# Tools for Dense and Durable Embolizations

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Penumbra, Inc. has been successful in bringing new detachable coil technology to physicians, helping to facilitate dense and durable embolizations with soft, large-volume coils. 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, physicians are better able to deliver a high volume of embolic material, even to distal vessels (Figure 1). The Ruby Coil is much softer than conventional coils (Figure 2). The softness of the coil allows up to 60 cm of coil to be delivered in a single device, dramatically reducing the number of coils per case, which, in turn, minimizes radiation exposure to patients.

More recently, Penumbra expanded its coil offering on the same design platform. POD® (Penumbra Occlusion Device; Penumbra, Inc.) is an extremely valuable tool in high-flow vessel sacrifice. POD features a robust distal anchoring segment, helping the coil to anchor where traditional coils would be unable to because of high flow. The proximal portion of the coil then becomes softer, allowing it to densely pack behind the leading anchor segment.

POD Packing Coil, the newest addition to the platform, is an ultrasoft, shapeless coil that conforms to any vessel diameter. With lengths up to 60 cm, the shapeless configuration of POD Packing Coil can be delivered to even the smallest vessels in a single device.

The softness of Ruby, POD, and POD Packing Coil offers important advantages over conventional technol-

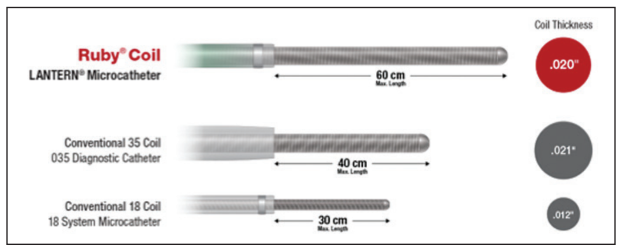


**Figure 1. Volume advantage size comparison of the Ruby Coil versus a conventional 35 coil and a conventional 18 coil. Image provided by Penumbra.**

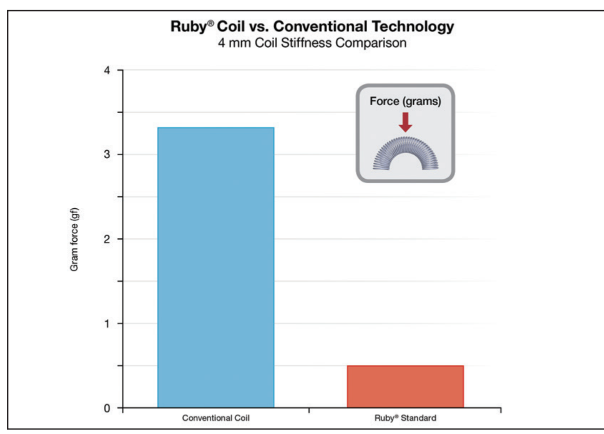


**Figure 2. Coil stiffness data comparing the relative softness of Ruby Coil compared to a conventional detachable coil. Data on file at Penumbra.***

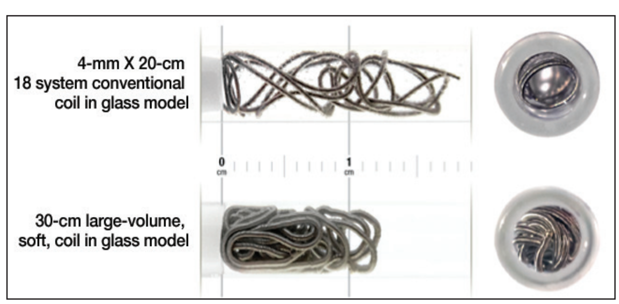


**Figure 3. Softness comparison showing the advantage of large-volume, soft, bare platinum coils versus conventional technology. Soft coils pack more densely, creating cross-sectional occlusion. Image provided by Penumbra.**

*Coil stiffness was assessed using a coil loop deflection test. A single 4-mm conventional 18 system detachable coil was compared to standard and soft 4-mm Ruby Coils. Three data points were collected for each coil, and an average was taken.

