Endovascular reconstruction of intracranial arteries by stent placement and combined techniques

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Object. The authors investigated the feasibility, safety, and short-term outcome of stent treatment for intracranial aneurysms, stenoses, and dissections.

Methods. One hundred twenty-three consecutive patients with intracranial saccular, dissecting, and fusiform aneurysms, atherosclerotic lesions, and dissections were selected for intracranial stent implantation with or without adjunctive coil placement. One hundred eleven patients (mean age 47 years, range 3–73 years) underwent stent treatment; 12 patients (9.8%) were not treated. These 111 patients were divided into four groups: in Group 1 there were 62 patients with saccular aneurysms; Group 2 included nine patients (10 lesions) with dissecting or fusiform aneurysms; in Group 3 there were 36 patients with symptomatic intracranial atheromatous stenoses of more than 50%; and Group 4 included four patients with symptomatic intracranial dissections. All patients underwent computed tomography scanning and/or magnetic resonance imaging and cerebral digital subtraction angiography preoperatively. Of the 72 aneurysms in Groups 1 and 2, 59 (82%) were treated with combined endovascular stent implantation and endosaccular coil placement. In 67 aneurysms (93%) we achieved complete or nearly complete obliteration. All patients with arterial narrowing achieved residual stenoses of less than 30% postangioplasty. One patient required repeated angioplasty. The morbidity rate in the series was 10.9% and the mortality rate was 6.3%.

Conclusions. These findings indicate that stent treatment is feasible and seems to be an effective modality for arterial reconstruction. This versatile tool allows the treatment of a wide variety of challenging intracranial lesions.

Key Words • aneurysm • atheromatic stenosis • coil embolization • intracranial stent
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tients with intracranial saccular, dissecting, and fusiform
aneurysms, atherosclerotic stenotic lesions, and arterial dis-
sections were selected for intracranial stent placement with
or without adjunctive GDCs. In 12 patients (9.8%) the stent
did not reach the target and these patients were excluded
from further analysis. The patient population was composed
of 52 male and 59 female patients; patients with aneurysms
ranged from 3 to 64 years of age (mean 49 years) and pa-
tients with stenotic lesions ranged from 12 to 73 years of
age (mean 54 years).

The most common presentation for patients harboring
aneurysms was SAH (33 [46%]), followed by mass effect
(32 [45%]). Ischemic stroke was the presentation of patients
with atheromatous stenoses and dissections (40 [100%]).

Inclusion Criteria

Patients harboring aneurysms were selected for stent
treatment based on a number of factors, including the pa-
tient’s decision, failure of or contraindication for coil place-
ment, high surgical risks, poor neurological grade, and poor
medical status.

Patients with atherosclerotic stenoses and dissections
were included in this study after failure of antithrombot-
icty, which was defined as the occurrence of isch-
emic events (one or more transient ischemic attacks and/
or strokes) while they were receiving therapeutic doses of
aspirin (> 81 mg/day), warfarin (international normalized
ratio > 2), ticlopidine (500 mg/day), clopidogrel (75 mg/
day), or heparin (prolongation of partial thromboplastin
time > 1.5 times the baseline value) and a contraindica-
tion to antithrombotic therapy.

Stent treatment was contraindicated in patients with ex-
treme vessel tortuosity that might impair placement of the
device, or those with a history of bleeding diathesis or coag-
ulopathy or who would refuse blood transfusions, in pa-
tients who experienced significant gastrointestinal bleeding
within the past 6 months, or who presented with contraindi-
cations to aspirin or ticlopidine.

All patients underwent computerized tomography scan-
ing and/or magnetic resonance imaging and DS angiogra-
phy preoperatively. One of them had previously undergone
an incomplete clipping procedure and in six there was a
remnant of a previously coil-treated aneurysm. All proce-
dures were approved as part of a feasibility protocol by the
Institutional Review Board. Each patient or a responsible
relative understood the innovative “off-label” use of the
stents and provided written informed consent.

