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Evolution of Embolization

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Embolization techniques and technology are evolving every year. We have come a long way from flow-directed polyvinyl alcohol and pushable coils to reabsorbable materials and detachable technology with extremely high accuracy. I have been using detachable coils in addition to pushable technology in my practice for a number of years. The original reason for choosing detachable coils was their precision, which results in increased patient safety. Detachable coils allow us to accurately and safely embolize vessels and aneurysms. In today's environment, there are two additional factors to consider. Both cost and radiation exposure are at the forefront of physicians' and hospitals' minds. Hospitals would like to see a reduction in overall procedural cost, and physicians need to monitor and protect patients and themselves from radiation exposure.

Penumbra, Inc. has been successful in bringing new technology into the interventional space that allows operators to improve patient safety. The Ruby® coil (Penumbra, Inc.) was the first device that was introduced in 2013. By creating a coil that is similar in caliber to a 035 coil, but deliverable through a high-flow microcatheter, we are able to easily deliver a high volume of embolic material to the vasculature (Figure 1). Additionally, the softness of the coil allows up to 60 cm of coil in a single device. Each year, Penumbra has increased its offering by building on the same platform. POD® (Penumbra Occlusion Device; Penumbra, Inc.) is very useful in high-flow anatomy, and the new POD packing coil allows physicians to ignore variant vessel diameters and simply choose the desired length of soft packing material to deploy once the initial coil is placed. All three of these devices use the same detachment system and can be delivered through the same catheter. Having all of the devices on the same platform keeps the materials needed for any case very low. These devices can allow faster vessel occlusion, therefore partially reducing radiation and room time, which drive major cost concerns in interventional radiology. However, the real effect of these devices on cost savings should still be evaluated.

A new product addition is the Lantern™ low-profile High-Flow microcatheter (Penumbra, Inc.). This highly visible High-Flow low-profile microcatheter is extremely useful in procedures. Both the lower 2.6-F profile and the unique tracking technology allow it to track similarly to lower-profile microcatheters while still maintaining a large lumen to deliver a wider variety of devices. The new 3-cm visible segment is easy to see in the visceral anatomy, and I have found that I can track the catheter at times without a wire. These products work extremely well as a system and are very helpful additions to my embolization bag.

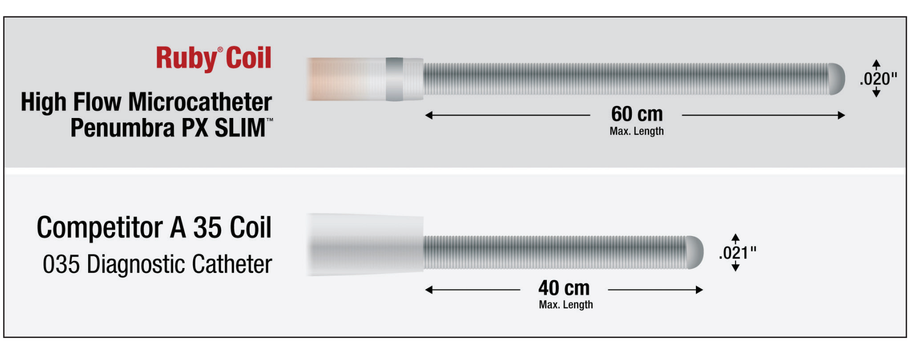

Figure 1. Size comparison of the Ruby coil and a 0.035-inch coil.

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In my practice, POD allows us to selectively and safely embolize targeted segments of arteries by packing a sufficient quantity of soft platinum coils to achieve occlusion in a similar fashion to existing bare-platinum embolization coils. The POD system consists of three components: a coil implant attached to a detachment pusher and a detachment handle. The coil implant of the POD is designed with a unique distal tip, which is stiffer and larger in diameter and is followed by a softer packing segment. Thus, the deployment of this distal end serves as an anchor, securing the coil construct. Advantages of such a device are: (1) only a 0.025-inch delivery microcatheter is required; (2) the coil may be removed and replaced until detachment; and (3) a single device may be used to achieve adequate packing. The following cases highlight the strength of the POD to complete trunk occlusion in various arteries.

CASE REPORT 1

A man in his early 60s with a medical history of pelvic trauma and osteosynthesis 3 months prior presented with symptoms of pulsatile pelvic mass and pain. He was admitted to our institution with a 6-cm aneurysm arising from the right posterior gluteal artery approximately 3 to 4 cm distal to its origin (Figure 1A).