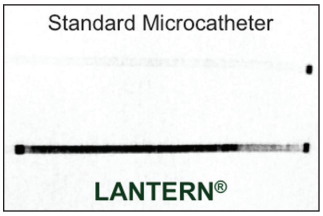


**Figure 4. Fluoroscopic image comparing LANTERN's radiopaque distal shaft and dual marker bands to a conventional single marker microcatheter. Image provided by Penumbra.**

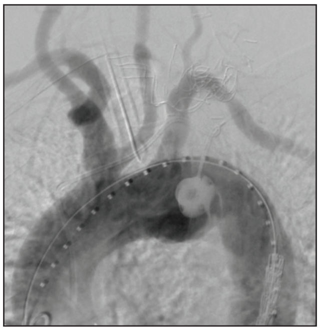

**Figure 5. Preprocedure imaging of the thoracic aortic aneurysm.**

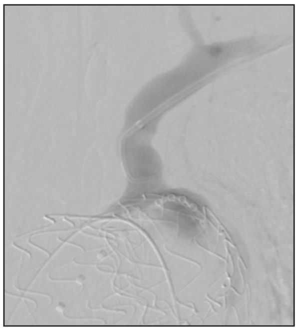

**Figure 6. Postdeployment imaging showing that the endograft was covering the right subclavian artery. Flow was visualized behind the endograft.**

**Figure 7. Postprocedure imaging showing dense coil packing with Ruby and POD Packing Coil and complete occlusion of the subclavian artery.**

ogy. Softer coils allow me to achieve higher packing density by delivering more embolic material in a given landing zone (Figure 3). With more embolic material, I am less reliant on the clotting cascade to fill empty spaces within a coil mass to generate occlusion. As a result, I have seen a dramatic decrease in recanalization rates in my practice.

All three devices use the same mechanical detachment system and can be delivered through the LANTERN® high-flow microcatheter (Penumbra, Inc.). This highly visible catheter is extremely useful in these procedures (Figure 4). With its low profile (2.6 F) and advanced tracking technology, LANTERN helps to access lesions further distally than I otherwise would be able to through a diagnostic catheter. The radiopaque distal 3-cm segment is easy to see in visceral anatomy, and the angled tip shapes help to facilitate dense packing by directing the coil toward the vessel wall. These devices work extremely well as a system and have streamlined my embolization algorithm, even in complex vessels and aneurysms.

## CASE REPORT

The patient presented with a thoracic aortic aneurysm (Figure 5). Because of the location of the aneurysm and the patient's bovine arch, excluding the aneurysm with a thoracic endograft required covering the right subclavian artery with the endograft (Figure 6). To maintain perfusion to the left arm, carotid-subclavian bypass was performed and the left subclavian artery was embolized to prevent reflux blood flow from causing an endoleak behind the endograft.

To embolize the subclavian artery, a diagnostic catheter was introduced from a radial approach. Through the 4-F diagnostic catheter, a 115-cm, 45° LANTERN microcatheter was introduced and tracked distally. To embolize the 12-mm origin of the subclavian artery, a 12-mm X 40-cm standard Ruby Coil was first delivered, creating a backstop for soft POD Packing Coils to densely pack behind it. Using LANTERN, two 60-cm POD Packing Coils and one 30-cm POD Packing Coil were deployed (Figure 7).

## DISCUSSION

In these scenarios, I prefer using Ruby and POD Packing Coil over traditional plugs because of the ability to densely occlude vessels. The softness of the coil allows me to pack tightly against the endograft, creating a dense metal occlusion with no interaction between the plug nipple and endograft material. With a dense occlusion, I can reliably shut down the vessel without relying as heavily on thrombus formation and without worry of recanalization. Furthermore, with Ruby, POD, and POD Packing Coil, I can perform procedures from a radial approach, utilizing a 4-F sheath. Using a 4-F catheter and the LANTERN microcatheter, I can easily track through the curvature of the left subclavian artery to minimize any complications utilizing brachial access.

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Packing density is known to be a leading factor in stable embolic occlusions in the treatment of cerebral aneurysms. Studies have supported that dense volumetric filling greater than 24% of the aneurysm volume promotes occlusion stability in the neurovasculature. Similar data supporting packing density in the periphery have been sparse, with the exception of a study by Yasumoto et al, which found a 24% packing density threshold in the treatment of visceral aneurysms.[1]

The ACE registry is single-arm multicenter registry that has recently completed enrollment. The registry is designed to further validate the concept of packing density in peripheral aneurysms as well as peripheral vessel sacrifice using soft, large-volume coils like Ruby, POD, and POD Packing Coil.

In my practice, achieving tight packing with Ruby, POD, and POD Packing Coil has been an important contributor to long-term occlusion stability in both vessels and aneurysms. The following case shows how I am able to achieve dense packing in both saccular spaces and vessels with these devices.

## CASE REPORT

The patient originally presented for treatment of a type II endoleak in 2014. At that time, the patient's inferior mesenteric artery was treated with coil embolization. Two years, later the patient presented again with a second leak, this time through a lumbar collateral (Figure 1).

