplopia</td>
<td>giant</td>
<td>lt cav ICA</td>
<td>yes</td>
<td>embolic stroke</td>
<td>hemiparesis</td>
</tr>
<tr>
<td>7</td>
<td>63, F</td>
<td>diplopia &amp; ptosis</td>
<td>giant</td>
<td>large</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>8</td>
<td>69, F</td>
<td>mass effect causing cranial nerve deficit</td>
<td>large</td>
<td>lt cav ICA</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>9</td>
<td>53, M</td>
<td>enlarging iatrogenic pseudoaneurysm after cavernous sinus tumor resection</td>
<td>pseudoaneurysm</td>
<td>rt cav ICA</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>10</td>
<td>29, F</td>
<td>recurrent aneurysm after clip application</td>
<td>recurrent</td>
<td>basilar trunk</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>11</td>
<td>50, F</td>
<td>diplopia</td>
<td>giant</td>
<td>lt cav ICA</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>12</td>
<td>51, F</td>
<td>embolic stroke aneurysm</td>
<td>giant</td>
<td>basilar tip</td>
<td>yes</td>
<td>none</td>
<td>infarction of perforating artery</td>
</tr>
<tr>
<td>13</td>
<td>77, M</td>
<td>SAH (Hunt &amp; Hess Grade IV)</td>
<td>aneurysm</td>
<td>VBJ</td>
<td>yes</td>
<td>none</td>
<td>none</td>
</tr>
</tbody>
</table>

* Cav ICA = cavernous ICA; ICA Bif/M1 = bifurcation of ICA and M1 segment of MCA; V4 = fourth segment of VA.
† Large aneurysms range in diameter from more than 1.5 to 2.5 cm; giant aneurysms are larger than 2.5 cm. Entries listed simply as aneurysm indicate lesions 1.5 cm or smaller.
Percutaneous intracranial stent placement

Illustrative Cases

Case 1

Five years before she underwent stent-assisted treatment at age 72, this woman underwent induced cardiac standstill and satisfactory clip occlusion of a giant basilar trunk aneurysm (Fig. 1A). Initially the patient did well, but the aneurysm recurred (Fig. 1B) and was treated by coil embolization (Fig. 1C). The patient returned with headaches, and angiography demonstrated a marked recurrence of the aneurysm (Fig. 1D and E). The planned treatment was stent placement followed by coil embolization at a later date. After initial images were obtained, a 0.014-in microguidewire (Synchro; Precision Vascular, West Valley City, UT) was advanced beyond the aneurysm; along this a microcatheter (Prowler; Cordis, Miami, FL) was moved and placed in the basilar artery. Another wire (Choice 0.014 exchange-length wire; Boston Scientific, Natick, MA) was introduced through the microcatheter, after which the latter was removed. After a 3 × 14-mm stent (Radius; Boston Scientific) could not be advanced beyond the level of C1–2, a 3 × 12-mm stent (AVE S670; Medtronic, Advanced Vascular Engineering, Santa Rosa, CA) was passed successfully to the level of the aneurysm. The stent was implanted and excellent flow was noted (Fig. 1F). At this point, treatment was halted pending possible thrombosis of the aneurysm in response to stent placement alone and to allow time for the stent to become incorporated into the vessel wall.

One month later the patient returned for embolization of the aneurysm. Initial images showed that approximately 80% of the aneurysm had thrombosed (Fig. 1G). A small residual aneurysm was present at the inflow zone along the distal aspect of the aneurysm neck. Three coils were implanted uneventfully, and angiographic images confirmed complete obliteration of the aneurysm (Fig. 1H and I). At an 8-month follow-up examination, the patient was symptom free and the aneurysm remained completely occluded.

Case 7

This 63-year-old woman sought treatment for intermittent diplopia caused by palsy of the sixth cranial nerve and a persistent headache that had been managed inadequately by medication. Cerebral angiography revealed a bilobed, irregular, and broad-necked aneurysm in the left cavernous ICA (Fig. 2 upper). It was decided to treat the aneurysm with stent-assisted coil embolization.

