USE OF THE AMPLATZER VASCULAR PLUG AS AN ANCHORING SCAFFOLD FOR COIL-MEDIATED PARENT VESSEL OCCLUSION: TECHNICAL CASE REPORT

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OBJECTIVE: Parent vessel sacrifice is a useful treatment strategy for fusiform intracranial aneurysms. Originally performed using the detachable silicone balloon, endovascular arterial occlusion is currently achieved using coils, a process which can be limited by coil mass migration.

METHODS: We demonstrate the use of the Amplatzer vascular plug as a fixed anchor within the target parent vessel to facilitate coil-mediated occlusion, especially in vascular segments not encased by a bony canal. The technique was used successfully in two patients: a 90-year-old woman presenting with IIIrd and VIth cranial nerve palsy from a fusiform left cavernous internal carotid aneurysm and a 44-year-old man with distal thromboemboli from a fusiform dissecting-type right vertebral artery involving the origin of the posterior inferior cerebellar artery.

RESULTS: Both patients were treated successfully with proximal parent vessel occlusion using coils after deployment of an Amplatzer vascular plug proximal to the target lesion. With the Amplatzer device acting as a fixed anchor in the parent vessel, coils were deployed proximally in a compact configuration. After deployment of the vascular plugs and coils, hermetic occlusion of the parent vessel was documented angiographically.

CONCLUSION: The Amplatzer vascular plug can facilitate coil occlusion of large cervical vessels by acting as a focal coil and embolic material immobilizer, which can prevent coil mass migration and lead to improved packing density.

KEY WORDS: Amplatzer vascular plug, Carotid artery sacrifice, Dissecting vertebral aneurysm, Fusiform aneurysm, Intracranial aneurysm

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The treatment of intracranial vascular lesions is usually undertaken with the goal of parent artery preservation. In some instances of fusiform aneurysms, parent vessel preservation is not possible and deconstructive closure of the artery is the only therapeutic option (14). Traditionally performed using the detachable silicone balloon (DSB; Boston Scientific Corp., Natick, MA) (9), endovascular arterial ligation is currently performed mainly with detachable coils, because the DSB has been withdrawn from the market and remains unavailable. Fibered coils can be used to accelerate thrombosis (8) and Hydrogel-coated coils (MicroVention, Inc., Aliso Viejo, CA) can be used to improve volumetric filling (12). Nonetheless, stable positioning of detachable coils within a cylindrical vascular structure can be complicated by distal coil migration, as the outward radial force may not be sufficient to anchor the coil to the vascular intima. The compliance of the vascular wall can be especially counterproductive for coil-mediated occlusion in segments of the parent vessel that are not confined within a bony canal.

A number of devices have been developed for the closure of peripheral vascular structures and cardiopulmonary shunts. The use of one such family of devices, the Amplatzer detachable plug (AGA Medical, Golden Valley, MN), has recently been reported in the treatment of several congenital heart abnormalities including patent foramen ovale (3, 10, 19). Comprised of an expandable cylindrical Nitinol mesh cage, the deployed device anchors itself to the vascular wall with sufficient outward radial force, thereby creating a fixed plug that promotes flow stasis and thrombosis. In this article, we detail the use of the Amplatzer vascular

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plug in conjunction with detachable coils in the endovascular proximal parent vessel occlusion and treatment of two symptomatic fusiform intracranial aneurysms.

ILLUSTRATIVE CASES

Patient 1

Clinical Presentation

A 90-year-old woman presented with a complete left third nerve and partial sixth nerve palsy of longer than 1-month duration. Magnetic resonance angiography demonstrated a large left internal carotid aneurysm of the cavernous segment. Biplane and rotational three-dimensional angiography of the left internal carotid artery (ICA) demonstrated a fusiform aneurysm measuring 17 by 10 mm with an 11-mm neck in the narrowest dimension. The dome projected laterally into the cavernous sinus, and the neck extended the length of the carotid siphon in the widest dimension (*Fig. 1, A–C*). The aneurysm morphology, along with the proximal and distal parent vessel tortuosity, precluded a vessel-preserving endovascular treatment with currently available endovascular tools. Carotid cross-compression revealed a patent robust anterior communicating artery, and the vertebral artery injection showed flow through a left posterior communicating artery.