The 111 patients included in the study were divided into
four groups: in Group 1 there were 62 patients with wide-
necked saccular aneurysms; Group 2 included nine patients
(10 lesions) with dissecting or fusiform aneurysms of the
VA (nine lesions) or the ICA (one lesion); in Group 3 there
were 36 patients with symptomatic intracranial ICA or VA
atheromatous stenoses of more than 50%; and Group 4 in-
cluded four patients with symptomatic intracranial dis-
sections, two (50%) in the ICA, one (25%) in the VA, and one
(25%) in the BA.

All saccular aneurysms except three (5%), were located
in the anterior circulation; the most common location was
the ICA–ophthalmic artery segment (23 [37%]), followed
by the ICA–posterior communicating/anterior choroidal ar-
tery segments (18 [29%]), ICA–cavernous artery segment
(16 [26%]), and the M, segment (two [3%]). Conversely, all
dissecting and fusiform aneurysms except one were located
in the posterior circulation.

The most common locations for stenotic lesions were
the distal VA (12 [30%]) and the petrocaudaneous ICA (12
[30%]), followed by the supraclinoid ICA (six [15%]),
the vertebrobasilar junction (four [10%]), the BA (three
[7.5%]), supraclinoid ICA–M, segment (two [5%]), and the
M, segment (one [2.5%]).

Embolization and Angioplasty Grading Protocol

All treated aneurysms were evaluated using selective DS
angiography and transcranial Doppler ultrasonography af-
fter treatment and at follow-up examination. Transcranial
Doppler ultrasonography was used to monitor SAH-related
vasospasm and the patency of the stent-treated artery.

Considering that the subset of aneurysms currently se-
lected for stent placement (that is, those with unfavorable
geometry) pose the greatest technical difficulty for surgical
clipping and endovascular treatment without complications,
we used a modified outcome scale. Aneurysm occlusion
was based on a three-tiered scale of complete occlusion (no
residual neck or irregularity at the level of the aneurysm or-
ifice, or a small residual neck < 1 mm not amenable to fur-
ther coil placement); neck remnant (1–2 mm residual neck);
or partial occlusion. Stent placement was recorded as op-
timal when the stent was positioned across the aneurysm
orifice with enough overlap on each side, and suboptimal
when the stent did not overlap on both sides but still cov-
ered more than 66% of the aneurysm orifice.

Atheromatous lesions were classified according to the
system of Mori, et al., in three groups on the basis of lesion
morphological features. Type A lesions are 5 mm or less
in length, concentric or moderately eccentric, and less than
totally occlusive; Type B lesions are 5 to 10 mm in length,
extremely eccentric or totally occlusive, and less than 3
months old; and Type C lesions are more than 10 mm in
length, angulated more than 90˚, excessively tortuous or to-
tally occlusive, and 3 or more months old. For angioplasty
of vessel stenosis, the primary objective was the reduction
of stenosis to less than 50% without worsened neurological
status. Accordingly, we defined Grade I as a reduction in
the degree of stenosis to less than 50% without worsened
neurological status and Grade II as any reduction in the de-
gree of stenosis not reaching 50% or worsened neurological
status after percutaneous transluminal angioplasty.

General Surgical Procedure

Each patient was taken to the endovascular suite for cere-
bral angiography and endovascular treatment. Neuroleptic
anesthesia was preferred for cooperative patients; otherwise
general anesthesia was indicated. A unilateral (or bilateral)
intraarterial approach after standard Seldinger puncture and
catheterization was used and an 8F introducer sheath was
placed in the right femoral artery under full heparinization.

Protocol for Antithrombotic Agents

Our protocol consists of a 10,000-IU bolus dose just be-
fore the start of the therapeutic procedure, with a mainte-
nance booster of 1500 IU administered every hour to pro-
vide an activated clotting time longer than 250 seconds.
before stent placement. Patients who did not present with acute hemorrhage received oral doses of uncoated aspirin (500 mg/day) and ticlopidine (250 mg twice daily) for 3 days before the stent procedure was performed, and they received both medications for at least 90 days, after which ticlopidine was discontinued. Patients who presented with acute SAH were started on antiplatelet agents on the same operative day.