To embolize the lumbar collateral, 6-F access was gained to the ipsilateral hypogastric artery. Through the sheath, a 115-cm, 45° LANTERN microcatheter was advanced over a 0.016-inch microwire. The LANTERN tracked through the multiple lumbar collaterals into the aneurysm sac and was then manipulated into the distal lumbar outflow vessel. The microwire was then removed, and 750-psi contrast injection was performed through the LANTERN (Figure 2). Using this angiogram, the vessel measured approximately 3 mm in diameter: therefore, sizing one to one, the first device selected was a 3-mm X 15-cm soft Ruby Coil. Despite significant tortuosity, the coil was easily delivered through LANTERN and formed a backstop to deliver a 30-cm POD Packing Coil (Figure 3). Next, a second 3-mm X 15-cm soft Ruby Coil was deployed to occlude the outflow.

With dense packing in the outflow, the LANTERN microcatheter was then brought proximally into the endoleak sac. Based on the initial CT, the aneurysmal space measured 14 mm in diameter. Again, sizing one to one, the saccular space was first framed using two 14-mm X 60-cm standard Ruby Coils. While framing the aneurysm, mural thrombus was visualized forming within the aneurysm sac. Smaller-diameter soft coils were selected in succession to fill the aneurysm space concentrically. In few devices, I was able to densely pack with soft coils achieving a 50% packing density (Figure 4).

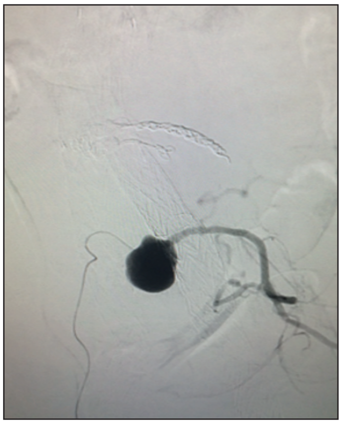

**Figure 1. Contrast injection through LANTERN showing a 14-mm aneurysm sac and 3-mm outflow artery. A coil mass from a previous inferior mesenteric artery embolization is visualized.**

**Figure 2. Contrast injection through LANTERN in a 3-mm outflow artery. The dual marker bands are easily visualized.**

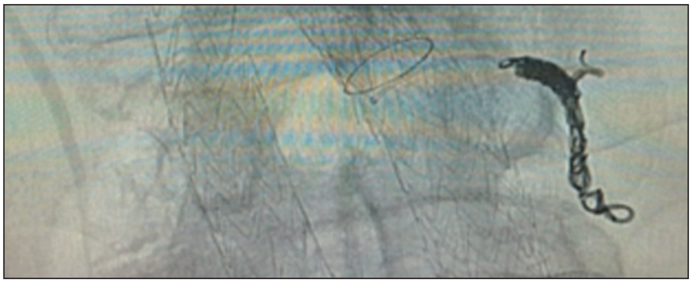

**Figure 3. LANTERN visualized in the outflow vessel after deploying POD Packing Coil.**

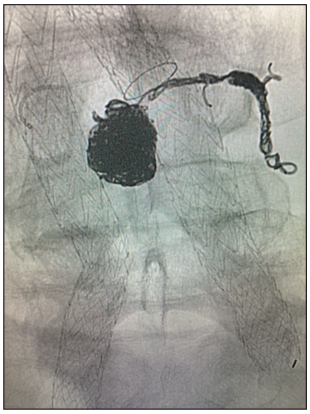

**Figure 4. Dense packing with Ruby and POD Packing Coil in the outflow vessel and aneurysm sac.**

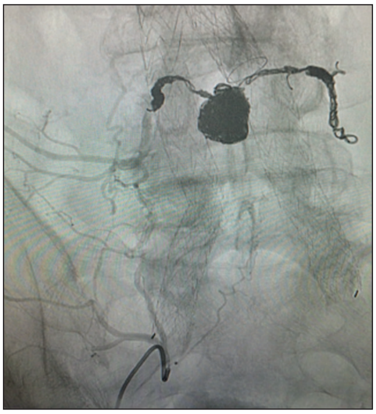

**Figure 5. Completion angiogram showing no flow beyond the coil mass in the inflow artery.**

After coiling the aneurysm sac, we then brought the LANTERN microcatheter back into the 3-mm inflow artery. This was coiled with a 3-mm X 15-cm soft Ruby Coil followed by a 15-cm POD Packing Coil. The embolization was completed with a 4-mm X 15-cm soft Ruby Coil in a slightly larger segment of the vessel. This led to complete occlusion of the outflow artery, aneurysm sac, and inflow artery for complete treatment of the endoleak (Figure 5).

1. Yasumoto T, Osuga K, Yamamoto H, et al. Long-term outcomes of coil packing for visceral aneurysms: correlation between packing density and incidence of coil compaction or recanalization. J Vasc Interv Radiol. 2013;24:1798-1807.