The patient underwent a balloon test occlusion of the left ICA with hypotensive challenge, which was tolerated without neurological deficit; a deconstructive left internal carotid sacrifice was chosen for treatment.

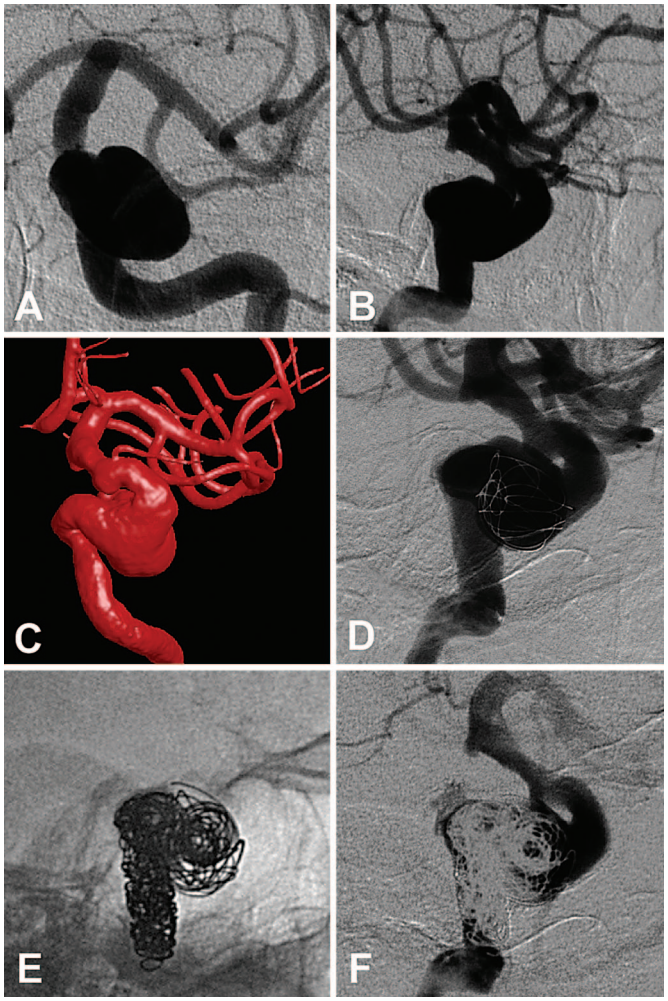


FIGURE 1. *Digital subtraction angiography of the left ICA in the anteroposterior* (A)*, lateral* (B)*, and three-dimensional rotational* (C) *angiography model demonstrating a 17 × 10 mm fusiform aneurysm of the cavernous ICA, which is not amenable to embolization with parent vessel preservation. After successful balloon test occlusion, a series of Hydrogel and Matrix bioactive coils are deployed within the aneurysm dome* (D) *and proximal parent vessel* (E)*. Despite filling approximately 2 cm of the parent vessel proximal to the aneurysm with the coil mass, antegrade blood flow is still seen percolating through the coil mass distal to the aneurysm* (F)*.*

