Tools for Dense and Durable Embolisations

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Penumbra, Inc. has been successful in bringing new detachable coil technology to physicians, helping to facilitate dense and durable embolisations 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 35 system 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

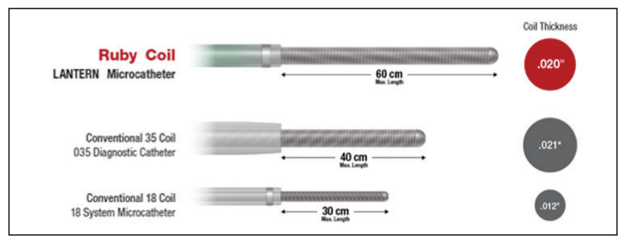

Figure 1. Volume advantage size comparison of the Ruby Coil versus a conventional 35 system coil and a conventional 18 system coil. Image provided by Penumbra.

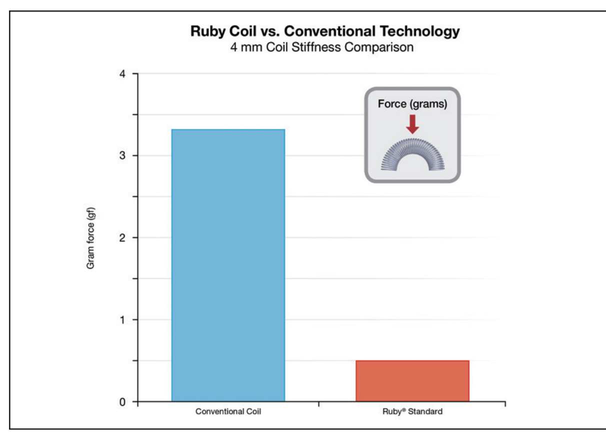

Figure 2. Coil stiffness data comparing the relative softness of Ruby Coil compared to a conventional detachable coil. Data on file at Penumbra.*

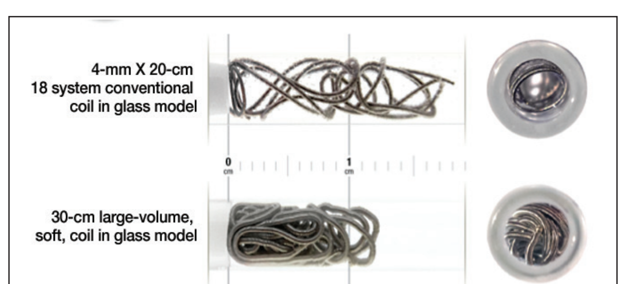

Figure 3. Softness comparison showing the advantage of large-volume, soft, bare platinum coils versus conventional technology. Soft coils pack more densely, creating cross-sectional occlusion. Image provided by Penumbra.

*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.

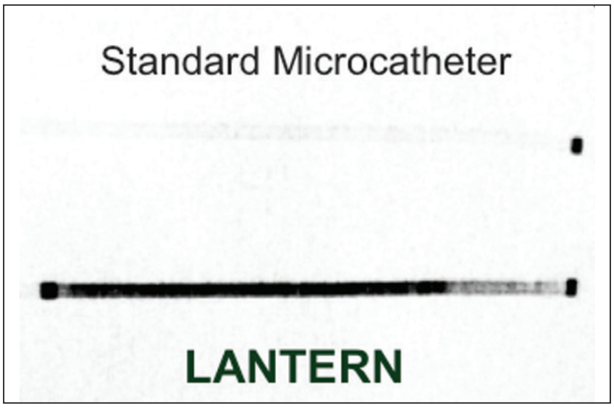

Figure 4. Fluoroscopic image comparing LANTERN's radiopaque distal shaft and dual-marker bands to a conventional single-marker microcatheter. Image provided by Penumbra.

technology. 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 embolisation algorithm, even in complex vessels and aneurysms.

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Ruby, POD, and POD Packing Coil offer a significant volume advantage compared to conventional technology, allowing for faster embolisations of vessels and saccular spaces with fewer devices. As large-volume coils that are deliverable by high-flow microcatheters, I am able to deliver significantly more volume per device, even to distal or hard to access anatomies. The following case is an example of how I efficiently embolise large endoleaks in my practice.

CASE REPORT

A man in his late 70s presented to our institution with abdominal and back pain that radiated into the legs after endovascular repair of a left common iliac aneurysm with a bifurcated aortic stent graft and an iliac branched device in another hospital. The patient had a history of a type A dissection of the thoracic aorta, which was treated with ascending aortic replacement. A residual dissection was extending into the descending thoracic aorta to the level of the origin of the celiac trunk. The visceral vessels and abdominal aorta were not involved.

