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Technical Note

# Bare Stent-Graft Technique: A New Method of Endoluminal Vascular Reconstruction for the Treatment of Giant and Fusiform Aneurysms

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**Summary: We present our initial experience with a newly developed endovascular stent graft technique in the treatment of two patients with giant aneurysms. In both of these patients, surgery and conventional endovascular techniques were likely to fail. The technique resulted in the successful management of the aneurysms in both cases. Our technique is described, and related experiences in the literature are discussed.**

The treatment of intracranial aneurysms has substantially improved in recent decades. Advances in microsurgery and anesthesiology have rendered conventional surgery safer and more effective, and recently developed endovascular techniques now make the minimally invasive treatment of intracranial aneurysms possible. As surgical and endovascular techniques have evolved, many of the technical challenges specifically associated with the management of smaller aneurysms have been resolved. The management of larger or more complicated aneurysms, however, requires further investigation and development in patients with giant cerebral aneurysms of the internal carotid artery (ICA) and in those with fusiform aneurysms of the basilar artery (BA). The ideal technical approach has yet to be definitively established (1–3). These two types of aneurysms represent notable challenges for the surgeon. Giant aneurysms involving the ophthalmic segment of the ICA are difficult to completely obliterate during surgery because of bony obstacles and the difficulty of proximal control (2, 4). Ruptured fusiform aneurysms of the BA may also have noncontiguous inflow and outflow, a feature that substantially limits treatment options (5–7).

We believe that the use of metallic vascular stents is a feasible technique for the treatment of large or complicated intracranial aneurysms. For the past several years, the combination of metallic vascular stent placement and balloon angioplasty has been widely used to treat atherosclerotic disease in the coronary, renal, and peripheral vascular systems. More recently, stents have also been used to treat atherosclerotic disease in the extracranial carotid artery. Vascular stent technology is advancing quickly, and the many highly effective stent delivery systems now available have enabled use of stents in the treatment of intracranial circulatory abnormalities. We herein report two cases that were treated with a stent and stent graft combination. One involved a ruptured giant aneurysm in the paraophtalmic segment of the right ICA, and the other involved a ruptured fusiform aneurysm arising from the vertebrobasilar junction. These aneurysms could not be treated with surgery or conventional endovascular techniques.

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## Case Reports

### *Case 1*

*Clinical Presentation and History.*—A 44-year-old woman with an acute-onset headache and nuchal stiffness followed by vomiting and confusion presented for care at a center other than ours. The patient's medical and family history were unremarkable.

*Diagnostic Examinations.*—Neurologic examination revealed slight confusion (Hunt-Hess grade II), dysfunction of the cerebellum, and neck stiffness. The patient was afebrile, with a blood pressure of 145 mm Hg systolic and 75 mm Hg diastolic, a pulse of 74 beats per minute, and a respiratory rate of 16 per minute. Emergency cranial CT revealed a giant, partially thrombosed aneurysm in the right premedullary region and subarachnoid hemorrhage (SAH) in the posterior fossa. Results of a lumber puncture also confirmed SAH. Cranial MR imaging revealed a giant, partially thrombosed aneurysm in the vertebrobasilar junction, as well as compression of the brain stem. Digital subtraction angiography showed a giant fusiform aneurysm that extended over the vertebrobasilar junction up to the midbasilar level (Fig 1A). The aneurysm incorporated the origin of both anterior inferior cerebellar arteries (AICAs). Another fusiform aneurysm was present at the distal right distal right vertebral artery (VA) of the posterior inferior cerebellar artery (PICA), and distal segment after PICA was hypoplastic (Fig 1B). The posterior communicating artery was absent on the left side, but a small posterior communicating artery (PCA) was observed on the right side. The results of the complete blood count and a routine chemistry panel and the prothrombin time and partial thromboplastin time were within normal limits. In consultation, neurosurgeons and neuroradiologists determined that endovascular treatment was necessary because of surgical inoperability.

*Endovascular Procedure.*—Endovascular treatment was performed with the patient under general anesthesia via unilateral femoral approach. The patient's oxygen saturation, heart rate, blood pressure (measured invasively), and urine output were monitored throughout the procedure. Two intravenous lines were used to administer drugs.