Materials and Methods

Under monitored anesthesia care and intravenous anticoagulation with heparin (target activated clotting time ≥ 250 s), a 6-French 90-cm MPD guide catheter (Cordis Neurovascular, Miami Lakes, FL) was positioned into the proximal left ICA. An Excel 14 microcatheter (Boston Scientific Corp., Natick, MA) was then navigated over an Agility 14 standard microguidewire (Cordis) through the guide catheter to a position within the aneurysm under biplane roadmap guidance. Once the microcatheter positioning was confirmed, a framework of Matrix polyglycolide/polylactide-coated bioactive coils (Boston Scientific Corp.) was deployed within the aneurysm lumen to provide a framework for subsequent thrombus formation and fibrosis (6). After deploying a loose network of coils within the aneurysm (*Fig. 1D*), the microcatheter was withdrawn into the ICA just proximal to the aneurysm neck and a series of Hydrogel-coated and fibered-GDC coils were deployed to achieve occlusion of the vessel (*Fig. 1E*). Despite using a total of eight Hydrogel coils and four long fibered-GDC coils in the petrocavernous ICA, a small amount of delayed antegrade contrast opacification could still be seen within the ICA distal to the coil mass during the late arterial phase (*Fig. 1F*). Additional coil

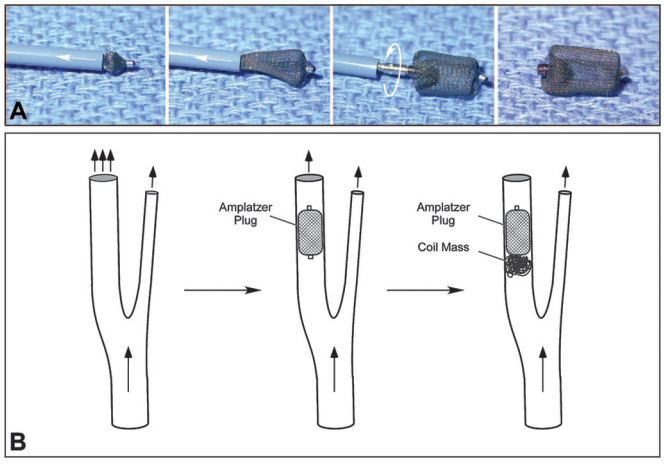


FIGURE 2. A, *Amplatzer detachable vascular plug is shown in its sequential deployment steps, which include unsheathing the self-expanding plug followed by counterclockwise rotation of the delivery wire to unscrew the wire from the plug. Use of the Amplatzer as an endovascular fixed scaffold to enable proximal tight coil packing without the risk of distal migration* (B)*.*

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deployment resulted in proximal coil mass extension without a significant increase in the intra-arterial coil packing density.

Rather than continuing to deploy additional coils, a decision was made to deploy an Amplatzer vascular plug in tandem fashion to promote thrombosis and to use the proximal plug as a fixed-anchor scaffold in the left ICA. The Amplatzer vascular plug is a self-expanding cylindrical device made of a Nitinol wire mesh attached to a 135-cm stainless steel delivery wire which can be navigated through a 5- to 8-French guide catheter, depending on the diameter of the expanded cage (*Fig. 2*). Upon deployment, the plug provides sufficient outward radial force on the vessel wall to anchor it and prevent flow-induced migration. Deployment is achieved by unsheathing the device from the guide catheter at the target site by holding the stiff delivery cable fixed and withdrawing the guide catheter. It is possible to resheath and redeploy the device if positioning is deemed suboptimal; once in position, final detachment of the device is accomplished by counterclockwise rotation of the delivery cable thus unscrewing the cable from the plug (*Fig. 2A*). The first device used measured 4 mm in diameter by 7 mm in length, and was deployed at the level of C2 after repositioning the guide catheter at this level over a Glidewire (Terumo Medical Corp., Somerset, NJ) (*Fig. 3*). Angiographic runs after deployment showed persistent antegrade contrast opacification distal to the vascular plug, but stopping short of the previously placed coils. Delayed images confirmed a small amount of persistent filling of the vessel between the vascular plug and the coil mass, but no contrast distal to the aneurysm (*Fig. 3C*). Complete occlusion of the left ICA was achieved with a second device deployed 2 cm distal to the carotid bifurcation. To ensure apposition of the plug to the vascular intima, a larger 6 to 7 mm plug was selected, unsheathed, and detached from the guide catheter (*Fig. 3D*). Two additional Hydrogel coils and one GDC coil were then deployed proximal to the second vascular plug (*Fig. 3, D* and *E*) using the latter as a fixed intravascular scaffold (*Fig. 2B*), resulting in angiographic occlusion of the entire length of the left ICA (*Fig. 3F*). Injection of the contralateral ICA showed excellent flow across the anterior communicating artery with slight retrograde opacification of the left supraclinoid ICA segment to the ophthalmic artery distal to the aneurysm (*Fig. 3G*).

