Stent placement for the treatment of nonsaccular aneurysms of the vertebrobasilar system

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Vertebrobasilar nonsaccular aneurysms represent a small subset of intracranial aneurysms and usually are among the most challenging to be treated. The aim of this article was to review the literature and summarize the experience in the treatment of these lesions with endovascular approaches. The method of stent implantation as it is performed at the authors’ institution, including options available for vertebral artery access, is described. Practitioners involved in the treatment of these lesions should be aware of the potential application of intravascular stent placement as well as the associated postprocedure risks and potential complications.

KEY WORDS • dolichoectatic aneurysm • fusiform aneurysm • intracranial stent placement • nonsaccular aneurysm

OVERVIEW

Nonsaccular aneurysms of the posterior circulation represent a small subset of intracranial aneurysms. The spectrum of this disease entity includes fusiform, dolichoectatic, transitional, and giant serpentine aneurysms. These lesions are usually associated with a clinical presentation distinct from that of their saccular intracranial counterparts. They can cause a constellation of clinical symptoms that can be grouped according to three mechanisms: mass effect, rupture, or ischemia. Compression of surrounding neural structures is the most common cause of symptoms. Existing data indicate that vertebrobasilar nonsaccular intracranial aneurysms have a poor natural history that leads to a poor outcome in patients with this disease.

Current invasive management of these aneurysms includes vessel sacrifice via endovascular or surgical approaches, with or without a vascular bypass procedure. Stent placement may present a viable therapeutic option for these patients. The flow diversion created by the placement of a stent into the parent vessel lumen across the aneurysm may have a meaningful hemodynamic effect, redirecting much of the flow away from the aneurysm and back into the arterial lumen.

The aim of this article was to review the incidence, natural history, and pathological features of nonsaccular intracranial aneurysms as well as to summarize our endovascular approach for stent placement, including access in the event of excessive tortuosity of proximal vessels. Although the focus of this review is placed on fusiform and dolichoectatic lesions, many of the concepts used for their management can also be applied in the treatment of acute dissecting aneurysms.

Incidence of the Lesions

Nonsaccular aneurysms of the vertebrobasilar system are uncommon intracranial lesions. In their review of almost 10,000 autopsies performed over the course of 42 years, Housepian and Pool found 10 cases of patients with these lesions, with an incidence less than 0.1%. Yu, et al., identified 31 patients with fusiform aneurysms (0.06%) in their review of 50,000 cerebral angiograms. Because nonsaccular aneurysms of the vertebrobasilar system occur so infrequently, the experience of Drake and Peerless in the surgical treatment of 120 cases between 1965 and 1992 represents the largest case series reported in the literature.

Natural History

When reviewing the natural history of these lesions, one should keep in mind the different manifestations of chronic fusiform, dolichoectatic, and giant serpentine aneurysms, compared with those of acute dissecting aneurysms. Patients with acute dissecting aneurysms of the intracranial VA usually present with SAH, and the tendency of these lesions to rebleed has been well documented. Nonsaccular aneurysms (chronic fusiform, dolichoectatic, and giant serpentine lesions) and acute dissecting aneu-
in contrast with dissecting aneurysms, for which the natural history has been documented fairly well, the low incidence of chronic nonsaccular aneurysms and the associated paucity of data make it difficult to define the natural history of these lesions. Management dilemmas have arisen because little is known about the long-term risks and the factors predicting ischemia, compression, and rupture. Fleming and colleagues at the Mayo Clinic attempted to determine the annual risk of rupture in a series of 159 patients with vertebralbasilar nonsaccular intracranial aneurysms characterized by dilation, elongation, and tortuosity of intracranial arteries, excluding dissections. Based on a retrospective review of records and neuroimaging studies, a prospective survey was sent to patients to identify possible cases of hemorrhage. The results of the survey disclosed that 74% of the patients were men, and that the mean age at diagnosis was 64 years. Five patients (3%) initially presented with hemorrhage; four of these died during the follow-up period. The mean duration of the follow-up review was 4.4 years. Nine patients (6%) experienced hemorrhage after presentation; six hemorrhages were definitely related to the aneurysm. Six of these nine patients died within 1 week after bleeding. The prospective annual rupture rate was 0.9% overall, with an increase to 2.3% in patients with transitional or fusiform aneurysm subtypes (classified according to appearance on neuroimages). More recently, in an analysis of serial CT or MR imaging studies obtained in the same series of 159 patients with vertebralbasilar nonsaccular intracranial aneurysms, the Mayo Clinic investigators found that aneurysm enlargement was predictive of significant morbidity and death.