A 7F femoral introducer was placed into the right groin, and selective catheterization of the left VA was performed by using a

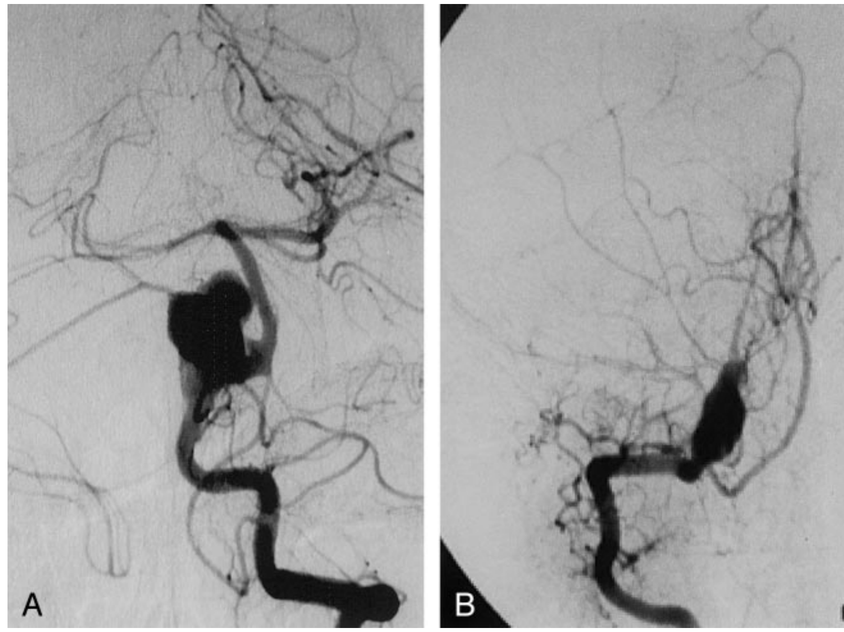



FIG 1. Case 1. Initial anteroposterior arteriograms in a 44-year-old woman who presented with SAH.

*A*, Image obtained with a left vertebral arterial injection shows a giant fusiform aneurysm that extends over the vertebrobasilar junction up to the midbasilar level.

*B*, Image obtained with a right vertebral arterial injection shows another fusiform aneurysm in the V4 segment of right vertebral artery a just before the the origin of the PICA. Note hypoplasia of distal V4 segment of right vertebral artery.

6F guiding catheter (Envoy; Cordis, Miami Lakes, FL). Through the guiding catheter, a microcatheter (Rapid Transit; Cordis) was advanced over a microguidewire (16 GT; Terumo Corp, Tokyo, Japan) and subsequently placed into the P1 segment in the right PCA. Then, the microguidewire was exchanged for a 300-cm-long 0.014-inch-diameter microguidewire (Medtronic-AVE; Medtronic, Santa Rosa, CA) within the right PCA.

By using road map guidance, a 3 × 30-mm coronary stent (AVE; Medtronic) was positioned across the neck of the aneurysm for support. The stent was then firmly anchored at both ends of the aneurysmal neck (Fig 2). Control angiograms showed a rerouting of the flow toward the lumen of the BA and a reduction in the filling of the aneurysm sac. Both of the AICAs were patent. To stop aneurysmal inflow and to channel the flow toward the normal BA, a 3 × 12-mm stent graft (Jostent; Jomed International, Helsinborg, Sweden) was navigated into the aneurysm inflow zone and placed into the first stent at the exact level of the aneurysm (Fig 3). No portion of the normal-appearing VA or of the basilar trunk was covered. Control angiography showed total occlusion of the inflow of the aneurysm and an absence of turbulent flow in the aneurysmal sac (Fig 4). Both of the AICAs were patent, and both of the PCA regions filled normally.

*Postoperative Course.*—Postoperatively, the patient received an oral 300-mg loading dose of clopidogrel (Plavix; Bristol-Meyers Squibb/Sanofi Pharmaceuticals, Princeton, NJ) followed by a daily oral dose of 75 mg. Aspirin was also administered in daily doses of 325 mg. The patient tolerated this procedure well and experienced marked clinical and neurologic improvement. The patient had headaches during her hospital stay; these responded to analgesic drugs. One week after the procedure, an early control angiogram was obtained before the patient was discharged home. It confirmed progressive occlusion of the aneurysm with little residue at the outflow zone where both of the AICAs originated. After the procedure and at 2-month clinical follow-up, the patient did not have any recurrent hemorrhage, and her neurologic condition continued to improve. Four months later, the patient's neurologic condition was normal, and a control angiogram revealed total occlusion of the remaining sac. Both AICAs were patent, and the basilar trunk appeared to be reconstructed (Fig 5A). MR imaging revealed a decrease in the mass effect of the aneurysm (Fig 5B).