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At our endovascular practice, we prefer Ruby Coils for aneurysm occlusion and vessel sacrifice. Ruby Coils have a variety of large diameters (up to 32 mm) and long lengths (up to 60 cm). Larger and longer Ruby Coils allow proper sizing when treating large aneurysms, resulting in more accurate and complete aneurysm occlusion using dramatically fewer Ruby Coils than with other coil technologies.

When embolizing large aneurysms or vessels, we typically frame the space with Ruby Coils that are sized one-to-one with the diameter of the target. For example, in a 32-mm aneurysm, we would initially choose to frame with a 32-mm X 60-cm standard Ruby Coil. We like to frame with standard coils because the complex three-dimensional shape spreads out and distributes very well within aneurysms and malformations. Once we have adequately framed the lesion with standard Ruby Coils, we continue to pack the space by stepping down to smaller-diameter Ruby Coils. This method concentrically fills the space and allows a densely packed coil mass, achieving the highest packing density possible with the fewest number of coils.

## CASE REPORT

The patient presented with a history of a ruptured abdominal aortic aneurysm that was repaired with open surgery. He presented 15 months later with a 35-mm right hypogastric artery aneurysm, which had enlarged as compared to the CT performed at the time of rupture (Figure 1). The aneurysm had a wide mouth at its origin from the iliac bifurcation. In addition, the common iliac artery was ectatic, precluding simple stenting (Figure 2). To treat the aneurysm and prevent rupture, we elected to deploy an endograft limb from the common iliac artery to the external iliac artery, covering the origin of the aneurysmal hypogastric artery. Simultaneously, we would coil the hypogastric aneurysm behind this stent "jail."

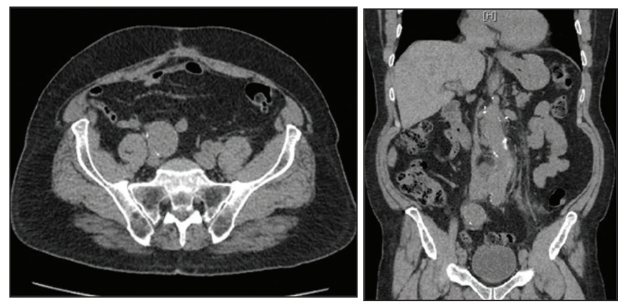

**Figure 1. CT imaging showing a 35-mm right hypogastric artery aneurysm.**

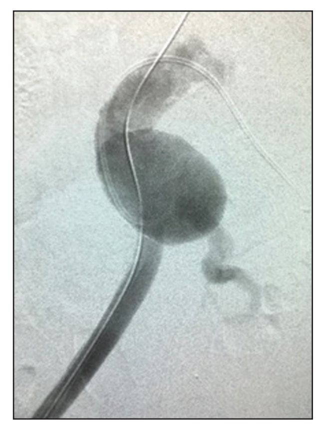

**Figure 2. Pre-embolization angiogram showing aneurysmal hypogastric artery orgin.**

To accomplish this, bilateral femoral access was achieved. The ipsilateral femoral approach was an open exposure. From a contralateral percutaneous approach, the hypogastric aneurysm was first accessed with a 5-F diagnostic catheter and a 115-cm, 45° LANTERN microcatheter. A 16-F sheath was placed and used to deploy the endograft limb from the ipsilateral groin. This, in effect, trapped our diagnostic catheter and microcatheter in the aneurysm behind the endograft (Figure 3). We then deployed Ruby Coils into the aneurysm sac behind the endograft, minimizing risk of maldeployment through the large aneurysm mouth.

To embolize the 3-cm space, three 32-mm X 60-cm standard Ruby Coils were delivered through the LANTERN