A potent inhibitor of platelet aggregation and wall deposition, abciximab was started prophylactically in every patient harboring complex atheromatous stenoses (Mori Type B or C). Before angioplasty, an intravenous bolus dose of 0.25 mg/kg was administered, followed by a maintenance dose of 10 µg/minute for 12 hours.

**Endovascular Technique for Aneurysm Treatment**

After antithrombotic and antiplatelet agents had been administered, a 6F Envoy guiding catheter with a 0.068-in inner diameter coaxial to an 8F catheter was then advanced into the ICA or VA by using a standard 0.035- or 0.038-in guidewire. Selective DS angiography was performed and the target lesion routinely outlined in multiple projections with rotational three-dimensional angiography. The caliber of the parent vessel above and below the target lesion and the aneurysm/neck diameters were calculated using the guiding catheter as a reference.

In cooperative patients with large cavernous or ophthalmic artery aneurysms, a functional balloon test occlusion was routinely performed before treatment. If the stent failed to reach the target, or complications such as significant arterial dissection, thrombosis, or rupture occurred, CA occlusion was considered.

A microcatheter (Excel, Prowler, or Rapid Transit) was then advanced over a tapered 0.014-in, 150-cm-long guide wire, allowing a safer navigation through the targeted vessel. The Envoy guiding catheter, the Prowler and Rapid Transit microcatheters were supplied by Cordis Endovascular Systems, Miami, FL, and the Wallstent by Schneider Inc., Minneapolis, MN. The Excel microcatheters were obtained from Boston Scientific, S. Natick, MA. The Transend-14 delivery system with 6 to 10 atm of pressure, according to the specifications of the selected stent. After stent placement, the aneurysm lumen usually continues to fill with contrast material. In patients presenting with hemorrhage, packing the aneurysm lumen with coils after positioning the tip of a microcatheter through the stent struts is mandatory. In nonhemorrhagic cases, however, with marked intraluminal stagnation of contrast material after stent implantation, a wait-and-see attitude before a second procedure may be reasonable.

**Endovascular Procedure for Atherosclerotic Stenoses**

The caliber of the parent vessel above and below the target lesion and the degree and length of the stenosis are calculated using the guiding catheter as a reference. Urokinase infusion or predilation with a balloon may be required, especially when proximally or distally located atherosclerotic plaques may prevent advancement of the stent. To traverse a complicated plaque or a tight dissection safely with the microguidewire, it is important to consider the use of a microcatheter for more precise control of the tip of the wire. A delicate 0.010-in microguidewire may allow distal microcatheter placement, after which the guidewire can be safely replaced with a stiffer 0.014-in one that will provide better support. Every maneuver should be executed very slowly and carefully, with constant control of the distally placed tip of the wire. This tip should be placed in the safest available artery (that is, one that supplies less eloquent areas, with a wide diameter, and no atherosclerotic infiltration).

In general, dilation is performed with a balloon for which the diameter is a ratio of 1:1 with the diameter of the vessel; however, a more conservative choice should be made when dealing with long, severe lesions or with BA lesions in which suboptimal results may be considered not only acceptable but less risky. The stent should cover the plaque while extending from healthy artery to healthy artery, and for this purpose more than one stent may be needed. Special attention should be paid to detect plaque dissections at each end of the implanted stent.

**Stent Selection and Description**

Careful stent sizing is very important: the stent should be chosen to match the diameter of the reference vessel and to correspond with the length of the lesion, or the aneurysm neck. In our early experience, we used devices that are currently applied in interventional cardiology, such as the Angiostent, a balloon-expandable metallic stent made of platinum; the coronary Wallstent; the Velocity balloon-expandable stent, the Med-X stent; and the AVE gfx, which is made of stainless steel. More recently, a new generation of stents, such as the AVE inx, has been introduced. The AVE inx consists of a metallic, radiopaque device with a more flexible design that is mounted on a delivery-placement catheter.