*Case 2*

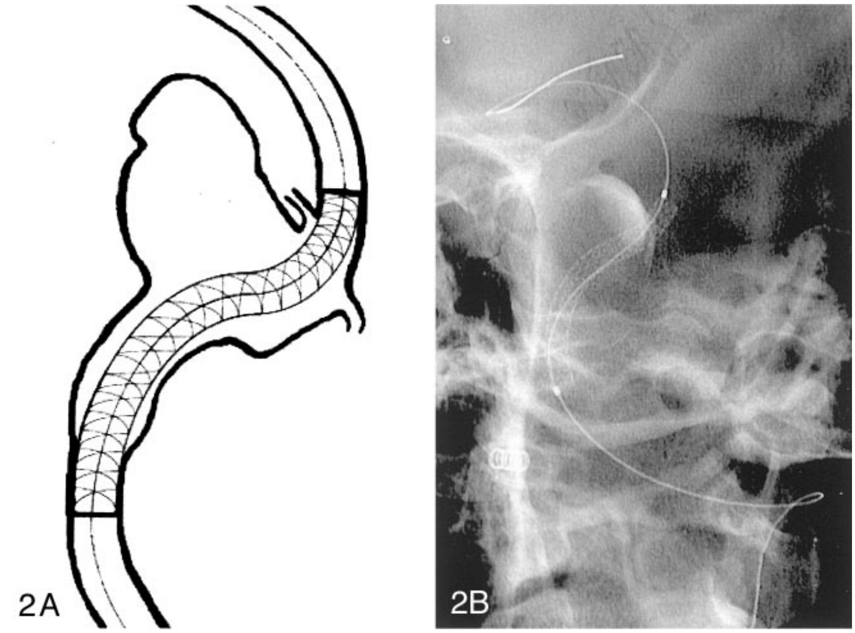
*Clinical Presentation and History.*—A 59-year-old woman was admitted to the hospital with an acute-onset severe headache. Physical examination revealed that the patient had nuchal rigidity. Her medical history included untreated hypertension of 3-year duration and left-sided blindness that had developed over several years.

*Diagnostic Examinations.*—Neurologic examination revealed slight confusion and signs of meningeal irritation (Hunt and Hess grade II). Cranial CT performed immediately thereafter revealed SAH in the anterior interhemispheric fissure and a parasellar hyperattenuated aneurysm sac. Angiography revealed a giant wide-necked paraophtalmic segment aneurysm in the left ICA (Fig 6A). Simultaneous selective right ICA injection and left external compression to the common carotid artery (CCA) showed 2-second delays in the arterial, parenchymatous, and venous phases in the left hemisphere that indicated an equivocal tolerance. Because the tolerance to the left ICA occlusion was not clear, we decided that the parent artery should be kept patent, if possible, by using a stent and stent graft combination.

*Endovascular Procedure.*—The endovascular procedure was performed with the patient under general anesthesia. The patient's oxygen saturation, heart rate, blood pressure (measured invasively), and urine output were monitored throughout the procedure. Two intravenous lines were used to administer drugs during the procedure.

By using a unilateral femoral approach, a 7F femoral introducer was placed into the right groin, and selective catheterization of right ICA was performed with a 6F guiding catheter (Envoy; Cordis). A microcatheter (Rapid Transit; Cordis) was advanced over a microguidewire (Dasher 14; Boston Scientific Target, Natick, MA) and subsequently placed in segment M2 of the middle cerebral artery (MCA). A 300-cm-long 0014-inch-diameter light-support exchange wire (Medtronic-AVE; Medtronic) was placed within the microcatheter.