During a 30-minute balloon occlusion test, the patient’s neurological status remained unchanged. Because it is well known that tolerance of a test occlusion does not exclude the possibility of failure and stroke with permanent occlusion, preservation of the parent vessel was desired. Having performed the test occlusion, treatment with stent-assisted coil placement could be undertaken with greater confidence, knowing that the fall-back strategy of parent vessel occlusion was viable. A microcatheter (Excel-14; Boston

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Aneurysm Neck (mm)</th>
<th>Aneurysm Dome (mm)</th>
<th>Dome/Neck Ratio (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15</td>
<td>25</td>
<td>1.67:1</td>
</tr>
<tr>
<td>2*</td>
<td>10</td>
<td>20</td>
<td>2:1</td>
</tr>
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<td>3</td>
<td>6</td>
<td>7</td>
<td>1.2:1</td>
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<tr>
<td>4*</td>
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</tr>
<tr>
<td>5*</td>
<td>10</td>
<td>26</td>
<td>2.6:1</td>
</tr>
<tr>
<td>6</td>
<td>20</td>
<td>40</td>
<td>2:1</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
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<td>30</td>
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<td>10</td>
<td>10</td>
<td>14</td>
<td>1.4:1</td>
</tr>
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<td>11</td>
<td>13</td>
<td>26</td>
<td>2:1</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td>30</td>
<td>3:1</td>
</tr>
<tr>
<td>13</td>
<td>7</td>
<td>7</td>
<td>1:1</td>
</tr>
</tbody>
</table>

* Patients in Cases 2, 4, and 5 were not treated with stent-assisted coil embolization.

TABLE 2

Morphological characteristics of aneurysms in 13 patients

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Size of Remnant (mm)</th>
<th>Angiographic Findings</th>
<th>Follow Up (mos)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>no residua</td>
<td>8</td>
</tr>
<tr>
<td>2†</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>3</td>
<td>none</td>
<td>recurrence</td>
<td>1</td>
</tr>
<tr>
<td>4‡</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>5‡</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>lost to follow up</td>
<td>NA</td>
</tr>
<tr>
<td>7</td>
<td>1</td>
<td>unchanged remnant</td>
<td>15</td>
</tr>
<tr>
<td>8</td>
<td>3</td>
<td>recurrence</td>
<td>7</td>
</tr>
<tr>
<td>9‡</td>
<td>4</td>
<td>NA</td>
<td>died</td>
</tr>
<tr>
<td>10</td>
<td>3</td>
<td>no residua</td>
<td>18</td>
</tr>
<tr>
<td>11</td>
<td>none</td>
<td>lost to follow up</td>
<td>NA</td>
</tr>
<tr>
<td>12‡</td>
<td>2</td>
<td>none</td>
<td>died</td>
</tr>
<tr>
<td>13‡</td>
<td>none</td>
<td>NA</td>
<td>died</td>
</tr>
</tbody>
</table>

* NA = not applicable.
† The patients in Cases 2, 4, and 5 were not treated with stent-assisted coil embolization.
‡ The patients in Cases 9 and 13 died during hospitalization of causes unrelated to their treatment. The patient in Case 12 died 1 month posttreatment of infarction of a brainstem perforating artery; the death was related to stent placement.

Results of follow-up cerebral angiography in 13 patients*

* Table 3
Scientific/Target, Fremont, CA) was placed into the MCA to allow an exchange length of 0.014-in wire (Choice) to be advanced to the branches of the M3 segment. The microcatheter was removed and a stent (4 × 18–mm AVE S670) was advanced across the neck of the aneurysm. The stent was implanted and the angioplasty balloon was inflated to 12 atm. The balloon was then deflated, and angiography demonstrated excellent blood flow with a somewhat slower emptying of the aneurysm and excellent positioning of the stent. At this point treatment was halted, pending possible thrombosis of the aneurysm with stent placement alone and to allow the stent to become incorporated into the vessel wall.