**Sources of Supplies and Equipment**

The Envoy guiding catheter, the Prowler and Rapid Transit microcatheters were supplied by Cordis Endovascular Systems, Miami, FL, and the Wallstent by Schneider Inc., Minneapolis, MN. The Excel microcatheters were obtained from Boston Scientific, S. Natick, MA. The Transend-14
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**TABLE 1**

Endovascular techniques and occlusion in 72 intracranial aneurysms at 3 to 6 months of follow up*

<table>
<thead>
<tr>
<th>Endovascular Technique</th>
<th>No. of Cases</th>
<th>Occlusion</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Complete</td>
<td>Neck Remnant</td>
</tr>
<tr>
<td>Group 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stent</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>stent &amp; coils</td>
<td>52</td>
<td>49 (15)</td>
</tr>
<tr>
<td>coils then stent &amp; coils†</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>subtotal</td>
<td>62</td>
<td>57</td>
</tr>
<tr>
<td>Group 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stent</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>stent &amp; coils</td>
<td>8</td>
<td>7 (1)</td>
</tr>
<tr>
<td>subtotal</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>total</td>
<td>72</td>
<td>66</td>
</tr>
</tbody>
</table>

* Numbers in parentheses indicate the number of patients who required extra coil implantation in a different procedure.
† Partial primary coil placement was followed by stent insertion and coil placement.
‡ Considered for further coil placement.

and Choice guidewires and the magnetic device used to exchange microguidewires were purchased from Scimed Life Sciences, Maple Grove, MN. The platinum Angiostent was acquired from Angio Dynamics, Queensbury, NY. The Velocity balloon-expandable stent was obtained from Johnson & Johnson Medical, Arlington, TX. The Med-X stent was purchased from Med-X Co., Lille, France. The AVE gfx and the AVE inx were acquired from Arterial Vascular Engineering, Inc., Santa Rosa, CA.

**Results**

**Treatment Feasibility**

The overall success in reaching the target lesion with stents was 90.3% (112 of 124 targets). Of 72 aneurysms (Groups 1 and 2), 59 (82%) were treated with combined endovascular stent implantation and endosaccular coil placement. In 32 cases (54%) coil placement was performed immediately after stent insertion during the same endovascular procedure, in 21 (36%) coils were placed in a second procedure, and in six cases (10.2%) incomplete coil placement was followed by stent insertion and further coil treatment. In 12 cases (20%), a second coil placement procedure was performed order to achieve complete aneurysm occlusion.

Stent delivery and positioning was considered optimal in 58 lesions (81%) and suboptimal in 14 (19%). In all cases with suboptimal placement, a second (10 cases) or even a third stent (four cases) was placed in a telescoped fashion, achieving complete coverage of the aneurysm orifice. Ninety stents were implanted (mean 1.25 stents per lesion); the AVE inx was used in 64% (58 cases), the AVE gfx in 16% (14 cases), the Med X in 7% (six cases), the Velocity 8% (seven cases), and others in 5% (five cases).

Atheromatous stenoses and dissections (Groups 3 and 4) were completely covered with one stent in 30 cases (75%), with two stents in six cases (15%), and with three stents in the other four cases (10%). Fifty-four stents were implanted in these two groups (mean 1.35 stents per lesion): the AVE inx was implanted in 67% (36 cases), followed by AVE gfx in 17% (nine cases), Velocity in 11% (six cases), and others in 5% (three cases).

**Treatment Efficacy: Angiographic Results**

**Group 1.** As shown in Table 1, of 62 aneurysms, 51 (82%) were treated with the combined procedure and 11 (18%) with a stent only. On immediate postoperative angiographic studies, in 46 aneurysms (74%) complete occlusion was achieved; five cases (8%) presented with neck remnants or partial occlusion after stent and coil placement, and 11 (18%) presented with no occlusion after stent placement. On 3-month follow-up review, 19 cases were treated with coils because of recanalization (eight), partial occlusion (four), or no occlusion (seven). Recanalization was directly related to an unfavorable neck/fundus ratio and suboptimal coil packing.

Unexpectedly, three patients treated with stents and no coils presented with complete obliteration. Overall, at 3- to 6-month follow up, complete or nearly complete occlusion was achieved in 57 cases (92%).