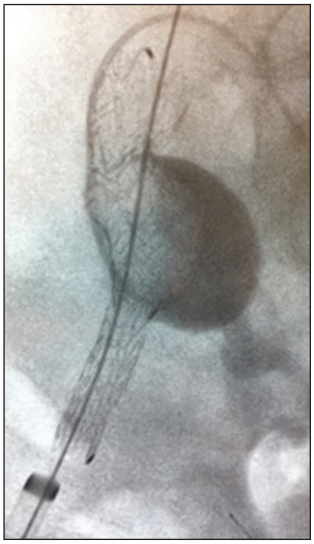

**Figure 3. Deployed endograft limb covering the origin of the aneurysmal hypogastric artery.**

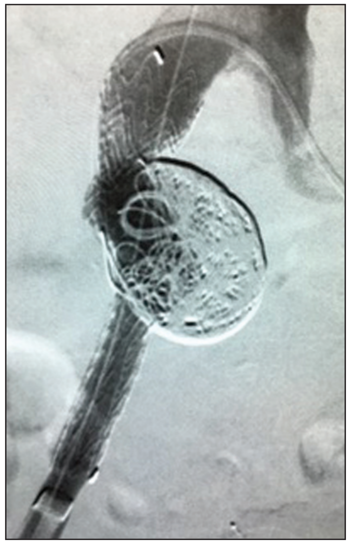

**Figure 4. Postembolization angiogram showing dense packing with Ruby Coils behind the endograft in the aneurysm sac.**

microcatheter. Despite the oblong area behind the endograft, the standard Ruby Coils evenly distributed across the aneurysm dome and framed the aneurysm sac. We then switched to smaller-diameter coils to concentrically fill the coil mass as follows: two 24-mm X 57-cm standard Ruby Coils, followed by two 20-mm X 60-cm standard Ruby Coils (Figure 4) were deployed. The coils' softness allowed effortless delivery despite the long length. The design of the coils allows them to be completely retrieved and repositioned for optimum placement. The softness also allows dense packing within the aneurysm.

To complete the case, the diagnostic catheter and LANTERN microcatheter were removed from behind the endograft, and dilatation of the endograft limb was performed with an angioplasty balloon. Final angiography was performed from the right groin sheath, showing brisk flow through the endograft limb from the common iliac into the external iliac artery and complete exclusion of the hypogastric aneurysm.

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Traditionally, high-flow vessel sacrifice, especially in larger vessels, has lacked a simple solution. In the past, successful embolization required plugs that were hard to deliver or coils that were difficult to land. Both options resulted in incomplete embolization that relied on the clotting cascade to completely occlude the vessel.

Vessel sacrifice has been made easier with POD. The robust anchor segment predictably anchors in vessels with diameters ranging from 3.25 to 8 mm. The proximal portion of the coil becomes softer, allowing it to pack tightly behind the anchoring segment. Despite the tight packing of POD, additional coil mass is sometimes necessary to occlude a vessel. Selecting a secondary device used to be a challenge, often requiring additional vessel diameter measurements and multiple devices. This was especially true in vessels requiring large coil volume to completely arrest flow.

With POD Packing Coil, an ultrasoft and shapeless high-volume coil, secondary coil selection is simplified. After creating a backstop with your first device, either POD or Ruby Coil, simply choose a POD Packing Coil (15, 30, 45, or 60 cm) based on the length of remaining landing zone available. Because it is both shapeless and ultrasoft, POD Packing Coil will act similarly to a liquid, seeking out the empty spaces within the coil mass. The result is a denser occlusion using fewer coils.

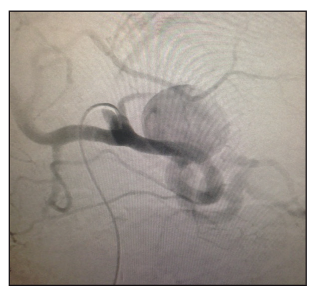

**Figure 1. Angiogram showing a 5.5-cm splenic artery aneurysm with 8-mm outflow and 6-mm inflow vessels.**

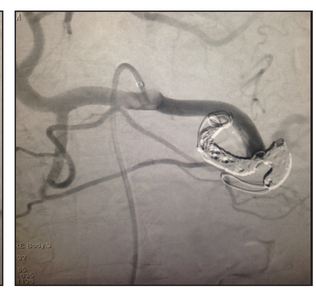

**Figure 2. Postembolization imaging showing complete occlusion of inflow and outflow vessels and dense packing of POD and POD Packing Coil.**

Like Ruby and POD, POD Packing Coil has a predictable mechanical detachment that gives the operator the ability to retract the coil and reposition it, even when the entire coil mass is outside the catheter. This results in more accurate coil placement, helping facilitate tighter packing.

## CASE REPORT

The patient presented with a 5.5-cm splenic artery aneurysm. To treat the aneurysm, we elected to embolize both inflow and outflow vessels. The splenic artery was initially accessed with a 5-F diagnostic catheter.

Upon accessing the proximal splenic artery, angiography was performed showing very high flow (Figure 1). Using this angiogram, both the 6-mm inflow and 8-mm outflow segments were measured.

To embolize, a 135-cm, 45° LANTERN microcatheter was introduced over the wire and tracked easily through tortuosity. Once the outflow was catheterized, I selected a POD8 device to embolize the 8-mm vessel. The POD8 anchored easily despite the high flow. With POD8 deployed, two 60-cm POD Packing Coils were delivered and densely filled the empty space behind the POD. After delivering the second POD Packing Coil, angiography was performed showing no flow beyond the outflow (Figure 2).

The same technique was used to embolize the 6-mm inflow. Sizing one-to-one, a POD6 device was initially placed. Behind the POD6, two 45-cm POD Packing Coils were delivered, completely shutting down the inflow.