Eight weeks later, angiography confirmed persistent filling of the aneurysm with stent placement alone and to allow the stent to become incorporated into the vessel wall. The aneurysm was embolized with multiple GDCs (Boston Scientific/Target) (Fig. 2 lower). Seven months later, the patient’s left frontal headaches had resolved and her diplopia had improved.

Case 8

This 69-year-old woman had undergone surgery to treat a VBJ aneurysm, which had been discovered after she had survived a motor vehicle accident 5 years earlier. Surgical clip application was unsuccessful and the aneurysm was wrapped. Postoperatively, the patient began to experience increasing diplopia, loss of hearing in the left ear, and vocal paralysis on the left side. Follow-up angiography revealed that the aneurysm had enlarged (Fig. 3 upper), and the patient was referred to our institution for endovascular treatment.

A right transradial approach was performed. An Allen test was performed before the right radial artery was catheterized with the aid of a No. 6 French sheath. To prevent vasospasm, an infusion of verapamil (2.5 mg), cardiac lidocaine (20 mg), and nitroglycerin (100 μg) was administered through the sheath after the catheter had been placed.11 A No. 6 French guide catheter was advanced to the distal right VA, and angiography revealed a relatively broad based aneurysm at the VBJ.

A self-expanding stent (Radius, 3.5 × 14 mm), which had been advanced via the right VA to bridge the neck of the aneurysm, was implanted. After the guidewire had been removed, the stent shifted distally and bridged only the distal portion of the aneurysm neck. The left posterior cerebral artery was reentered using the guidewire to provide adequate support for placement of a second stent (Radius, 3.5 × 14 mm). The stent extended from the level of the right anterior inferior cerebellar artery into the right VA. Twenty-one GDCs were then detached within the aneurysm sac. Filling continued in the inferoposterior aspect of the aneurysm. Further attempts to place the microcatheter into this region were unsuccessful.

Angiography performed 2 days after the procedure showed progressive thrombosis of the aneurysm (Fig. 3 up-
The next day the patient was discharged with no new neurological deficits. Six-month follow-up angiography showed compaction of the coil mass with recurrence of the aneurysm (Fig. 3 lower left), which again was packed with coils uneventfully (Fig. 3 lower right).

Discussion

Few authors have described their techniques and outcomes of placing intracranial stents. Lanzino, et al., described 10 patients with intracranial aneurysms in whom intracranial stents were placed. Eight patients also underwent transfemoral embozitilization with GDCs. Two patients who were treated with only a stent are being followed. Follow-up review of these cases revealed only one case of in-stent stenosis. There were no permanent neurological complications. In the two patients treated with only a stent no evidence of aneurysm thrombosis was found on follow-up angiograms. That series is similar to ours with a few exceptions. In one of our patients (Case 1) partial thrombosis of the basilar trunk aneurysm developed after she underwent stent placement alone. Two of our patients suffered permanent neurological complications. Phatouros, et al., described seven patients in whom an extracranial pseudoaneurysm was treated with stent-supported coil embolization. Only three of their patients underwent treatment for an intracranial aneurysm.

Mechanical Benefits of Stent Placement

Broad-based intracranial aneurysms present significant challenges for endovascular treatment. The broad base creates a high risk of coil herniation into the parent vessel and increases the risk for delayed coil compaction and recanalization of the aneurysm. Stent placement across the base of the aneurysm enables a mechanical scaffold to prevent the coils from herniating into the parent vessel and potentially permits tighter packing of the aneurysm. For broad-based aneurysms, “balloon remodeling” has been helpful. Whereas the balloon is removed after coil delivery, a stent can serve as a permanent mechanical scaffold against which coils can be packed. Balloon remodeling techniques require multiple inflations and deflations of the balloon in the parent vessel with each placement of coils. This repetitive inflation can cause ischemic injury related to temporary parent vessel occlusion as well as traumatic injury to the endothelium. Endothelial injury can cause thromboembolic complications. In contrast, stent placement requires only a single step.