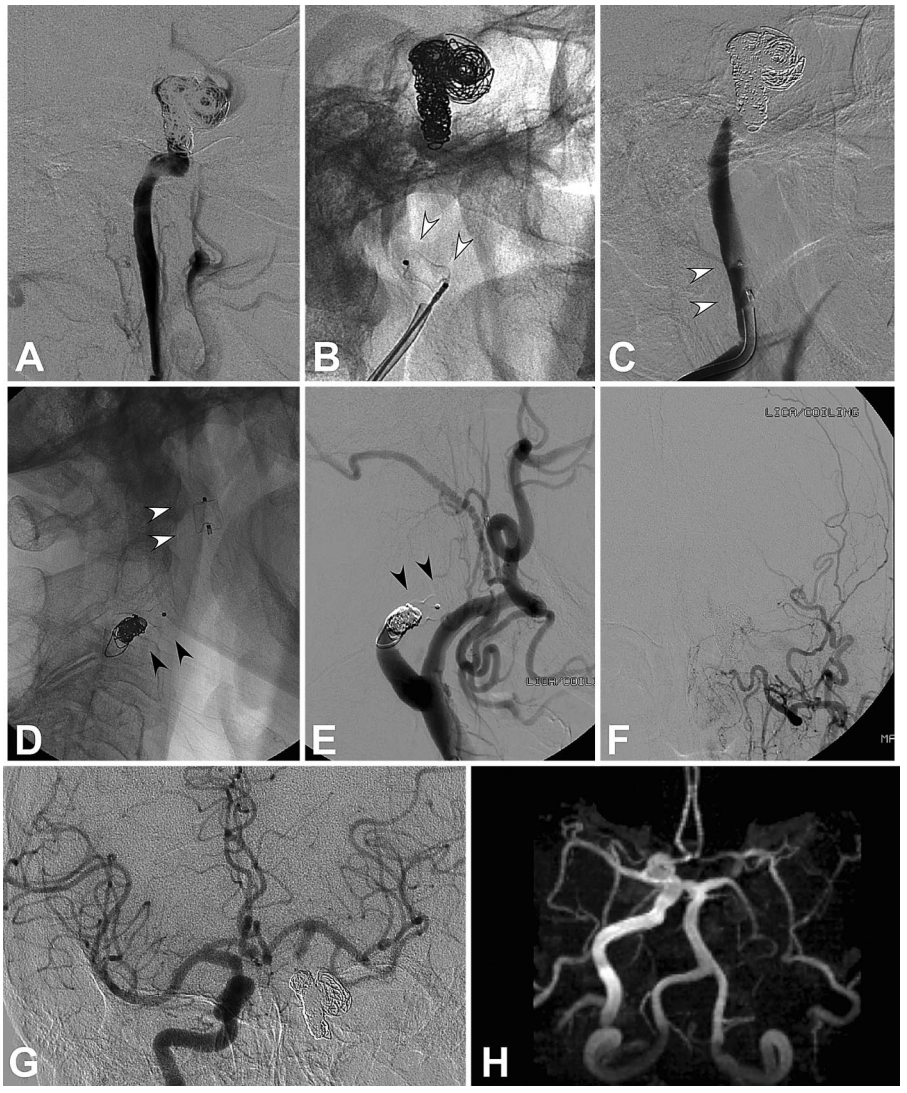


FIGURE 3. *Use of the Amplatzer vascular plug as an intravascular scaffold.* A, *left internal carotid angiogram demonstrating slow persistent flow past the coil mass into the supraclinoid segment.* B, *the first Amplatzer vascular plug is unsheathed by withdrawing the guide catheter (between* arrowheads*), then detached at the C1 vertebral level. Injection though the guide catheter shows persistent flow past the Amplatzer plug which is porous (*C*).* D, *a second vascular plug is deployed more proximally (*black arrowheads*) just distal to the carotid bifurcation.* E, *this proximal plug is then used as a buttress to enable the proximal deployment of a series of additional coils. Injection through the guide catheter now shows a hermetic seal with no flow past the coil-plug complex.* F, *common carotid injection shows only filling of the external carotid artery branches.