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Chronic pelvic pain is a condition that affects up to one-third of women and constitutes approximately 20% of outpatient gynecology appointments. Although there are numerous possible causes of chronic pelvic pain in women, pelvic congestion syndrome is considered the second most common cause after endometriosis. The typical symptoms of pelvic varices include pain that worsens with prolonged standing or sitting, postcoital pain, dysuria, and premenstrual pain. Visual analog scale improvement from 8/10 to 2/10 was shown in several studies that performed bilateral ovarian vein embolization with a combination of sclerosant and coil embolization.[1-3]

The ideal method for treating pelvic congestion syndrome likely includes treatment of the variceal bed in the pelvis, as well as complete closure of the refluxing ovarian veins to prevent recurrent venous hypertension and recurrent of pelvic varices.

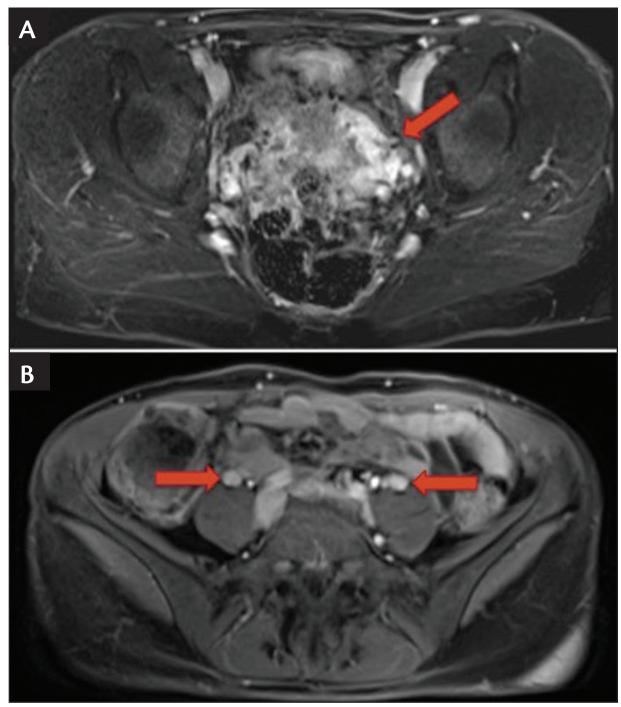


**Figure 1. Axial postcontrast MRI of the pelvis showing left periuterine/perivaginal varices (red arrow) (A), as well as dilated bilateral ovarian veins (red arrows) (B).**

## CASE 1

A patient with a history of bilateral lower extremity varicose veins presented for evaluation of pelvic pain, vulvar varicose veins, and recurrent leg varicose veins. She first developed lower extremity varicose veins in her 20s, which did not respond to multiple treatments and continued to cause tiredness, fatigue, and throbbing in both legs. She had vulvar varicose veins with each of her three pregnancies, but they were much worse with her second and third pregnancies. The veins diminished slightly after pregnancy, but she continues to have itching and fullness with her menstrual cycle and postcoitally. She tried pelvic floor physical therapy for 8 months without improvement.

MRI was performed showing prominent perivaginal/vulvar veins with 8-mm ovarian veins demonstrating retrograde flow (Figure 1). Ovarian vein embolization was then performed from an internal jugular vein approach. After using a 5-F diagnostic catheter to access each ovarian vein, a 2.6-F LANTERN microcatheter was advanced into the pelvic varices for sclerosis. The catheter was then withdrawn into the ovarian vein where Ruby Coils were deployed as a scaffold followed by POD Packing Coils, resulting in complete vessel occlusion (Figure 2).

## CASE 2

A patient with a history of chronic low back and pelvic pain was found to have abnormal veins in her pelvis on a lumbar spine MRI. The patient reported pelvic pain and low back pain (left > right) for 5 years that she described as dull in quality and worse with standing, sit-

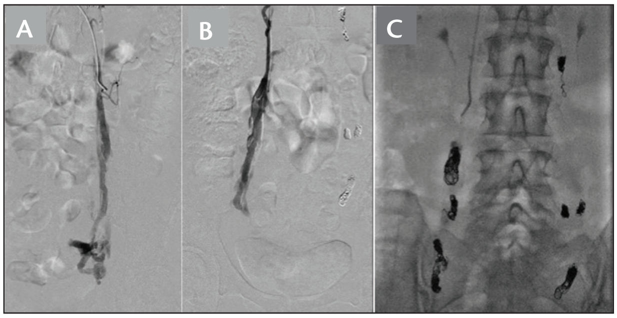


**Figure 2. Left (A) and right (B) ovarian venograms demonstrating retrograde flow and filling of the pelvic varices. Dense coil masses in the ovarian veins after deployment of Ruby Coil and POD Packing Coil (C).**

ting, and lifting heavy objects. The pain improved with cessation of activity and intermittently with lying down. She also reported painful intercourse, with pelvic pain persisting during and for 5 to 10 minutes after cessation.