A 4 × 15-mm coronary stent (AVE; Medtronic) was positioned across the base of the aneurysm under road map guidance and deployed over the exchange microguidewire to provide a bridging scaffolding for support. Control angiograms indicated a rerouting of the blood flow to the lumen of the parent artery and partial filling of the aneurysmal sac. A 4 × 9-mm stent graft (Josten; Jomed International) was navigated over the microguidewire into the neck of the aneurysm and



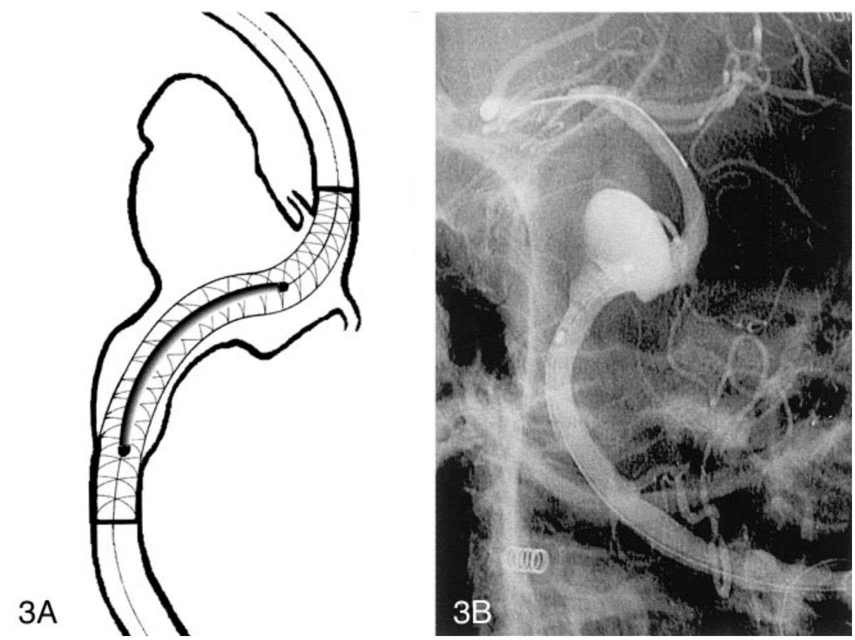


FIG 2. Case 1.
*A*, Illustration of bare stent placement.
*B*, Corresponding angiographic image.

FIG 3. Case 1.
*A*, Illustration of stent graft positioning.
*B*, Corresponding angiographic image.

placed into the deployed bare stent (Fig 6B). Control angiography revealed total exclusion of the aneurysm and the reconstruction of the ophthalmic artery via the external carotid artery (Fig 6C and D).

*Postoperative Course.*—Postoperatively, the patient received an oral 300-mg loading dose of clopidogrel (Plavix, Bristol-Meyers Squibb/Sanofi Pharmaceuticals) followed by a daily oral dose of 75 mg. Aspirin 325 mg was administered daily. The patient tolerated this procedure well and experienced a marked clinical and neurologic improvement. After the procedure and at her 1-month clinical follow up, the patient had no recurrent hemorrhaging. Her condition continued to improve neurologically, and the patient had no signs of ischemia or infarction related to the procedure. A control angiogram obtained at 3 months showed the persistence of exclusion of the sac. Slight intimal hyperplasia was present at the proximal edge of the stent and stent graft combination (Fig 6E). This hyperplasia appeared to have no hemodynamic consequence, because the narrowing was less than 50%.

## Discussion

Many new techniques are now available for the treatment of complicated aneurysms. The release of a three-dimensional Guglielmi detachable coil (GDC) represents an important advance in coil technology (8), and balloon-assisted embolization has proved helpful in the treatment of broad-necked aneurysms (9). The adequate management of giant or fusiform aneurysms, however, requires a new concept in vascular reconstruction. The use of liquid embolic agents for embolization of cerebral aneurysms, both with or without stent or balloon combinations, has also been reported in the literature (10). In an attempt to achieve complete aneurysmal occlusion, the use of a combination of stents and detachable coils has recently been suggested for both extracranial and intra-