* G, *right ICA injection demonstrates cross filling of the left anterior cerebral artery and middle cerebral artery territories at the end of the procedure.* H, *follow-up magnetic resonance angiogram demonstrates no flow in the left ICA.*

Postoperatively, the patient was maintained on systemic intravenous anticoagulation for 24 hours with heparin, and oral antiplatelet therapy with aspirin for 1 week. The patient was maintained on flat bed rest for 24 hours postprocedure with intravenous hydration, underwent a progressive increase in activity, and was discharged from the hospital on postoperative Day 5. Magnetic resonance imaging and angiography obtained before discharge showed no evidence of ischemia on diffusion-weighted images and no detectable flow within the left ICA (*Fig. 3H*).

Patient 2

Clinical Presentation and Treatment

A 44-year-old man complained of acute-onset dizziness with nausea and vomiting upon awakening that had been preceded by 1 week

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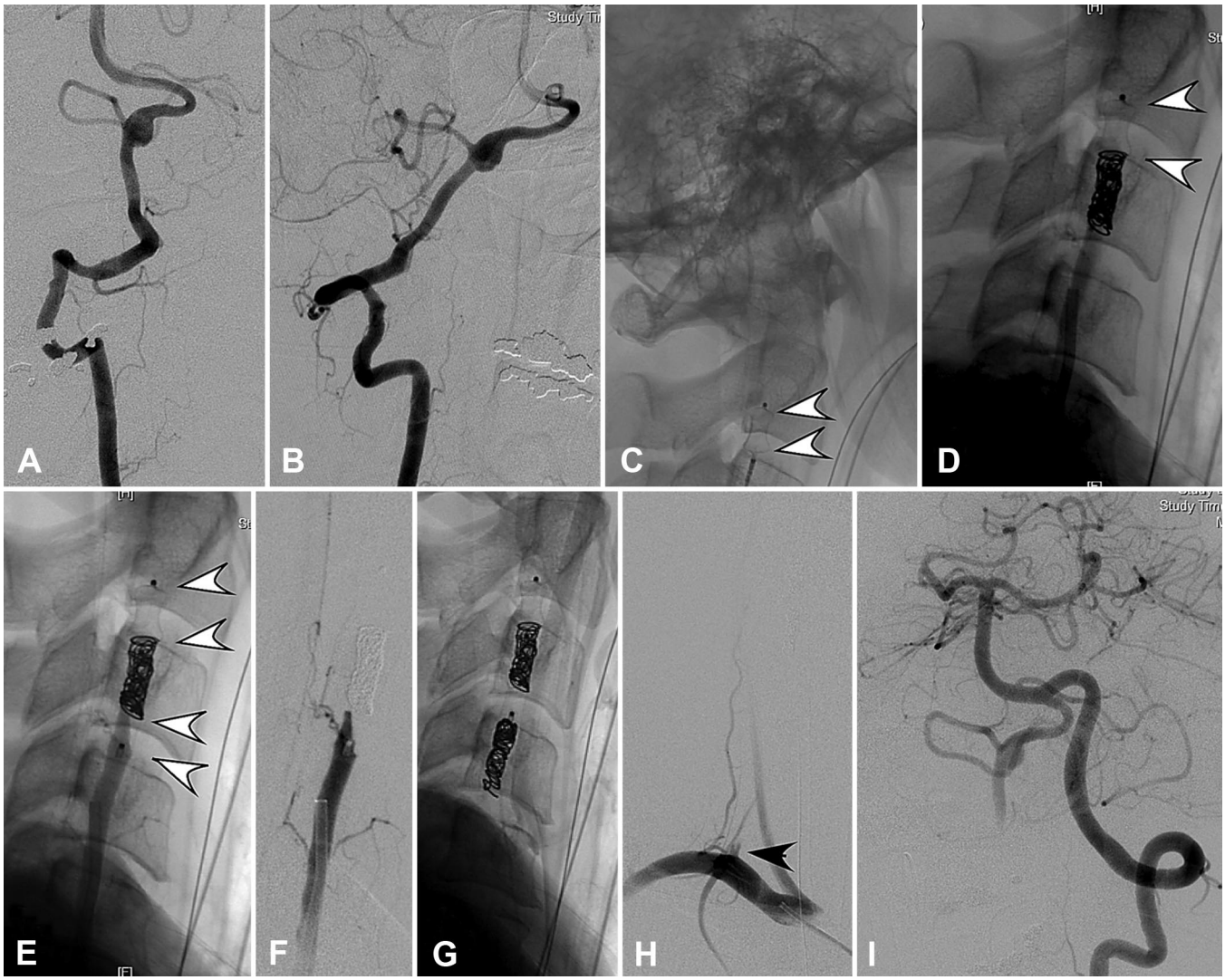