**Group 2.** Eight aneurysms were completely occluded with combined methods in the same procedure (Figs. 1 and 2). On follow up, one partially recanalized aneurysm required further coil treatment for complete occlusion and one patient harbored a small neck remnant that is being followed conservatively. Two patients, one with a dissecting and one with a fusiform aneurysm treated with stents only, presented with complete occlusion at the 3-month follow-up visit. Overall, at 3 to 6 months of follow up, complete or nearly complete occlusion was 100%.
Group 3. Thirty-six lesions with stenoses ranging from 60 to 95% (mean 78%), and 3 to 27 mm in length (mean 11 mm) were treated. According to morphological findings, nine lesions were recorded as Type A (25%), 19 as Type B (53%), and eight as Type C (22%). Thirty-two patients (89%) were categorized as postoperative Grade I and four patients (11%) achieved Grade II (see Embolization and Angioplasty Grading Protocol). All the patients achieved residual stenoses of less than 30% (mean 16%) postangioplasty. Figure 3 illustrates a lesion from this group.

Group 4. This group included four patients with stenoses ranging from 65 to 100% (mean 80%). All patients achieved residual stenoses of less than 20% postangioplasty. Figure 3 illustrates a lesion from this group.

Technical Limitations and Complications

A total of 133 embolization procedures were performed for the treatment of 112 lesions. In these procedures the following complications were seen.

Inability to Reach the Target. In 12 of 123 patients we were unable to reach the target with the available stents. All of these targets were located on the ICA, and the most common limiting segments were the anterior bend of the cavernous artery segment (five lesions), followed by the petrous CA (five lesions), the posterior bend of the cavernous artery segment (two lesions), and the cervical ICA (one lesion).

Unintended Stent Dislodgement. Five stents were unintentionally detached from the balloon before reaching the target. Four of them were successfully retrieved with a snare. One stent was not recovered, however, and thus was placed at a proximal site. No clinical complications were detected in this instance.

Stent Displacement. On balloon inflation the mounted stent tends to advance from the selected position. After deflation, removing the balloon may cause the stent to move backward. This event occurred in five cases, resulting in suboptimal stent implantation that required additional stent placement.

Inability to Place Coils Through the Stent. Currently available microcatheters are able to traverse the stent mesh. A gentle 90° catheter curve and a microguidewire tip with moderate-to-high stiffness may assist in correct microcatheter placement. Coil placement is generally uneventful and soft coils may be useful when backward motion of the catheter is a major concern. When dealing with telescoped stents, the preferred microcatheter position is in the single-mesh segment of the stent. With this approach all the selected targets were adequately filled with coils.

Hemorrhagic Complications. No aneurysm bled during the embolization procedure. In three patients a cerebral hematoma developed that was caused by vessel tearing with the microguidewire; two individuals made a complete recovery and one presented with a moderate deficit at follow-up review. In two cases target vessel rupture occurred while we were placing the stent. In one patient in whom a giant cavernous artery symptomatic aneurysm was being treated, inadequate selection of the stent size led to vessel perfora-
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tion, with subsequent parenchymal hemorrhage and SAH; the hematoma was surgically evacuated but the patient died. The second patient harbored a severe stenosis of the midbasilar trunk, and although the stent was adequately positioned, while we were inflating the balloon to nearly 80% of the normal artery diameter, the vessel ruptured catastrophically (see Discussion).

Ischemic Complications. Five patients presented with neurological deficits associated with procedure-related emboli; four of them required fibrinolysis, and these four made a complete recovery. One patient presented with a P1 thrombosis related to dissection of a local atherosclerotic plaque by the microguidewire; fibrinolysis was ineffective, and moreover the clot extended to the BA tip and the contralateral P1. This patient suffered a biocapital and brainstem infarction and died.

Complications Related to SAH. Two of 33 patients who presented with SAH died; their deaths were caused by vasospasm and septic shock. Three other patients presenting with symptomatic SAH-related vasospasm required mechanical (two patients) and/or pharmacological angioplasty (one patient); all three achieved good neurological recovery.