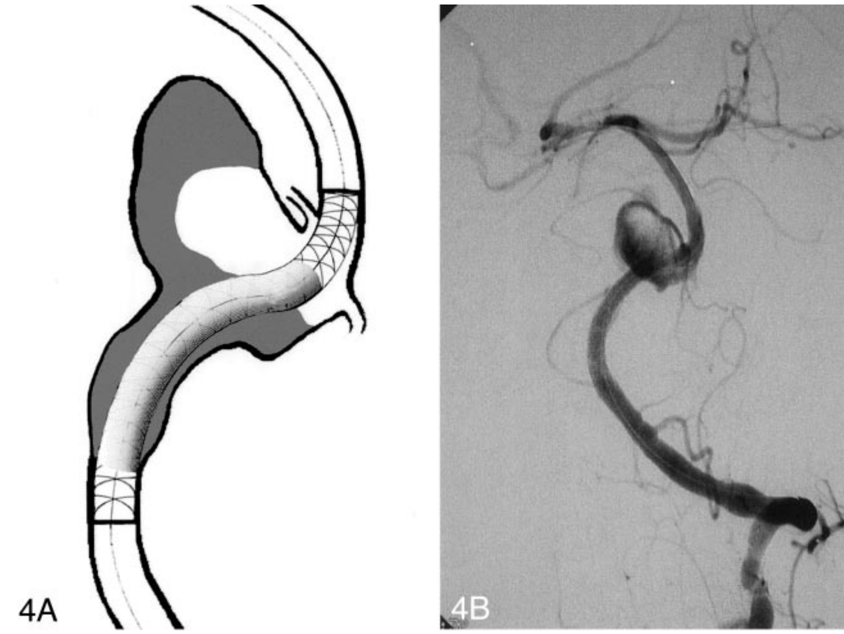



FIG 4. Case 1.

*A*, Illustration of the deployed stent graft. Note the peripheral thrombosis of the aneurysm (*shaded area*).

*B*, Angiogram obtained immediate after graft stent placement angiogram shows total occlusion of the inflow to the aneurysm and an absence of turbulent flow in the aneurysmal sac. Both of the AICAs are patent, and both of the PCA regions are filling normally.

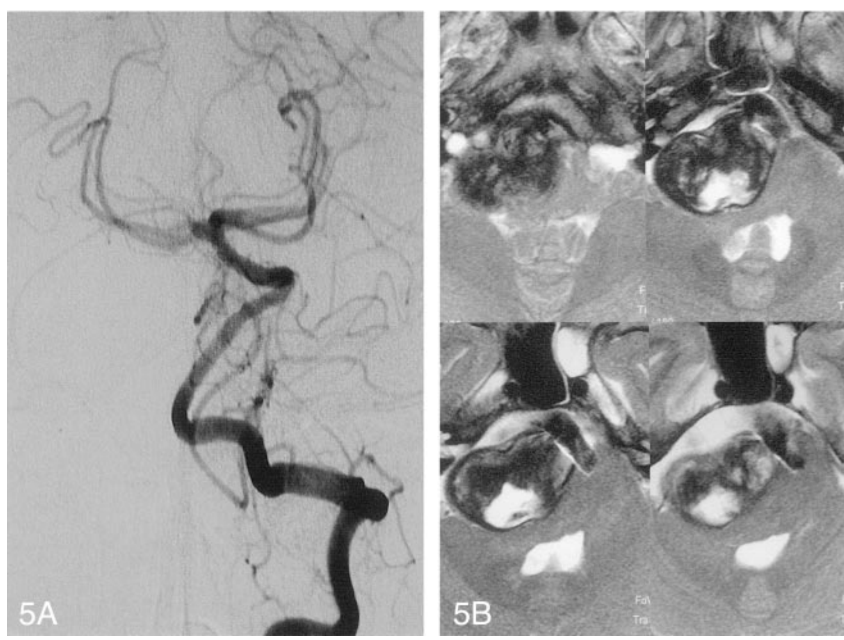



FIG 5. Case 1.

*A*, Control angiogram obtained at 4-month follow-up reveals the progression of thrombosis and the disappearance of the giant fusiform aneurysm.

*B*, Four consecutive T2-weighted (4600/100/2 [TR/TE/NEX]) axial MR images obtained at the level of the brain stem show normal findings rather than compression of the thrombosed aneurysm.

cranial aneurysms. That combination is currently considered as an alternative to single stent placement, remodeling, or parent vessel occlusion (5, 11, 12). However, the clinical use of this technique is restricted by the difficulty associated with the endovascular navigation of stents into the cerebral vasculature. The advent of new-generation flexible stents permits safe and reliable percutaneous access to the intracranial vasculature, and they have therefore transformed this technique into a viable therapeutic option. This approach is now feasible in the treatment of many fusiform or giant intracranial aneurysms or pseudoaneurysms, including those involving the petrous ICA, the VA, the vertebrobasilar junction, and the paraclinoid segment of the ICA or the BA (5, 11, 12). Recently, Benndorf et al (13) reported on the use of double stent placement in the complete exclusion of a ruptured dissecting right VA aneurysm.