Fujita, et al., reported a mortality rate of 46% over the course of a mean follow-up period of 4 years (range 1 month–12 years), with 32% of the deaths attributed to intracranial hemorrhage in a series of 28 patients harboring giant aneurysms. Fusiform and dolichoectatic intracranial lesions of the vertebralbasilar circulation tend to behave more aggressively than saccular intracranial aneurysms, and these lesions should be treated with the intention to overcome their poor natural history.

Pathological Features of Nonsaccular Aneurysms

Histologically, nonsaccular aneurysms are caused by diseased vessel walls with microdissections and plaque formation that sometimes lead to circumferential expansion of the entire wall of the vessel. Nakatomi, et al., divided these lesions into two categories based on their clinical course. One category is the acute dissecting aneurysm (as previously mentioned). Acute disruption of the intimal elastic lamina, which leads to intramural hemorrhage, with or without a luminal connection, is considered to be the primary cause of an acute dissecting aneurysm. The other category is the chronic fusiform aneurysm. These aneurysms grow relatively slowly but may cause serious complications as they progress. Several studies have indicated that chronic fusiform aneurysms might comprise a spectrum of vascular abnormalities ranging from asymptomatic, small fusiform lesions to symptomatic, giant, so-called dolichoectatic aneurysms. Nevertheless, the mechanisms of progression within this spectrum remain unclear.

From a comparative analysis of serial MR and other imaging studies as well as histological findings, Nakatomi, et al., suggested a possible stepwise mechanism for the growth of chronic fusiform aneurysms, starting with fragmentation of the intimal elastic lamina, followed immediately by intimal hyperplasia (possibly as a normal reaction to this damage). When intimal thickening reaches a certain level, neovascularization occurs within the thickened intima. New vessels within the intima then cause bleeding and intimal hyperplasia. Repeated recanalization of thrombus and further bleeding from those vessels lead to rapid growth. Among these steps, intimal hyperplasia seemed to be the most critical event, because it apparently forced the aneurysm to progress and, in most cases, led to hemorrhage. Although further studies are needed to confirm the hypothesis proposed by Nakatomi, et al., the knowledge of this possible mechanism of growth and of corresponding MR imaging characteristics could help to determine the timing of surgical intervention. Moreover, a specific surgical or endovascular intervention to decrease the risk of intimal hyperplasia could be considered when intraluminal contrast enhancement is observed. Such an intervention might prevent disease progression.

The findings reported by Nakatomi, et al., are in part related to atherosclerotic changes in the vessel. Dandy was probably the first to state that cerebral artery dolichoectasia had an atherosclerotic origin. Later reports supported the theory of atherosclerotic degeneration of the vascular wall as the initial pathogenic factor in the development of these lesions. Nevertheless, atherosclerosis may not be the sole or even the most common cause of dolichoectatic aneurysms. The occurrence of these lesions is quite uncommon when compared with that of atherosclerotic disease, which indicates that other factors contribute to the development of nonsaccular aneurysms. Underlying congenital defects and local hemodynamic effects may also play a role in the genesis of these conditions, as well as microdissection (as previously mentioned).