A 4-F sheath was inserted into the left femoral artery, and a 4-F Cobra C2 angiographic catheter was used to select the right superior gluteal artery (Figure 1B). Next, a PX Slim microcatheter (Penumbra, Inc.) was used to select the feeding arteries over a 0.018-inch guidewire. Distal embolization was performed using a 3-mm X 15-cm soft Ruby coil. The microcatheter was replaced and then advanced into the proximal portion of the trunk of the gluteal artery. Embolization was performed by placing one POD4 (4 mm X 30 cm) in < 5 minutes. Multiple angiograms were obtained after embolization, showing no contrast flow into the sac (Figure 1C). There were no procedural complications. At 3-month follow-up, the aneurysm remained completely occluded (Figure 1D).

DISCUSSION

Since using the POD technology, I have noticed a significant decrease in complexity and procedure time for embolization procedures performed into the trunk of arteries. One main advantage of the POD is that complete occlusion of an artery can be achieved, much like a plug, but using only a high-flow microcatheter. However, some technical points must be considered. Adequate selection of the POD size is important to secure the delivery and allow for a more compact coil mass. In fact, the diameter of the POD must closely match the diameter of the vessel to avoid migration during coil deployment. Three to four loops of the distal segment seem sufficient to allow secure delivery of the POD at the desired point. Moreover, as the anchor zone transitions into a softer and smaller-diameter mass, adequate packing must be performed. During deployment of this section, forward loading the delivery microcatheter within the anchor seems to allow the softer coil to bury itself inside the frame and then limit the length of packing. This has resulted in a more compact coil mass with the deployment of this single device compared to other techniques.

CASE REPORT 2

A woman in her late 50s with a medical history of renal transplantation presented with a large acquired arteriovenous fistula (AVF) into the graft. Progressive renal function impairment was observed. MRI showed a 1-cm AVF that had been increasing in size (Figure 2A). A large dilation of the renal vein was observed as consequence of the high flow within the

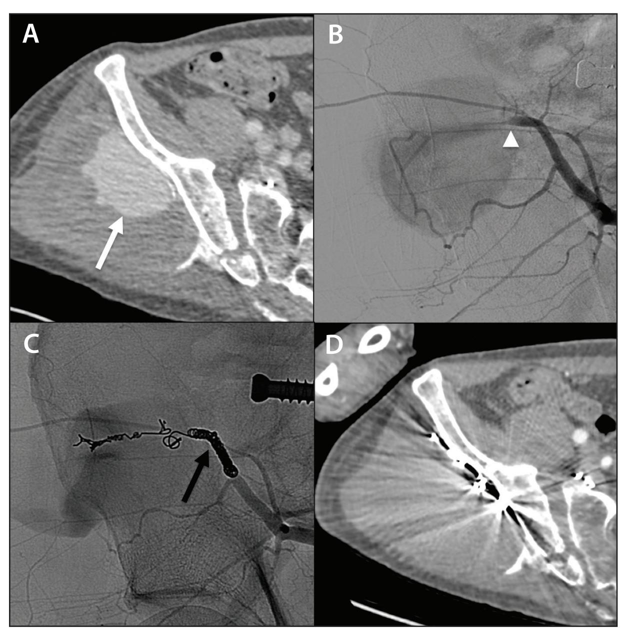

Figure 1. CT showing a 6-cm aneurysm arising from the right posterior gluteal artery (arrow) (A). Angiogram showing a 4-F Cobra C2 angiographic catheter selecting the right superior gluteal artery (arrowhead) (B). Angiogram after embolization showing no contrast flow into the sac (arrow) (C). CT at 3-month follow-up showing that the false aneurysm remained completely occluded (D).