FIGURE 4. *Amplatzer plug used as a scaffold to anchor coils used to occlude the right vertebral artery proximal to a dissecting aneurysm. Selective right vertebral artery injection shows the fusiform aneurysm involving the right PICA in the anteroposterior (*A*) and lateral (*B*) projections.* C, *the first Amplatzer vascular plug is deployed and detached close to the distal end of the foraminal segment of the vertebral artery (between* arrowheads*).* D, *coils are deployed proximal to the Amplatzer plug, followed by deployment of a second Amplatzer plug to trap the coil mass securely between the two plugs (*E*).* F, *injection through the guide catheter shows no flow past the proximal Amplatzer device.* G, *additional coils were deployed proximally to the second vascular plug.* H, *injection of the right subclavian artery shows stasis of the flow in the right vertebral artery beyond the origin (*black arrowhead*).* I, *right anterior oblique projection of a left vertebral artery injection shows retrograde filling of right PICA.*

of mild to moderate neck pain. Magnetic resonance imaging scans of the brain revealed three small areas of infarction in the right posterior inferior cerebellar artery (PICA) territory. Injection of the right vertebral artery showed an intracranial fusiform dissecting-type aneurysm involving the origin of the right PICA, which was not amenable to unassisted coiling and was ill-suited for stent-assisted coil embolization because of its shallow depth (*Fig. 4, A* and *B*). After discussion of surgical and endovascular treatment options, the patient elected to undergo proximal right vertebral artery occlusion with flow reversal (2, 13).

Under monitored anesthesia care and systemic anticoagulation (target activated clotting time $\geq$ 250 s), a 5-French 90-cm MPD guide catheter (Cordis Neurovascular) was gently advanced into the right vertebral artery. A 4 $\times$ 7 mm Amplatzer vascular plug on its delivery wire was navigated to the highest level (C2 vertebral body) of the straight portion of the cervical right vertebral artery (*Fig. 4C*). A number of coils were deployed within and proximal to the occluder plug (*Fig. 4, D–F*) and a second similar Amplatzer plug was deployed proximally followed by additional coils to decrease the risk of recanalization (15) (*Fig. 4G*). This resulted in complete angiographic occlusion of the right vertebral artery as confirmed by right subclavian and right vertebral injection on follow-up angiography (*Fig. 4H*). Contralateral left vertebral artery injection showed retrograde filling of the right PICA (*Fig. 4I*).