Postprocedure Morbidity and Mortality Rates

Two patients with intracranial atherosclerosis presented postoperatively with transient ischemic attacks. Control DS angiography was performed and failed to show abnormalities at the level of the implanted stents. In three patients a drug-related cutaneous rash was observed on follow-up review. One patient who presented with bilateral severe stenoses of the supraclinoid and proximal M1 segments was successfully treated and an adequate revascularization of the left supraclinoid ICA and M1 was achieved. Nonetheless, this patient suffered a delayed cerebral hematoma related to reperfusion of a chronically ischemic nonauto-regulating parenchyma. An operation was performed, but a contralateral infarction developed and the patient died. Pathological specimens demonstrated diffuse amyloid angiopathy. The other patient, who harbored a Type C vertebrobasilar atheromatous stenosis, died of a myocardial infarction 6 months after the procedure. The overall morbidity rate was 10.9%, and the overall mortality rate in this series was 6.3%.

Clinical and Angiographic Follow Up

Clinical follow up was performed in all 107 discharged patients either with scheduled visits (98 patients, 91.6%) or with phone interviews (nine patients, 8.4%). Seven patients (6.5%) were evaluated at 1 month, 42 (39.3%) at 3 months, 27 (25.1%) at 6 months, 27 (25.1%) at 1 year, and four (4%) at more than 2 years. The mean clinical follow up was 6.7 months. The overall clinical outcome of the patients in the series was good (Glasgow Outcome Scale Scores 4 and 5) in 101 patients (91%), fair in four (3.6%), and six (6.3%) died.

Angiographic follow up was performed in 81 (77%) of 105 patients who survived: in 18 patients at 1 month (22%), in 28 at 3 months (35%), in 23 at 6 months (29%), in 10 at 1 year (12%), and in two at 2 years (2%). The mean angiographic follow up was 5 months. Asymptomatic low-grade dissection at the proximal parent artery was detected in two patients on the 3-month DS angiography follow-up study, and was probably related to trauma exerted by the guiding catheter. None of the patients was considered to require endovascular treatment and they were given antithrombotic therapy; on follow-up review both lesions had healed (6-month DS angiography follow up). Asymptomatic subacute VA stent thrombosis was incidentally detected on a 3-month DS angiographic follow-up study in a noncompliant patient. Three patients harboring stenotic lesions presented with asymptomatic in-stent de novo stenosis; two of them had received single stents and one had three telescoped devices. One of these patients had a 50% stenosis that was successfully treated with repeated angioplasty. It is noteworthy that none of the patients harboring aneurysms presented with in-stent de novo stenosis.

Discussion

The availability of recently introduced flexible stents that can be navigated through the tortuosities of proximal intracranial vessels has prompted endovascular neurosurgeons and neuroradiologists to consider the stent-assisted method in the endovascular treatment of wide-necked saccular, dissecting, and fusiform aneurysms that are unsuitable for GDCs alone.

Wide-necked saccular lesions constitute a persistent challenge for GDC treatment even after development of three-dimensional GDCs and balloon-assisted techniques. On the other hand, dissecting and fusiform aneurysms usually are not treatable by standard clipping and endovascular procedures such as coil placement, because the aneurysm neck is not adequate to hold the coils or clip in place. In these settings, a stent can be used to create a neck in the aneurysm that holds the GDCs in place, virtually avoiding coil protrusion and migration, and furthermore allowing tighter packing of the lesion. In addition, the stent may disrupt the aneurysm inflow tract, thereby inducing stasis and facilitating intraaneurysmal thrombosis. This mechanism played a major role in five cases, obviating the need for further coil placement. Blood stasis after stent insertion was observed only in lateral type aneurysms; and although the cases in which we achieved complete occlusion with stents were lateral type aneurysms, we did not observe a consistent relationship between postoperative intraaneurysmal blood stasis and complete occlusion.

Stent-assisted angioplasty has evolved to become a promising treatment for symptomatic intracranial atherosomatous lesions and dissections. The need for additional coils can be minimized, iatrogenic dissection may also be limited, and the plaque and intimal flap are covered by the stent.

This broad potential of the stent for the treatment of a variety of intracranial lesions resides in its capability for vessel reconstruction as a primary target. In other words, the diseased artery and not just a lesion is the target in every situation. The stent provides the matrix for structural reconstruction of vessels, assisting primary procedures such as fibrinolysis or balloon predilation, or secondary techniques including coil placement or balloon postdilation.