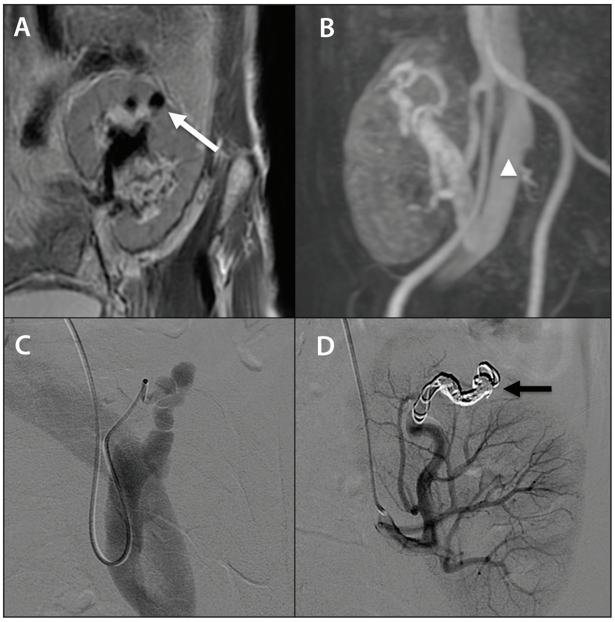

Figure 2. MRI showing a 1-cm AVF (arrow) (A). Large dilation of the renal vein (arrowhead) (B). The microcatheter was introduced into the AVF in order to preserve the renal branches (C). Embolization performed with one POD8 (arrow) (D).

AVF (Figure 2B). The patient was admitted to our institution for embolization.

A 4-F sheath was inserted into the right femoral artery, and a Cobra C2 angiographic catheter was used to select the renal artery. Next, a PX Slim microcatheter was used to select the AVF over a 0.018-inch wire, which was then advanced into the AVF. The artery was tortuous; however, the flexibility of the PX Slim microcatheter easily negotiated the loops. This allowed for a stable construct before embolization (Figure 2C). Embolization was performed with placement of one POD8 (8 mm X 60 cm) in < 5 minutes (Figure 2D).

The flow into the vein decreased, and the renal parenchyma was well visualized. Multiple angiograms were then obtained, which documented complete embolization with no contrast flow remaining into the AVF. There were no procedural complications. At 3-month follow-up, the AVF remained completely occluded, and normal renal function was recovered.

DISCUSSION

In order to secure the delivery, we use a catheter allowing adequate stabilization of the microcatheter and push of the POD system. This is important because the detachment pusher remains stiff, even in 0.02 inches. Although it was not essential in this specific case, a shepherd's hook or Simmons catheter seems adequate to achieve proximal embolization in splenic, mesenteric, or renal arteries.

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Traditionally, vessel sacrifice has lacked a simple solution. In the past, successful embolization required hard-to-deliver plugs or hard-to-size coils. Both options often resulted in an incomplete embolization that relied on the clotting cascade to completely occlude the vessel.

More recently, vessel sacrifice has been made easier with POD. The POD robust initial coil predictably anchors in vessels with sizes allowing treatment of vessels between 3.25 and 8 mm. The remainder of the coil becomes softer, allowing it to pack tightly behind the anchoring segment. However, despite the tight packing of POD, additional coil mass is sometimes necessary to completely occlude a vessel. The selection of the next device to use has been challenging, often requiring additional vessel diameter measurements and multiple devices, especially in vessels that require a large coil volume to completely arrest flow.

Now, with the POD Packing Coil (an ultrasoft and shapeless high-volume coil), secondary coil selection for vessel sacrifice is made much simpler. After creating a backstop with your first device, either POD or the Ruby coil, simply choose either a POD Packing Coil (15, 30, 45, or 60 cm) based on the length of coil already delivered and the amount of remaining landing zone. Because it is both shapeless and ultrasoft, POD Packing Coil will act similarly to liquid metal, seeking out the empty spaces within the coil mass, resulting in a denser occlusion using fewer devices in any size vessel.

POD Packing Coil, like the POD and Ruby devices, is easily deliverable to challenging distal anatomy through Lantern, a low-profile, high-flow microcatheter. POD Packing Coil's predictable mechanical detachment gives the operator the ability to retract the coil and reposition it, even when the entire coil mass is outside the microcatheter. This results in accurate placement and allows for a dense occlusion with few devices.

CASE 1

After gaining 6-F access to the ipsilateral hypogastric artery using a renal double-curve sheath, a 115-cm 45° Lantern microcatheter was advanced over a 0.016-inch microwire. The Lantern tracked seamlessly over the wire to the desired lumbar collateral. The microwire was then removed, and a 750-psi contrast injection was performed. Using this injection, the vessels measured approximately 3 mm in diameter. Based on this measurement, the first device selected was a 3-mm X 20-cm standard Ruby coil. The coil was easily delivered through Lantern despite significant tortuosity and formed a backstop to deliver POD Packing Coil. Being careful not to obstruct crucial collateral vessels, two 15-cm POD Packing Coils were first deployed, followed by one 30-cm POD Packing Coil. A final contrast injection was then performed through the Lantern device, showing that the vessel had been completely shut down (Figure 1).