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The patient tolerated the procedure without neurological or iatrogenic complications; he was hydrated aggressively and remained anticoagulated for 2 days while undergoing progressive increase in activity. He was discharged home on postoperative Day 5 without focal neurological deficits on a 2-week course of oral antiplatelet therapy given his initial presentation with thromboembolism.

DISCUSSION

Trapping and parent vessel sacrifice have long been established as a treatment option for intracranial aneurysms that are not amenable to surgical clipping or reconstruction (1, 4, 5, 7, 16–18). The DSB had been the tool of choice for vessel occlusion because of its formation of a tight hermetic seal with the vessel wall, an important feature to avoid distal thromboembolism. Since the withdrawal of the DSB from the market by its manufacturer, the endovascular occlusion of high-flow arteriovenous fistulae, and of large parent vessels has relied primarily on coils. The method consists of first deploying an oversized coil, possibly a three-dimensional coil, a fibered spiral coil (8), or a Hydrogel coil (11), to form a scaffold that is then further embolized using additional coils. Although this is relatively straightforward in a small vascular branch, it can be complicated by possible distal coil mass migration when performed in a larger artery with a high flow rate, as well as by difficulty in controlling the density of the coil mass. This is even more critical in compliant arteries without external bony confines. In these patients, we used an Amplatzer vascular plug to achieve a fixed endovascular anchor to circumvent the drawbacks of coil migration and possible distal coil embolization.

Clinical use of the Amplatzer vascular plug has been described in a number of peripheral and coronary vascular applications including patients with aortopulmonary collaterals, pulmonary arteriovenous malformations, venovenous collaterals, shunts, coronary fistulas, and certain type of patent ductus arteriosus (3, 10, 19). The device has a different design for several of these applications, but because of the flexibility of the Nitinol mesh cage, we selected a cylindrical design which was slightly oversized with respect to the cervical segment of the ICA. Potential difficulties with delivery of the currently available Amplatzer plug include the need for distal positioning of a relatively large ($\geq$ 5-French) guide catheter at the target site as the device is deployed directly from the guide catheter and cannot be navigated distally once unsheathed because of its high-friction apposition to the intima. Although not desirable, vasospasm or a small arterial dissection is not a contraindication to the use of this device for arterial sacrifice. The plug is mounted on a stiff steel delivery cable which, in conjunction with the guide catheter, may straighten or deform tortuous vascular segments. Additionally, when releasing the plug from the delivery cable, the potential for perforation of the vessel by the stiff threaded end of the delivery cable exists. Care should therefore be taken to appose the guide catheter to the unsheathed vascular plug and ensure retraction of the delivery cable into the catheter after detachment.

From a cost-benefit perspective, the Amplatzer vascular plug can enable the exclusive use of inexpensive pushable fibered coils, which cost a fraction of the cost of controlled-detachment equivalents. In coil-mediated parent vessel occlusion, pushable coils are usually used only after a substantial number of controlled-detachment coils have been used to form a framework that is sufficiently dense to prevent embolization of the pushable coil, which cannot be controlled once released from the microcatheter. Although we did not use such an approach in the two cases presented here, deployment of the Amplatzer plug first followed by low-cost pushable fibered coils could result in significant cost savings.

The Amplatzer plug used in the current study is porous, and is, accordingly, insufficient to seal flow through the vessel. This is an important consideration because any flow through the plug may result in distal thromboembolism. Accordingly, the plug was not used as an occlusive device by itself, but rather as a simple mechanical anchor. The development of an Amplatzer plug variant, which is covered with an impermeable membrane on a lower profile delivery wire, may make such a device ideally suited for single-step occlusion of even smaller caliber arteries and more delicate intracranial vessels.

CONCLUSION

The Amplatzer vascular plug can be adapted for use in the cervical and base of cranial carotid and vertebral arteries as a fixed anchor that can assist in performing coil-mediated vessel occlusion with increased assurance against distal coil migration. This technique is a valuable addition to the endovascular therapy armamentarium, especially as an equivalent alternative to the detachable balloon device for the specific application of parent vessel occlusion.