Flexibility and trackability, although improved in the new stents, is still a major concern and may limit navigation in tortuous vessels. We report on a series of 111 patients whom...
we were technically able to treat with stent placement. In 12 cases the selected stent was not able to reach the target; the petrocavernous transition and the anterior bend of the cavernous ICA represented critical segments in five cases each. A retrospective analysis of these cases shows a tendency for more acute angles in relatively fixed segments. This relative limitation was overcome in several instances by improving proximal support (that is, advancing the guiding catheter) alone or in combination with more distally placed microguidewires, and eventually slightly bending the distal tip of the balloon with the aid of steam. The posterior circulation was safely navigated in all the cases and no procedure was aborted because of vessel tortuosity or balloon or stent limitations in this territory.

Longer stents tend to be less flexible and trackable, and in 23 instances, we placed two and even three shorter and more flexible stents in a telescoped fashion instead of a single stent that would not negotiate the vessel curves. Long, atheromatous lesions of the posterior circulation were frequently treated with multiple relatively long stents (10 or 12 mm long), but wide-necked aneurysms in the anterior circulation frequently required shorter stents.

Suboptimal stent placement was observed more frequently early in this series; however, the learning curve for inserting stents in intracranial lesions and avoiding technical problems has been steep. Selection of inadequate stent size (length and/or diameter), underexpansion of the stent (for fear of overdilation), and inability to deflate the balloon fully after insertion contributed to the displacement. In all cases, however, a second or even a third stent abutted or telescoped with the original one resolved the situation. Even when the orifice of the aneurysm is not completely covered, coil placement procedures can be performed through the mesh of the stent or through the remaining uncovered orifice of the aneurysm (stent assisted-remodeling technique). When dealing with telescoped stents, the preferred microcatheter position is in the single mesh segment of the stent; with this approach all the selected targets received adequate coil packing.

Problems affecting percutaneous transluminal angioplasty and stent treatment such as acute closure, stent thrombosis, and bleeding complications have been overcome to a large extent by use of better techniques and the availability of new drugs. In our series, one patient presented with a subacute asymptomatic stent thrombosis clearly related to noncompliance with their antiplatelet drug regimen; however, without pathological examination intimal hyperplasia could not be ruled out. There are no good long-term data on restenosis rates in the cerebrovascular tree, and any attempt to extrapolate the cardiology data should be considered inappropriate. In the neurointerventional literature there is no evidence indicating a relationship between single or multiple stents and intimal hyperplasia.

We observed an overall 10.9% morbidity rate and a 6.3% mortality rate in the 112 lesions treated in this study. The instances of morbidity were mainly the result of ischemic events caused by procedure-related emboli and hemorrhages caused by vessel tearing with a microguidewire. Adequate antaggregation and careful control of the distally placed microguidewire are essential. Precise measurements of the artery size are of paramount importance to match the size of the stent and the target lesion.

Overdilation is not an accepted practice in the intracranial circulation and may be especially dangerous in the BA, which different authors advocate underdilating (no more than half of the normal mid-diameter) because of insubstantial muscularis and adventitial layers of the artery wall and the subsequent elevated risk of perforation. A note of caution regarding stent placement in long, severe, and complex BA lesions must be added. In an unfortunate recent case, which is included in this series, a patient suffered a fatal arterial rupture after stent placement. An acceptable angiographically confirmed result was initially achieved, restoring the arterial diameter up to 50% without complications. A better result was considered possible, however, and an extra balloon inflation provoked artery rupture.

Although recent experience indicates that there have been significant advances in stent design, the flexibility, trackability, and especially radiopacity of currently available devices can still be improved.

Conclusions

The results of this study show that intracranial stent placement, although hazardous, is feasible in appropriately trained hands, with acceptable procedure-related complication, morbidity, and mortality rates. As in other practical fields, the experience quotient is important; the recent results are significantly better than those from our initial series. Reconstruction and preservation of the diseased artery is the objective, and assistive techniques will be chosen if needed, according to the particular type of lesion.

Disclaimer

The authors have no direct or indirect financial interest in the equipment or procedures discussed in this paper.

References

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