Coil selection with traditional coils would have been challenging in this case due to the tapering of the vessel distally. Because POD Packing Coil is shapeless, it proved to be the right size along the length of the tapering vessel, packing tightly into open spaces, regardless of the diameter. The ability of POD Packing Coils to be retracted and readvanced allowed me to confidently shut down only the target vessel while maintaining nontarget vessel patency.

CASE 2

Although POD Packing Coil is best used for vessel sacrifice, it can be very effective when embolizing a sacular space and the exact size or shape of the remaining volume is unknown. This endoleak measured about 3 cm and was accessed through the inferior mesenteric artery with the Lantern microcatheter (Figure 2). The sac was initially framed with three 32-mm X 60-cm Ruby coils (Figure 3). After use of the first few coils, the remaining shape of the space was not easily identifiable. I filled the remaining space with three 60-cm-long POD Packing Coils. Each coil sought out and filled any empty spaces (Figure 4).

DISCUSSION

POD Packing Coil allows me to more easily perform vessel sacrifices. After creating a backstop with either POD or Ruby coil, secondary coil selection is now simply a question of how much coil volume the vessel is able to accommodate, not diameter. Knowing how much coil landing zone remains and how much volume has already been deployed in the vessel makes this decision easy. For example, if a POD8 (8 mm X 60 cm) has been deployed as the first device, and the remaining landing zone looks as if it can accommodate an additional 60 cm of coil, I will select a 60-cm POD Packing Coil.

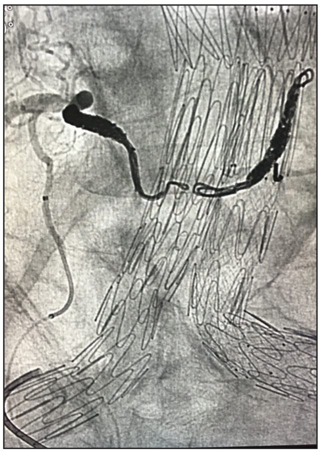

Figure 1. An endoleak with segments of varying diameter. POD Packing Coil was used to conform and fill these segments.

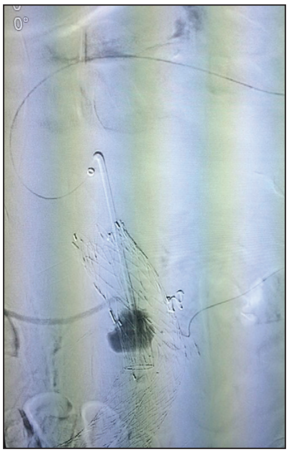

Figure 2. A large 3-cm endoleak confirmed via angiography.

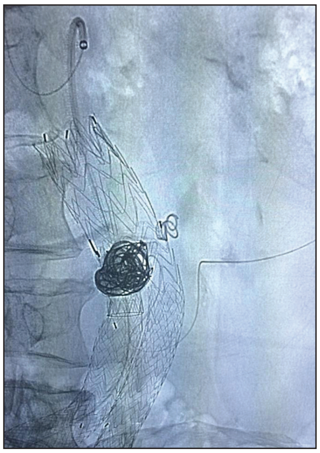

Figure 3. Large 32-mm X 60-cm Ruby coils used to frame the sacular endoleak. The remaining volume was of unknown size and shape.

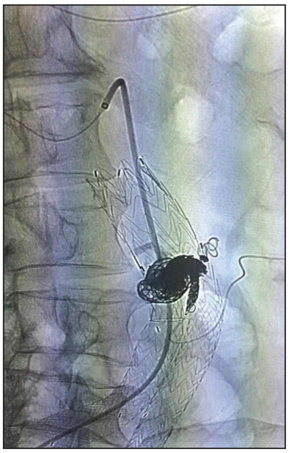

Figure 4. Three 60-cm-long POD Packing Coils used to seek out remaining space and pack tightly.

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Procedure time and radiation exposure are becoming increasingly more important to interventionists. Because of this, devices that allow interventionists to more easily access hard-to-reach anatomy while also performing the necessary intervention are in high demand. Lantern, a low-profile, high-flow microcatheter (Figure 1), allows for more simplified microcatheter selection, thus expediting procedure times by decreasing timely catheter exchanges. As a 2.6-F catheter with a high-flow lumen, Lantern bridges the gap between traditional 2.4-F catheters and larger 2.8-F high-flow catheters. Lantern's low profile allows it to track into distal anatomy like smaller 2.4-F catheters while also allowing operators to deliver high-volume contrast injections, large-volume coils, and embolics, previously only deliverable by larger, less trackable, 2.8-F devices.