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COMMENTS

Hoit et al. describe a technique using the Amplatzer vascular plug as scaffolding for parent vessel occlusion. Because detachable balloons are no longer sold in the United States, this certainly has been somewhat problematic with coil occlusion. As the authors mention, the length of the procedure with coil occlusion has increased as has the cost due to the number of coils that need to be deployed.

Our technique usually involves achieving flow arrest with a balloon distal to the coil mass or proximal to the coil mass so that a washout of involved material does not occur when the coils are deployed. This is a unique technique that may be applicable to certain cases, and I think it is something to consider.

The Food and Drug Administration has not approved this device, and patients need this explained in detail. The only concern about using this device is that it is fairly stiff with the delivery instrument, which can be somewhat problematic. Nevertheless, I think that this is a potentially useful tool to consider if parent vessel occlusion becomes problematic with either coil complex technique alone or balloon-achieved flow arrest with coil deposition. We anticipate that within the next year, the detachable balloons will be back on the market in the United States.

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Hoit et al. present the novel use of an Amplatzer plug as a scaffold for coil occlusion of a carotid and vertebral artery in difficult aneurysms. This is a clear example of fluid technology transfer from one specialty to another. The Amplatzer plug has been used in the cardiopulmonary circulation to close patent ductus arteriosus, postoperative saphenous vein aneurysms, and pulmonary arteriovenous fistula. This is the first report of carotid occlusion with this device. One can imagine that with a few modifications, an extruded device would, if appropriately sized, occlude the carotid without the need for coils. Endovascular tools are advancing rapidly and the utility and design of these devices are enriched by the diversity of backgrounds of the current endovascular community. Although innovative, the use of the Amplatzer plug is a very expensive means to coil occlude an artery.

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The authors report their experience using the Amplatzer vascular plug to effect therapeutic neurovascular occlusion. The off-label use of this device is described in two patients: a 90-year-old woman with a symptomatic fusiform cavernous internal carotid aneurysm and a 44-year-old man with a symptomatic fusiform dissection of the right vertebral artery.

As the authors note, since the withdrawal of the silicone detachable balloon (DSB) from the market by its manufacturer (Boston Scientific Corp., Natick, MA), neuro-interventionalists have had limited and suboptimal tools with which to achieve a therapeutic endovascular parent artery occlusion. The Amplatzer device described in this article is used as an endovascular basket to add stability to subsequent coils deployed adjacent to it in the artery being occluded. The authors suggest that by utilizing this device, there may be subsequent cost savings because less expensive pushable coils may be used in conjunction with it rather than the need for more expensive detachable coils, more commonly used to create an initial construct. Unfortunately, the larger Amplatzer basket, which appeared better suited for carotid occlusions in this report, requires an 8 French guiding catheter for delivery. The authors clearly describe the limitations of this device and make useful suggestions that may improve its functionality.

It is unfortunate for neuro-interventionalists that the manufacturer of the detachable balloon had decided to abandon this device at a time when no equally effective device is available to replace it. Having been trained at a time when the DSB was the treatment of choice for direct carotid cavernous fistulae and carotid occlusions, utilizing coils and even liquid embolic agents for this purpose seems a step backwards technically. Although the Amplatzer plug currently is not a substitute for the DSB, it does appear to offer an improvement to coil occlusion alone.

At our institution, we perform endovascular coil occlusions with the artery temporarily occluded with the use of a 5F latex temporary occlusion catheter with an 8.5 mm balloon. While the artery is occluded temporarily, we proceed with coil embolization through a microcatheter passed coaxially through the wire lumen of the balloon catheter. Temporary occlusion of the flow ensures that the first few coils deployed are not pushed downstream and prevents development of emboli that can develop before the artery is completely coil embolized.

Although the authors share their experiences with the Amplatzer vascular plug, perhaps with further development and modification of this device, as suggested by the authors, will result in a single-step occlusion device rather than a mechanical anchor for coil embolization.

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