Intracranial Stent Placement for Nonsaccular Aneurysms

The possibility of placing stents into intracranial vessels has led to the development of new therapeutic options for complex aneurysms and other intracranial vascular pathological conditions. Fusiform aneurysms of the vertebralbasilar junction have presented significant challenges to neurosurgeons. These lesions often necessitate the performance of difficult arterial bypass or parent vessel reconstruction procedures. Direct surgical clip ligation can be challenging and hazardous because of the amount of vessel wall deterioration. In the face of SAH, the treatment of these lesions is even more challenging. Initially described by Higashida, et al., and later by our group, stent-assisted coil occlusion of fusiform aneurysms has afforded patients a minimally invasive alternative to posterior circulation vascular surgery (Fig. 1). Some of the risks associated with open surgical revascularization can be avoided with endovascular therapy,
The porosity of the stent most likely determines the ability to redirect flow from the diseased wall and into the true lumen of the vessel. More recently, the placement of low-porosity self-expanding stents within intracranial fusiform aneurysms has achieved dramatic results, with complete vessel remodeling and healing after stent placement. The results of angiographic follow-up studies have demonstrated resolution of the pseudoaneurysmal components of these aneurysms. The traditional low-porosity self-expanding stents are stiff and more challenging to navigate into the intracranial space. Benndorf and colleagues treated dissecting artery aneurysms by placing two balloon-expandable porous stents in an overlapping fashion. By using this method, they gained the advantages of more flexible stents that could be advanced more readily across the aneurysm as well as reduced porosity of the stent across the aneurysmal portion of the vessel. Imbesi and Kerber demonstrated in vitro that aneurysms can be successfully treated by redirecting the flow vortices within the parent vessel lumen. Consequently, stents with porosity low enough to induce such changes could create a hemodynamic environment favorable to aneurysm thrombosis without the need for coils.

**Periprocedure Protocol**

**Initial Imaging Evaluation.** We routinely evaluate patients harboring nonsaccular aneurysms with a complete cerebral angiographic workup to assess potential pitfalls for the intervention. Analysis of access tortuosity and collateral flow are well documented using conventional angiographic imaging. Characteristics such as the dimensions of the parent vessel proximal and distal to the lesion and the presence of perforating vessels in the region of the aneurysm are better evaluated with a combination of conventional angiography and either three-dimensional angiography or three-dimensional CT angiography. The presence of intraluminal thrombus and vessel wall thickening are better elicited with MR imaging.

Intravascular three-dimensional reconstructions may facilitate the identification of perforating vessels originating within the aneurysm region. Computerized reconstruction of the vessel and lesion with a simulated stent placement can help in the preoperative planning with more adequate sizing of the stent.

**Medical Management.** Preparation for stent insertion is dependent on administration of anticoagulation and antiplatelet medications that will protect the patient against vessel thrombosis and occlusion while minimizing the risk of hemorrhagic complications. For elective stent placement procedures in unruptured nonsaccular intracranial aneurysms of the vertebrobasilar system, patients at our institution receive aspirin (325 mg/day) and clopidogrel (75 mg/day) for at least 3 days before the procedure. Alternatively, a loading dose of clopidogrel (450 mg) and aspirin (650 mg) is administered at least 4 hours before the start of the procedure. The effects of poor compliance with this regimen in the setting of posterior circulation stent placement can be catastrophic.

**Risks Associated With Rupture.** For cases of aneurysm rupture, placing a stent and the commensurate requirements for antiplatelet medications put the patient at high risk for intracranial hemorrhage, especially considering...
the potential need for additional surgical procedures (that is, ventriculostomy, ventriculoperitoneal shunt, tracheostomy, gastrostomy, and central venous line placement). Ideally, any aneurysm considered for stent placement would be one that has not ruptured and that can be treated in an elective fashion after appropriate antiplatelet therapy has been initiated.