Lantern's radiopaque distal 3-cm tip and dual marker band also provide unique advantages (Figure 2). Not only does this visible segment allow for confident Ruby coil deployment, but it also provides better visualization of tortuous anatomy, thus reducing overall fluoroscopy time and contrast needed. Using Lantern, the proximal end of Ruby coil is easily visualized as the nonradiopaque pusher passes through the radiopaque distal 3 cm of Lantern (Figure 3). As the proximal end of the coil nears Lantern's tip, the Ruby coil alignment marker, which is recessed 3 cm from the proximal end of the Ruby coil, is visualized approaching Lantern's proximal marker (Figure 4). When the Ruby coil alignment marker crosses Lantern's proximal marker, forming a "T," the Ruby coil can be deployed (Figure 5). This feature is essential, as it allows me to confidently deploy Ruby coils, even when I cannot see Lantern's distal tip due to dense coil packing.

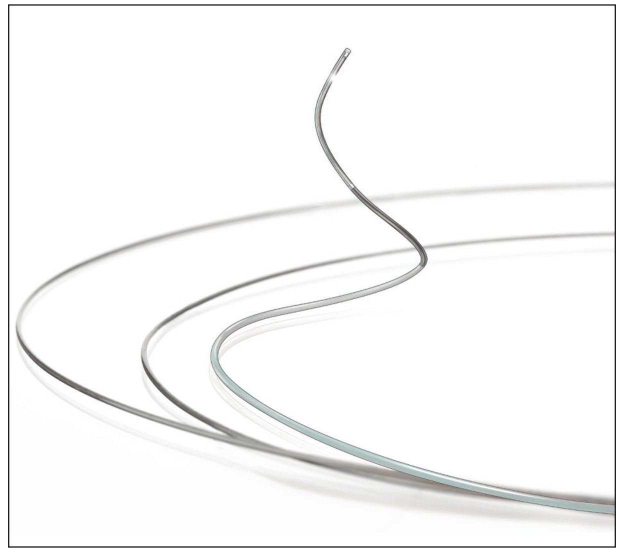

Figure 1. The Lantern device.

The microcatheter length options (115, 135, and 150 cm), coupled with its straight, 45°, and 90° tip shapes, make Lantern an all-purpose option that enables me to work more efficiently in challenging anatomy. In the case that follows, I describe how I used Lantern in some interesting clinical scenarios.

CASE REPORT 1

To begin, 6-F access was achieved in the right groin. The celiac artery was selected using a Simmons-shape

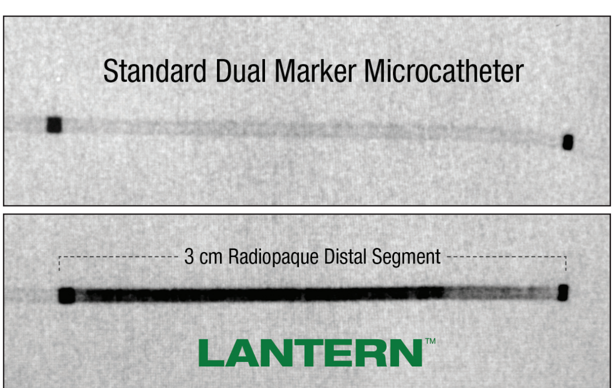

Figure 2. Lantern has a 3-cm radiopaque distal segment in addition to a proximal and distal marker band.

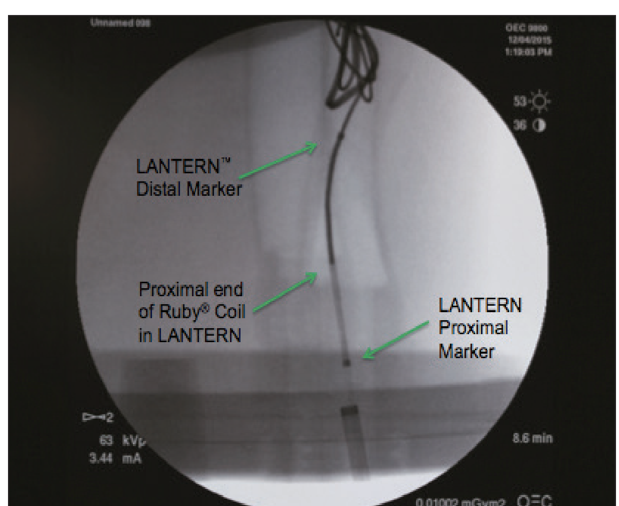

Figure 3. The proximal end of Ruby coil is easily visualized within the Lantern microcatheter.