In the last decade, the endoluminal placement of endovascular stent grafts has evolved as a promising alternative to most surgical repair techniques. Endovascular placements of stent grafts in the aorta, peripheral, visceral and coronary arteries have been reported as safe and effective alternatives to surgery (14–16). Thus far, the literature reports that the use of this type of stent is successful in treating percutaneously inaccessible anomalies such as fistulas, aneurysms, and coronary artery ruptures (16, 17). A few reports document the use of stent grafts in the supra-aortic arteries (18–20). Redekop et al (21) demonstrated that stent graft treatment of lesions involving the skull base region is both feasible and safe. Mac-

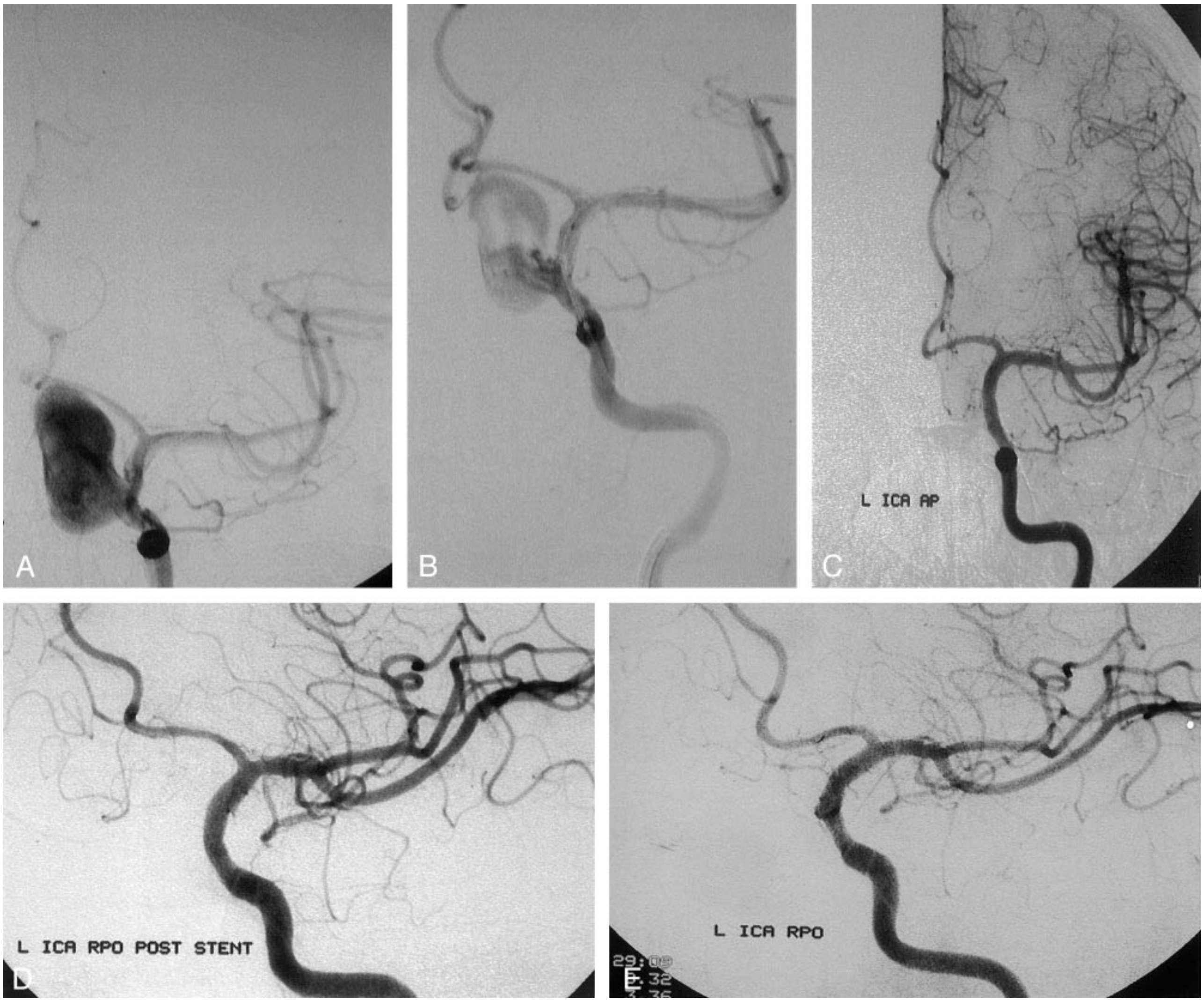



FIG 6. Case 2. A 59-year-old woman was admitted to the hospital with an acute-onset severe headache.