MRI was performed and showed prominent periuterine veins and ovarian vein reflux. Ovarian vein embolization was performed using a similar technique to Case 1 (Figure 3).

## DISCUSSION

A key component to successful ovarian vein embolization for relieving chronic pelvic pain is complete occlusion of the refluxing ovarian veins. Ruby Coils allow for confident deployment without the potential for migration of the coil mass. Ruby and POD Packing Coil allow for efficient and complete occlusion of the ovarian veins. The softness of the coil allows it to not only densely pack but also seek out and fall into collateral branches. This is important in preventing formation of additional varices and, more importantly, preventing recurrent symptoms.

1. Venbrux AC, Chang AH, Kim HS, et al. Pelvic congestion syndrome (pelvic venous incompetence): impact of ovarian and internal iliac vein embolotherapy on menstrual cycle and chronic pelvic pain. J Vasc Interv Radiol. 2002;13(2 Pt 1):171-178.
2. Kim HS, Malhotra AD, Rowe PC, et al. Embolotherapy for pelvic congestion syndrome: long-term results. J Vasc Interv Radiol. 2006;17(2 Pt 1):289-297.
3. Laborda A, Medrano J, de Blas I et al. Endovascular treatment of pelvic congestion syndrome: visual analog scale (VAS) long-term follow-up clinical evaluation in 202 patients. Cardiovasc intervent Radiol. 2013;36:1006-1014.

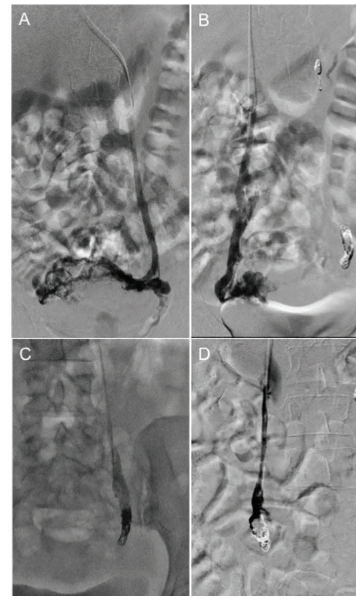


**Figure 3. Left (A) and right (B) ovarian venograms demonstrating retrograde flow and filling of the pelvic varices. Imaging after coil embolization demonstrating complete occlusion of the ovarian veins with absent filling of the pelvic varices (C, D).**

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*Disclosures: None.*

Devices that allow easy access to hard-to-reach anatomy while also performing the necessary intervention are in high demand. LANTERN is a low-profile, high-flow microcatheter designed specifically for delivering large-volume coils like Ruby, POD, and POD Packing Coil (Figure 1). As a 2.6-F microcatheter with a high-flow lumen, LANTERN bridges the gap between traditional 2.4-F microcatheters and large 2.8-F high-flow microcatheters. LANTERN's low profile allows it to track into distal anatomy like smaller 2.4-F catheters while also allowing operators to easily deliver larger-volume coils and high-quality contrast injections.

LANTERN's radiopaque distal 3-cm tip and dual marker bands also provide unique advantages when delivering Ruby Coil, POD, and POD Packing Coil. Not only does the radiopaque distal 3-cm tip allow for better visualization, but it also helps to facilitate dense coil packing.

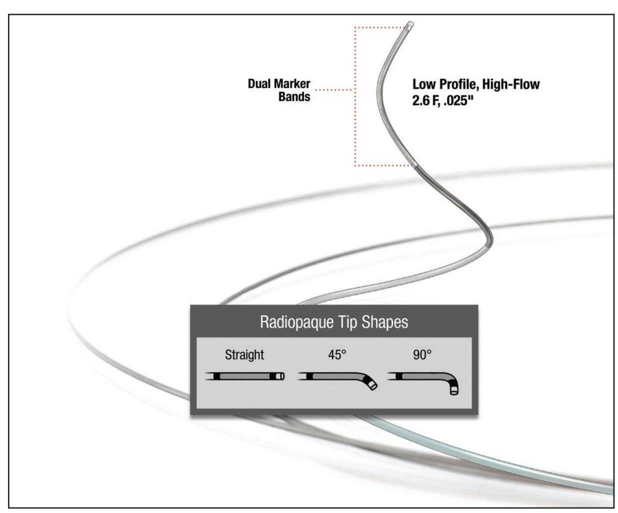


**Figure 1. The LANTERN high-flow microcatheter. Image provided by Penumbra.**

With traditional microcatheters that have a single marker band, it can be challenging to know when the coil has exited the microcatheter tip if that tip is buried in a dense coil mass.