In-Stent Stenosis With Intracranial Stents

In-stent stenosis is a well-described phenomenon in the coronary artery and CA literature. Intracranial stent placement has produced concerns about the develop-
Hemodynamic Benefits of Stent Placement

Wide-necked aneurysms are associated with significantly worse endovascular outcomes than small-necked aneurysms. Fernandez Zubillaga, et al., reported an 85% rate of complete aneurysm thrombosis for small-necked aneurysms (neck < 4-mm diameter) compared with a 15% rate in wide-necked aneurysms. The neck orifice, or inflow zone, is a surface whose area is proportional to the square of the radius of the neck. Because of this exponential relationship, a small change in the diameter of the neck can dramatically change the area of the inflow zone. Changing the hemodynamics of the inflow zone is critical for promoting thrombosis of wide-necked aneurysms. Placement of a porous stent across the inflow zone alters the dynamics of blood flow, often reducing flow into the aneurysm. The stent acts as a new flow conduit within that vessel, hemodynamically uncoupling the vessel. The result is stagnant and reduced flow vortices within the aneurysm. A new intima may form across the stent over time, reinforcing the durability of the stent and coil construct and reducing the likelihood of a recurrence.

Visual Benefits of Stent Placement

Visualization of the parent vessel can be difficult during coil embolization of complex, broad-based aneurysms. Placement of intracranial stents across the neck of the aneurysm can improve visualization of the parent vessel and increase confidence regarding the location of the coils.

Immediate Compared With Delayed Transstent GDC Embolization

Placement of a porous stent alone may change blood flow into intracranial aneurysms and related hemodynamics profoundly enough to produce spontaneous thrombosis. In vivo animal studies have shown that stents alone can cause permanent thrombosis of side-wall (pseudo) extracranial CA aneurysms. In addition, neointima may form along the intimal surface of the stent, remodeling the diseased arterial segment. Stent placement alone resolves some fusiform pseudoaneurysms of the cervical ICA.

Based on these hypotheses, we initially placed stents alone in only four of the 10 patients, and all their aneurysms filled slowly after stent placement. Six of the 10 patients, including all patients who presented with SAH, immediately underwent transstent GDC embolization. The four patients initially treated with stent placement underwent follow-up cerebral angiography in anticipation of their requiring GDC embolization. The configuration of the aneurysm was unchanged in three patients with no evidence of thrombosis, despite slower filling of the aneurysm. As planned, these patients underwent GDC embolization. The large, recurrent basilar trunk aneurysm in the patient in Case 1, however, displayed approximately 80% thrombosis and the small residual aneurysm was occluded with GDCs. Thus, the potential for significant thrombosis of aneurysms after stent placement alone does exist.

Risks and Benefits of Coil Embolization Alone Compared With Stent-Assisted Coil Embolization

Coil embolization alone is associated with lower rates of morbidity and mortality than stent placement followed by coil embolization. Stent placement increases the complexity of a case and, thus, the associated risk of complications, as evidenced by the 20% complication rate in our patients. In this series, however, the patients were not considered good candidates for open microsurgical treatment because of previous surgery and the location of the lesions. Balloon-assisted coil embolization can be helpful, but has limited utility in the treatment of very broad-necked aneurysms. In some patients in this series prior attempts at balloon remodeling had failed, and it was hoped that the stent would assist not only with coil stability, but with altering flow dynamics. Thus, stents were required to support coil embolization.