Alternative Antiplatelet Regimens. In selected cases in which an adequate dual antiplatelet regimen cannot be administered before the intervention, or in cases with evidence of thrombus formation within the stent, intravenous platelet glycoprotein IIb–IIIa receptor inhibitors (abciximab, eptifibatide, or tirofiban) may be used as a one-time bolus dose during the procedure or as an infusion for 24 hours postprocedure. Each of these agents yields a rapid onset of antiplatelet activity. Nevertheless, reversal of platelet inhibition after infusion is more rapid with eptifibatide and tirofiban, and both agents are more specific glycoprotein IIb–IIIa receptor inhibitors than abciximab. The use of such agents in cases of ruptured aneurysms is riskier, and this should be kept in mind when considering the use of glycoprotein IIb–IIIa receptor inhibitors in the setting of SAH.

An activated coagulation time of approximately 200 seconds is advisable when glycoprotein IIb–IIIa receptor inhibitors are used along with a heparin infusion to minimize the risk of hemorrhagic complications. Ideally, a CT scan should be obtained before initiating the glycoprotein IIb–IIIa receptor inhibitor infusion to rule out the presence of intracerebral hemorrhage.

Heparin Therapy. For most intracranial stent placement procedures, we administered a bolus dose of heparin (50–70 U/kg) just after groin sheath placement. In addition, all saline irrigation solutions are prepared with heparin (5 U/ml). The activated coagulation time is maintained at approximately 250 seconds for the duration of the procedure. After stent placement, heparin therapy is usually discontinued but not actively reversed. In some situations, such as when an angiographically visible dissection or thrombosis is present, the heparin infusion is continued to maintain the activated prothrombin time 1.5 to 2.3 times the control value. Aspirin (325 mg/day) and clopidogrel (75 mg/day) are administered for at least 4 weeks after the procedure.

Stent Placement Procedure

The following is a brief description of the stent placement procedure typically used at our institution for the treatment of nonsaccular aneurysms. The procedure is performed in the neuroendovascular suite, where biplane digital subtraction imaging and fluoroscopic imaging capabilities are available. Sedative hypnotic and analgesic drugs are administered to permit continuous neurologic assessment while the patient is in an awake state. Continuous monitoring of heart rate, blood pressure, urine output, electrocardiogram, and oxygen saturation is performed. A No. 6 French sheath is inserted into the femoral artery, and a No. 5 French catheter is advanced over a 0.035-in hydrophilic wire into the aortic arch. The intracranial artery of interest is catheterized proximal to the lesion. The diagnostic catheter is then removed, with the wire left in place. A No. 6 French guide catheter is placed in the vessel. An angiogram is obtained, and the road-mapping technique is used.

In cases in which extreme tortuosity of proximal vessels is noticed, additional support may be necessary for intracranial stent navigation. In this situation, the use of a guide sheath inserted into the subclavian or proximal VA, followed by placement of the guide catheter though the sheath should be considered (Fig. 2). For cases in which severe tortuosity of proximal vessels prohibits access, surgical exposure of the VA can be obtained and access accomplished at the C-1 spinal level (Fig. 3).

An array of balloon-mounted or self-expandable stents (generally those designed for coronary applications) is available for intracranial use. Two different methods can be used for intracranial navigation of the stent. In the exchange maneuver, a microcatheter and a 0.014-in microwire are used to cross the lesion, with the catheter and wire system being advanced a sufficient distance beyond the portion of the artery that will receive the stent to provide enough scaffolding to support delivery of the device, particularly if the vessel is tortuous. The microcatheter is removed; and a stiffer 300-cm, 0.014-in exchange wire is placed through the microcatheter. This system is then advanced across the lesion. The microcatheter is withdrawn and a balloon-mounted, over-the-wire stent is navigated across the area of interest, where it is deposited.

In the direct stent navigation method, a balloon-mounted or self-expandable stent is guided with the operators’ wire of choice primarily into the target vessel. This procedure has become more commonplace with the advent of more flexible, navigable stents. Direct navigation of the stent avoids the inherent risks associated with exchange maneuvers in the intracranial circulation and decreases the overall duration of the procedure.