*A*, Anteroposterior arteriogram obtained with a left carotid arterial injection shows a giant wide-necked aneurysm in the paraophtalmic segment of the left ICA.

*B*, Oblique angiogram shows stent graft placement into an already deployed bare stent.

*C* and *D*, Control anteroposterior (*C*) and oblique (*D*) arteriograms obtained immediately after the procedure reveal total exclusion of the giant aneurysm.

*E*, Oblique arteriogram obtained with a left carotid arterial injection 4 months after the procedure shows slight intimal hyperplasia at the proximal edge. The narrowing appears to be less than 50%.

donald et al (14) recently reported on their successful use of a cover stent in the treatment of an acute carotid blowout syndrome. In another case, Kocer et al (22) reported that an iatrogenic injury to a cavernous ICA that resulted in a carotid cavernous fistula and massive epistaxis during trans-sphenoidal surgery was successfully managed with the emergency placement of an endovascular stent graft. Recently, Chiaradio et al (23) also reported about the intravascular stent graft treatment of a ruptured fusiform dissecting aneurysm of the intracranial vertebral artery. These reports suggest that stent graft placement could be the easy and efficient way to preserve a parent artery, owing to the immediate exclusion of vascular lesions, including aneurysms. The main disadvantage associated with the use of stent grafts is the inevitable closure of the side branches stemming from the segment of the artery where the stent graft is deployed. This effect naturally limits the application of stent grafts in certain arteries such as cavernous carotid and extradural vertebral artery or certain segments of arteries.

In our first case, the aneurysm was judged to be unsuitable for surgical clip placement or endovascular coil placement because of its location and configuration. Although treatment by means of flow reversal is technically possible, whether the patient can tolerate the procedure, because of inadequate collateral flow, is doubtful. Because our first patient's aneurysm was ruptured and therefore high-risk, we decided to treat it by using a new endovascular technique called a stent graft. In this case, we inserted an uncovered stent from the V4 segment of left VA over the proximal portion of the BA up to midbasilar level. The stent extended from normal-appearing VA to normal upper basilar trunk. Then, the stent graft was deployed to cover the inflow zone. Because the stent graft is completely intra-aneurysmal, stopping the filling of the giant fusiform aneurysm was possible without closing any perforator of the BA or the bilateral origin of AICA. Although this incomplete closure of the aneurysmal sac immediately resulted in incomplete occlusion of the aneurysm (because the flow was then directed to the normal BA), it promoted progressive thrombosis and kept the AICA patent.

On the basis of both our successful treatment in the first patient and the favorable reports in the literature, we decided to attempt our novel endovascular technique in treating our second patient's giant ophthalmic segment aneurysm. Although balloon occlusion of the ICA at the site of the aneurysm might have been technically possible, it was not undertaken, because a selective right ICA injection with left external compression to the CCA showed equivocal delays in the arterial, parenchymatous, and venous phases in the left hemisphere that suggested doubtful collateral circulation.

That particular treatment resulted in occlusion of the ophthalmic artery. This result was accepted from the beginning and did not cause great concern. The dependence of the ophthalmic systems on the ventral and dorsal primitive ophthalmic systems and the stapedial artery is an embryologic characteristic. Thus, occlusion of its origin causes no clinical problem. Balloon occlusion with occlusion of the ophthalmic artery is well known to cause no ocular symptoms. However, extreme caution should be exercised with regard to the anterior choroidal artery when the stent graft is placed in the ICA and ophthalmic region. In the normal anatomy, the perforating vessels arise from critical segments such as the BA trunk and distal VA. However, the perforating branches originating from the fusiform aneurysmal segment of the VA or BA become dysfunctional on the wall of a fusiform aneurysm because of thrombosis (24). This situation explains the absence of neurologic sequelae after stent graft placement in our first case.