Management of Large or Giant Cavernous ICA Aneurysms

Two of our patients underwent transstent embolization of pseudoaneurysms. In one patient an iatrogenic pseudoaneurysm involving the cavernous ICA developed after surgical resection of a skull base tumor. The procedure was successful, but the length of follow up was limited because the patient died of unrelated causes. The second patient had SAH from a pseudoaneurysm of the intracranial VA. At his 1-month follow-up examination this patient’s aneurysm was found to have recurred and was treated successfully with parent vessel occlusion. Both patients were treated immediately with embolization of the pseudoaneurysm after stent placement. In patients with inadequate collateral flow, it is important to preserve the parent vessel when treating ruptured pseudoaneurysms. Nevertheless, on the basis of our admittedly small experience, we suggest that parent vessel occlusion for intracranial pseudoaneurysms may be preferable for patients who tolerate sacrifice of the parent vessel. Close follow up of patients whose parent vessel is preserved is necessary.
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occlusion test with induced hypotension to determine if the patient will tolerate sacrifice of the ICA. It is well known that tolerance of a test occlusion does not exclude the possibility of stroke with permanent occlusion, thus preservation of the parent vessel is desired. If the patient passes the temporary balloon occlusion test and if attempts at stent placement and coil embolization are unsuccessful, we proceed with endovascular occlusion of the ICA.

Analysis of Current Limitations

In this series, stents could not be delivered to the base of the aneurysm in three patients. Navigating stents beyond the OphA is difficult because the carotid siphon is consistently tortuous. Lanzino, et al., reported three paraclinoid aneurysms and Wilms and associates reported a paraclinoid aneurysm of the carotid siphon that were treated with transsphenoidal embolization. In the literature on percutaneous transluminal angioplasty and stent placement for atherosclerotic disease of the anterior circulation, only one case of stent placement has been reported distal to the paraclinoidal region. Gomez and colleagues electively placed a stent in a patient with an MCA stenosis.

The patients in our series were treated between June 2000 and November 2001. During this period there were no significant changes in stent technology and all stents used were designed for cardiological purposes. Since September 2002, however, the Neuroform stent (Boston Scientific), which is specifically designed for intracranial use, has been available in North America. We have now used the Neuroform stent in several cases and found significant differences between it and stents designed for cardiological indications. In several cases, for example, we have been able to place stents beyond the OphA in the anterior circulation (unpublished data). The stent is very flexible and appears to be significantly improved compared with previous ones. This should permit a wider spectrum of lesions to be treated, and the morbidity and mortality rates for these procedures may decline as well.

Future Directions

Besides the need for stents designed specifically for intracranial aneurysms, covered stent technology is the next logical step in endovascular therapy. In the intracranial or extracranial circulations, where small branches or perforating vessels are absent or not functionally important, a covered stent may represent adequate treatment by itself. All our cases required stent-assisted coil embolization. Thus select cases such as those involving the cavernous ICA could be treated with a covered stent alone. We must await the clinical availability of appropriate covered stents to evaluate their maneuverability and thrombogenicity, as well as the patency rates of the native vessel. Nevertheless, preliminary data in three patients with CA pseudoaneurysms that were treated using polyethylene terephthalate endografts demonstrated complete occlusion of one graft and in-graft stenosis ranging from 50 to 100% in the other grafts. To place stents in the intracranial circulation, guide catheters must be placed as far distally as possible to support the guidewire. Such maneuvers are challenging when dealing with tortuous vessels and stiff guide catheters, and iatrogenic dissection is a risk.

As stent, guide catheter, and guidewire technologies improve, many of these problems will be reduced and morbidity rates should decrease concomitantly. Nevertheless, follow-up review is still needed to determine the long-term outcome of endovascular treatment of these lesions. Questions exist about the recurrence rates of embolized aneurysms, their efficacy at protection from hemorrhage, and the potential development of in-stent stenosis from intimal hyperplasia.

Conclusions

Percutaneous placement of intracranial stents converted broad-based aneurysms unamenable to endovascular treatment into treatable lesions. It remains technically challenging, however, to navigate a stent into the intracranial circulation, particularly for aneurysms located distal to the carotid siphon. Intracranial stents provide mechanical and hemodynamic benefits for the treatment of broad-based aneurysms. They enable tighter packing and reduce blood flow throughout the inflow zone of the aneurysm. These benefits may increase the success and durability of endovascular treatment of broad-based aneurysms.

References


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