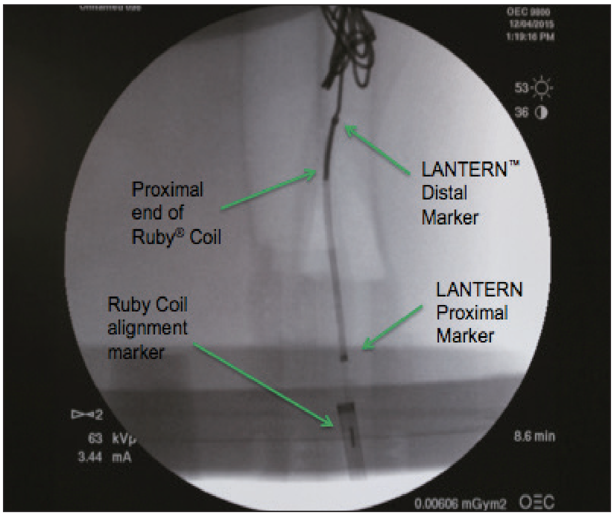

Figure 4. The Ruby coil advancing through Lantern microcatheter. The Ruby coil alignment marker entering the visual field.

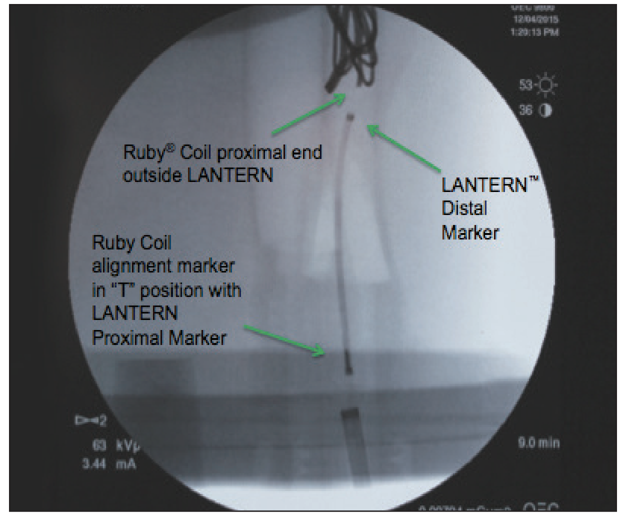

Figure 5. When the coil alignment marker crosses Lantern's proximal marker band, forming a "T," this signifies that the coil is fully deployed outside the distal tip of the microcatheter and can be detached.

diagnostic catheter over a 0.035-inch wire. A 115-cm, 45° Lantern microcatheter was then tracked over a 0.016-inch wire and parked in the common hepatic artery. Due to the risk of reflux with Y-90 particles, we decided to coil embolize the gastroduodenal artery (GDA). Lantern was easily advanced into the GDA (Figure 6). The GDA was measured to be approximately 4 mm in diameter. Using the microwire and Lantern, the GDA was selected, and Lantern was advanced to the desired coiling location. Based on the vessel's 4-mm diameter, the first device selected was POD4. The POD4 device was advanced through Lantern and was deployed when the coil alignment marker lined up with Lantern's highly visible proximal marker (Figure 7). A second contrast injection was performed using Lantern, which showed some flow through the coil mass. Noting that approximately half of the landing zone was occupied by the 30-cm POD4, a 30-cm POD Packing Coil was selected and easily delivered using Lantern (Figures 8 and 9). A final contrast injection was performed, showing no flow through the coil mass. After embolization of the GDA, macroaggregated albumin was easily infused through Lantern without the need to exchange catheters.

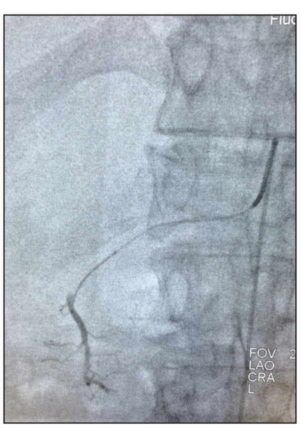

Figure 6. Angiogram of the GDA via the Lantern microcatheter.