Our technique consists of first placing a bare stent that is precisely anchored at both ends of the aneurysmal neck. This step creates a guiding strut on which the stent graft can be introduced. The shortest possible stent graft is then chosen and inserted through the first bare stent. The stent can then be carefully positioned to close the inflow to the sac as much as possible without covering the normal parent artery on both sides. This technique has two distinct advantages. First, the use of the shorter and less rigid sandwich stent graft allows for better control during navigation in the cerebral vasculature. Second, anchoring the guiding stent at both ends of the aneurysm allows the covered stent to be placed only on the neck of the aneurysm affecting the giant ICA or, in cases of fusiform aneurysms, in the aneurysm itself. Therefore, the stent does not cover the normal parent vessel wall from which perforating branches might stem. Although the second advantage is less prominent with sidewall aneurysms, it is pivotal in the treatment of fusiform aneurysms of the basilar trunk.

Our technique does, however, have some associated difficulties and risks. At the current time, we do not have stent grafts designed for neuroradiologic use and are therefore forced to use coronary stent grafts. The main technical limitation associated with the placement of coronary stent grafts in the intracranial arteries is the limited longitudinal flexibility. Adapting a semirigid stent graft designed for coronary use to the curves of the ICA or BA is somewhat difficult. The risk of ischemic complications must also be noted. A recent global survey reported a 4.4% risk of stroke within the 30 days after carotid stent placement (25). However, we are not aware of any data that specifically document the risk of stroke associated with stent graft placement in the ICA or BA. We hypothesize that the direct extrapolation of outcomes from this population would be inaccurate because of the underlying atherosclerotic carotid artery disease. Treating such aneurysms with a covered stent seems logical, because this approach probably poses a smaller risk of neurologic damage than that of not treating or incompletely treating a ruptured giant or fusiform aneurysm. Another consideration is the fact that more foreign bodies (overlapping stents) near the arterial wall could increase the risk of inflammation of the vascular wall, leading to luminal stenosis due to neointimal hyperplasia. However, overlapping and double stents are routinely used in cardiology. Reports documenting the circulatory response of coronary and peripheral arteries with the use of polytetrafluoroethylene (PTFE)-covered stents have been particularly favorable, with extremely low rates of neointimal hyperplasia that indicate a potential antiproliferative effect of sealing the vessel wall (21). Results of laboratory studies of PTFE-covered stents have confirmed these clinical observations, whereas Dacron- and silicone-covered stents have poor short-term patency rates due to the acute inflammation and exuberant ingrowth of fibrous connective tissue (21). Benndorf et al (13) evaluated 20-month follow-up arteriograms obtained after double stent placement in an extracranial carotid aneurysm and found only mild, nonstenotic intimal hyperplasia. This hyperplasia occurred in the area of the stent margins covered by the proximal single stent but not in the area of stent overlap. In our first case, an angiogram obtained at 4-month follow-up after stent graft placement in the BA aneurysms revealed no evident intimal hyperplasia. However, in the second case, the angiogram obtained at 3 months showed mild intimal hyperplasia that caused narrowing of less than 50%. Although the narrowing appeared to be hemodynamically insignificant, we was decided to control it angiographically. Because myointimal hyperplasia, a consequence of the vascular reaction to a foreign body, is usually evident in the first few months of treatment, it is likely to become stable with time. Nonetheless, it should be confirmed with long-term follow-up.

## Conclusion

To our knowledge, our experience with the aforementioned stent graft in stent technique is the first published demonstration of the use of endovascular stent grafts for the treatment of intracranial giant or fusiform aneurysms. In our cases, the use of stent grafts proved expedient, safe, and effective in the treatment of intracranial giant and fusiform aneurysms. In some patients with fusiform or giant aneurysms, direct surgical clip placement, conventional endovascular therapy, and parent artery occlusion are not feasible options. In a giant or fusiform intracranial aneurysm in the anterior or posterior region, the use of an intravascular bare stent to create a bridging scaffold followed by stent graft placement on the neck may provide another treatment option. Nonetheless, this technique should be considered as a last resort, when no other surgical or endovascular techniques are possible. The long-term patency of stent grafts in the treatment of aneurysms is still unknown. However, on the basis of the short-term control angiographic results in our initial experience, we expect a positive overall outcome. In addition, future technologic developments will most likely improve stent graft designs and yield more sophisticated delivery systems that will eventually overcome the current limitations.

## Acknowledgment

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