Results of Stent Insertion in the Treatment of Fusiform Aneurysms

Since early reports advocating its use in the late 1990s, stent placement in fusiform aneurysms is increasing in frequency. Lanzino, et al., reported on 10 patients with intracranial aneurysms treated with stent placement across the lesion. In eight procedures, coils were placed in the aneurysmal portion of the lesion. No permanent peri-procedural complications occurred, and immediate results demonstrated that more than 90% aneurysm occlusion was achieved in the eight patients treated using stent-assisted coil placement. Follow-up angiographic studies obtained in six patients at least 3 months later revealed one case of asymptomatic in-stent stenosis.

Lylyk, et al., reported their experience with stent placement for fusiform and dissecting aneurysms. Nine patients harboring 10 lesions were treated. Eight aneurysms were completely occluded after stent placement and adjunctive coil insertion were performed during the same session. At the follow-up review, one partially recanalized aneurysm required further coil treatment. Two patients, one with a dissecting and one with a fusiform aneurysm, were treated with stents only, resulting in complete resolution of the lesions at the time of 3-month follow-up imaging.

The initial experience with the use of Neuroform stents (Boston Scientific, Natick, MA) for the treatment of dis-
secting and fusiform aneurysms has been reported. Although the high porosity of the Neuroform stent does not seem to favor the use of this device alone for this application, the initial experience has been encouraging. Fiorella, et al., reported the treatment of dissecting or fusiform aneurysms with Neuroform stents alone, resulting in stabilization of disease progression in two patients and resolution of the aneurysm in a third.

The development of stents specifically designed for the intracranial circulation and modifications in stent design will certainly influence the treatment of nonsaccular aneurysms. Covered, lower-porosity, asymmetrical, and semi-covered stents will soon become available. The application of these devices will require further testing in the unique environment of the intracranial circulation, in which the existence of proximal vessel tortuosity and the presence of perforating vessels play a major role in clinical outcomes.

Anecdotal case reports describing the use of covered stents for aneurysms of the posterior circulation have been published. Islak, et al., reported a case of a giant mid-basilar aneurysm successfully treated with the combination of a long, bare stent and a short, covered one. The use of covered stents has potential for the reconstructive treatment of nonsaccular intracranial aneurysms. Further research and development are needed to optimize stent–graft technology for the cerebrovascular system.

**CONCLUSIONS**

As intracranial stent placement continues to find various applications in the treatment of cerebrovascular diseases, it is essential that all professionals involved in the treatment of these lesions become aware of the potential applications, postprocedure risks, and potential complications associated with this procedure. Advances in device technology will allow us to provide better therapeutic options for such challenging lesions. Future device development should take into consideration the uniqueness of the intracranial vessels, especially those harboring fusiform and dolichoectatic aneurysms.

![Angiographic studies obtained in a 54-year-old woman who presented with a history of multiple episodes of SAH.](image)
Fig. 3. Neuroimages and intraoperative photographs obtained in an 81-year-old man who presented with progressive dysphagia and gait disturbance. A: An MR imaging study of the head demonstrating brainstem compression. B and C: Angiographic studies revealing the fusiform aneurysm causing the compression. D and E: The therapeutic options were discussed, and because of the extreme tortuosity of the proximal vessels as demonstrated on angiographic studies, direct exposure of the left VA at the C-1 spinal level was performed. F–H: Intraoperative photographs. With the patient placed in a three-quarter prone position, the left VA was exposed and a No. 6 French sheath was introduced (F); the wound was then closed (G), and the sheath was left in place (H).
Fig. 3. continued: I–M: After this, we proceeded with stent placement to bridge the lesion. Initially, a 6 × 38-mm Dynalink stent (Guidant, Indianapolis, IN) was advanced, positioned (I and J), and successfully deposited (K–M). Because a residual portion of the aneurysm was uncovered proximally, a decision was made to advance a second stent. N: When trying to navigate the second stent into the proximal portion of the first one, vessel rupture occurred. Emergency craniotomy with clot evacuation was performed; unfortunately, the patient died 2 days later.
Disclosure

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