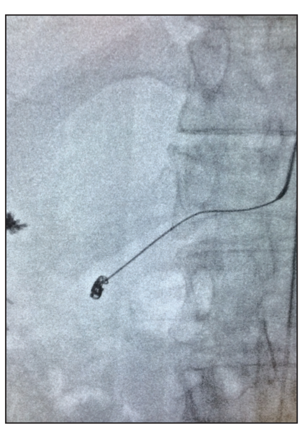

Figure 7. POD4 being deployed through the Lantern microcatheter into a 4-mm GDA.

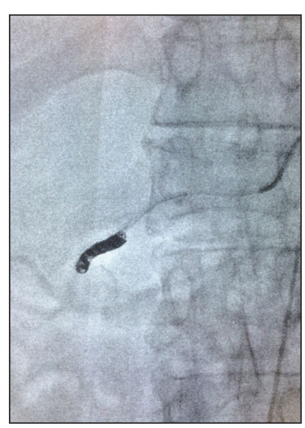

Figure 8. Visualization after deploying POD4.

Figure 9. Visualization after deploying a 30-cm POD Packing Coil.

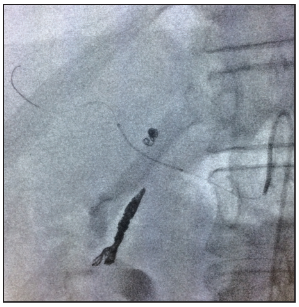

Figure 10. Lantern microcatheter tracking through the hepatic artery over a microwire.

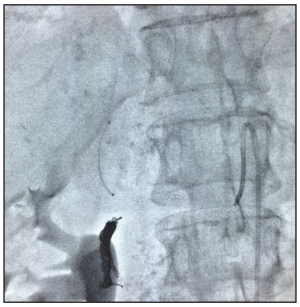

Figure 11. Lantern in the hepatic artery. The radiopaque segment and dual marker bands are visible on fluoroscopy without a guidewire.

CASE REPORT 2

Again working through a 6-F access into the right groin, the celiac artery was selected using a 5-F Simmons-shape diagnostic catheter over a 0.035-inch wire. A 115-cm straight-tip Lantern microcatheter was then tracked over a 0.016-inch wire and tracked distally into the hepatic artery. The GDA had previously been coiled during the mapping procedure. A superduodenal artery had become more prominent, so we elected to coil it. Lantern easily tracked into the vessel, and a Ruby coil (2 mm X 4 cm) was deployed (Figure 10). Lantern's highly visible 3-cm distal tip allows physicians to visualize the catheter's path in the vessel very easily (Figure 11). Lantern's 2.6-F outer diameter and its 0.025-inch lumen allowed the catheter to track distally like a 2.4-F catheter while still allowing me to deliver the radioactive microspheres through its high-flow lumen. This allows me to more safely and selectively deliver radiotherapy further distally (closer to the desired target lesion), thus limiting reflux.

DISCUSSION

With Lantern, I can perform Y-90 interventions with greater confidence. Lantern's angled tip shapes allow me to purposefully manipulate the wire and more easily access difficult anatomy. Once access is achieved, I am able to deliver a high-volume contrast injection to distal anatomy, embolize using Ruby coils, and inject the radioactive particles, all without exchanging microcatheters.

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For large visceral aneurysms, I like to use Ruby coils for their large diameter and long length offerings. In tortuous and high-flow anatomy, such as the splenic arteries, I use POD to anchor against the rapid blood flow. I typically fill behind it with Ruby coils, but the addition of POD Packing Coils makes secondary coil selection seamless. Finally, the Lantern microcatheter is the most trackable and visible microcatheter I have used. I can track into desired vessels very quickly over my microwire and deliver a wide variety of materials. These four devices work very well together and allow me to decrease my materials used and procedure times.