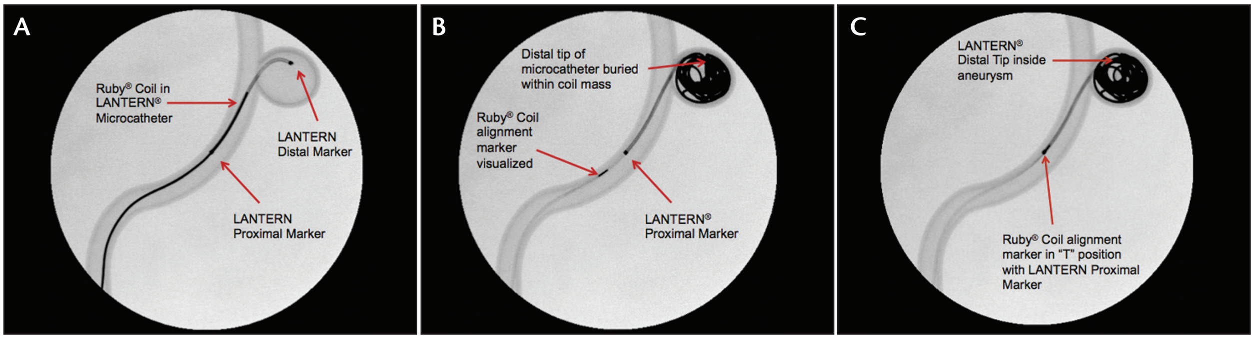


**Figure 2. The Ruby Coil advancing through the LANTERN microcatheter. The LANTERN's distal marker and proximal markers are easily identified (A). The coil alignment marker enters the visual field and approaches the LANTERN proximal marker as the Ruby Coil exits the catheter (B). When the coil alignment 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 (C). Images provided by Penumbra.**

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 2A).

As the proximal end of the coil nears the tip of the microcatheter, the Ruby Coil alignment marker (which is recessed 3 cm from the proximal end of the Ruby Coil) is visualized approaching LANTERN's proximal secondary marker (Figure 2B). When the Ruby Coil alignment marker crosses LANTERN's proximal marker (forming a "T"), the Ruby Coil can be deployed (Figure 2C). This feature is essential, as it allows me to confidently deploy Ruby, POD, and POD Packing Coil when I am densely packing both vessels and aneurysms. In the case that follows, I describe how I use LANTERN in my practice.

## CASE REPORT

The patient presented with acute onset of right flank pain. A CT scan demonstrated a large right retroperitoneal hematoma with a fatty renal mass containing a dominant aneurysm consistent with angiomyolipoma. The right renal artery was selected using a diagnostic catheter over a 0.035-inch wire. Renal angiography was then performed through the diagnostic catheter, revealing a 12-mm aneurysm being fed by a 3-mm early upper pole renal artery branch (Figure 3).

**Figure 3. Renal angiogram showing a well-circumscribed mass with the central feeding vessel and dominant 12-mm aneurysm.**

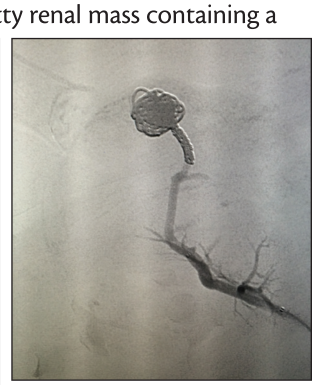

**Figure 4. Postembolization angiogram showing dense coil packing with occlusion of the feeding vessel. The proximal normal renal vessels were preserved.**

To select the desired renal artery branch, a 135-cm, 45° LANTERN microcatheter was tracked over a 0.016-inch microwire distally into the main renal artery. Using LANTERN's radiopaque and angled tip with the wire, the desired branch was easily subselected. The LANTERN catheter was then easily advanced over the wire into the aneurysm sac.

To embolize the aneurysm sac, three soft Ruby Coils were deployed. After coiling the sac, we then walked the LANTERN microcatheter back into the 3-mm inflow and coiled using a 3-mm X 15-cm soft Ruby Coil. Angiography was perfomed (Figure 4) and confirmed that the target vessel was occluded with no flow into the aneurysm sac along with preservation of branch vessels supplying the kidney.

## DISCUSSION

LANTERN allows me to easily deliver large-volume Ruby and POD Coils to distal and tortuous anatomy. The multiple transition zones and soft atraumatic tip help the catheter to effortlessly track over the wire. The coil-wound construction and high-flow lumen allow longer and larger-volume coils to be delivered to even the most distal vessels and aneurysms, promoting more durable, longer-lasting embolizations. ■

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