CASE REPORT

The patient presented with a splenic artery aneurysm on CT imaging. Angiography confirmed a 3.4-cm aneurysm (Figure 1). We occluded the lower lobe using the Lantern microcatheter and POD5. The anchoring segment and long length of POD held it in place against the high flow. The upper branch measured at 3 mm, and we elected to embolize this using standard 3-mm Ruby coils to frame and, subsequently, soft Ruby coils for packing (Figure 2). With the new POD Packing

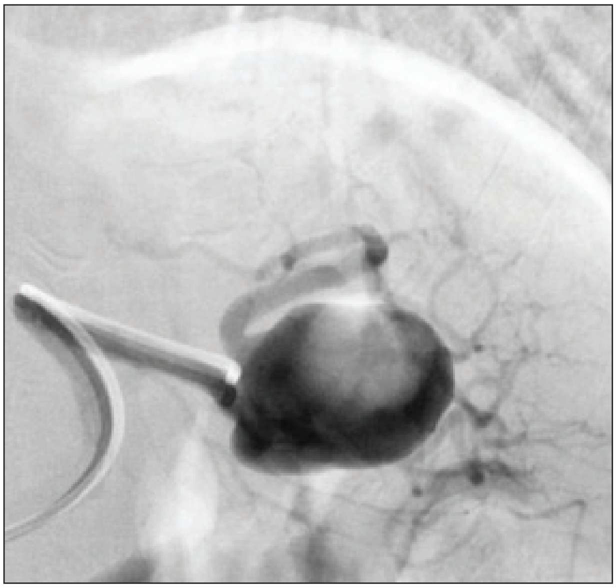

Figure 1. Angiography confirming a 3.4-cm aneurysm.

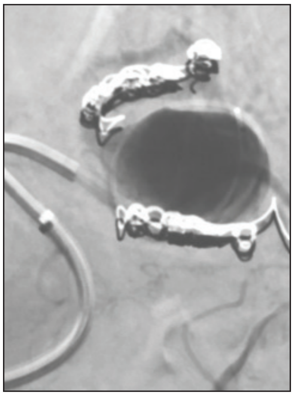

Figure 2. Angiography showing no flow through either outflow vessel. The lower lobe was occluded using POD5. The upper branch was occluded using standard and then soft 3-mm Ruby coils to frame and then pack.

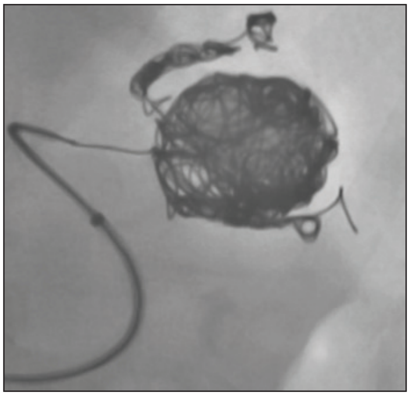

Figure 3. Visualization of coil deployment through Lantern into the aneurysm sac. Three 32-mm X 60-cm and two 28-mm X 60-cm standard Ruby coils were deployed into the aneurysm sac.

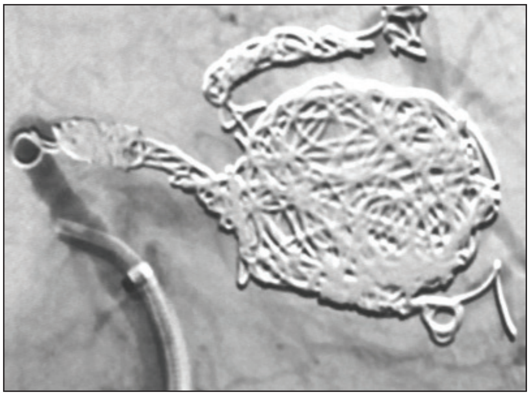

Figure 4. Angiogram showing stasis after a POD4 was deployed into the inflow vessel.

Coil, I would have simply chosen a device length of 15 or 30 cm to place after initial Ruby coil use.

Three 32-mm X 60-cm and two 28-mm X 60-cm standard Ruby coils were deployed into the aneurysm sac (Figure 3). A POD4 was deployed into the inflow vessel. The softness of the coil allowed tight packing, and we saw angiographic stasis after the final coil was deployed (Figure 4).

DISCUSSION

Hospitals can benefit from the use of the Ruby coil and POD systems because the total costs are potentially reduced. In my experience, I typically use the rooms for less time and open less devices when using Ruby and POD. As an endovascular surgeon, radiation exposure is very important to me. The less radiation I can be exposed to, the safer I feel. ■

Disclaimer: The opinions and clinical experiences presented herein are for informational purposes only. The results may not be predictive for all patients. Individual results may vary depending on a variety of patient-specific attributes.