A CT scan revealed a type Ia endoleak with contract filling from the abdominal aorta next to the stent graft and extending into the left common iliac artery. A double-barrel appearance of the stent graft was seen from the level of the renal arteries to the aortic bifurcation, which was caused by an extreme oversizing of the stent graft (36-mm in 25-mm aorta according to data obtained from the other hospital) with resultant infolding of the main body. This resulted in a large gutter extending from the origin of the stent graft into the aneurysm sac (Figure 1). The size of the left common iliac aneurysm had increased as compared to the preoperative CT scan. Because of the back pain radiating into the legs, an MRI was performed that showed signs of previous spinal cord ischemia. After discussion in our multidisciplinary vascular board, it was decided to proceed with embolisation of the type Ia endoleak using coils. The risk of embolisation with liquid embolic agents was considered too high because of the potential risk of occluding the lumbar arteries in their peripheral course in a patient with an already compromised spinal cord

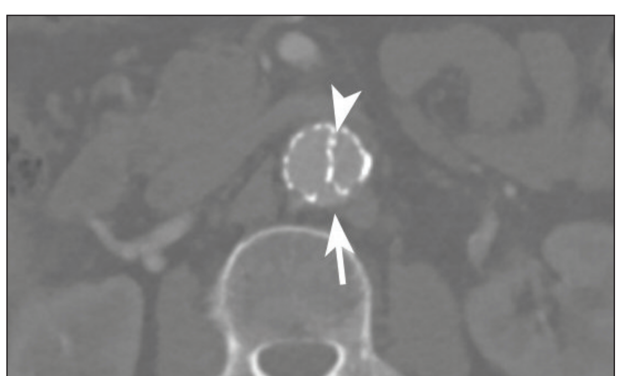

Figure 1. Axial slice of the CTA demonstrating posterior gutter (arrow) and infolding (arrowhead) at the level of the main body of the bifurcated stent graft.

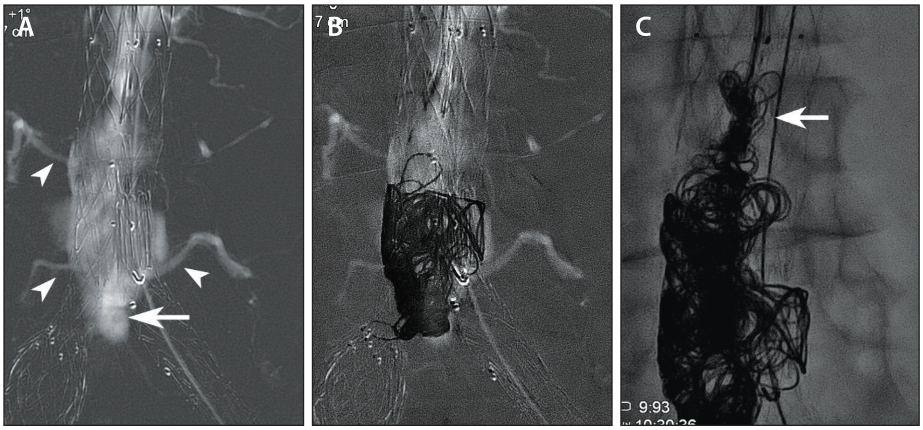

Figure 2. Roadmap image obtained after contrast injection through the microcatheter; the extension of the type Ia endoleak (arrow) can be clearly seen, as well as filling of several lumbar arteries (arrowheads) (A). Roadmap image after placement of several Ruby Coils (including 20 mm X 60 cm and 14 mm X 60 cm) (B). Fluoroscopic image obtained postembolisation (arrow) (C).

perfusion and concomitant dissection of the descending thoracic aorta.

The procedure was performed on an outpatient basis. A left common femoral artery approach was chosen, and after placement of a 4-F sheath, a diagnostic catheter was used to cannulate the anteriorly located gutter. Injection of contrast showed filling of the endoleak extending into the left common iliac aneurysm and filling of a large number of lumbar arteries. Using a coaxial catheter technique, the tip of a microcatheter was positioned in the most caudal part of the abdominal aorta and coiling of the entire gutter was performed, starting distally with a 16-mm X 60-cm standard Ruby Coil. Subsequently, multiple coils were placed, filling the gutter distally to proximally. The tip of the microcatheter was pulled back slightly after placement of each coil in order to allow filling of the entire space. As the final part of the embolisation procedure, the entry of the gutter was filled up with a 60-cm POD Packing Coil (Figure 2). In total, more than 900 cm of coils were inserted using just fifteen 60-cm coils. Using conventional technology would have required significantly more devices to deliver the same quantity of embolic material.

Hemostasis was achieved with manual compression. The patient was discharged the same day after 6 hours of bed rest. The clinical course was uneventful, and a CT scan performed at 1 month after embolisation demonstrated the absence of an endoleak and a stable aneurysm size. The patient had become asymptomatic.

DISCUSSION

The volume advantage of Ruby, POD, and POD Packing Coil compared to conventional technology has allowed me to use fewer devices per case. In my experience, the result has been decreased procedure time and ultimately decreased radiation exposure.

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Devices that allow easy access to hard-to-reach anatomy while also performing the necessary intervention are in high demand. The newly released 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.

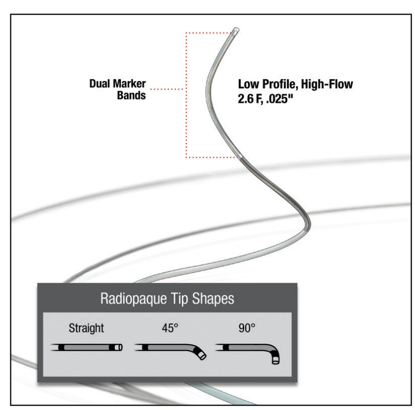

Figure 1. The LANTERN high-flow microcatheter. Image provided by Penumbra.

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. With traditional

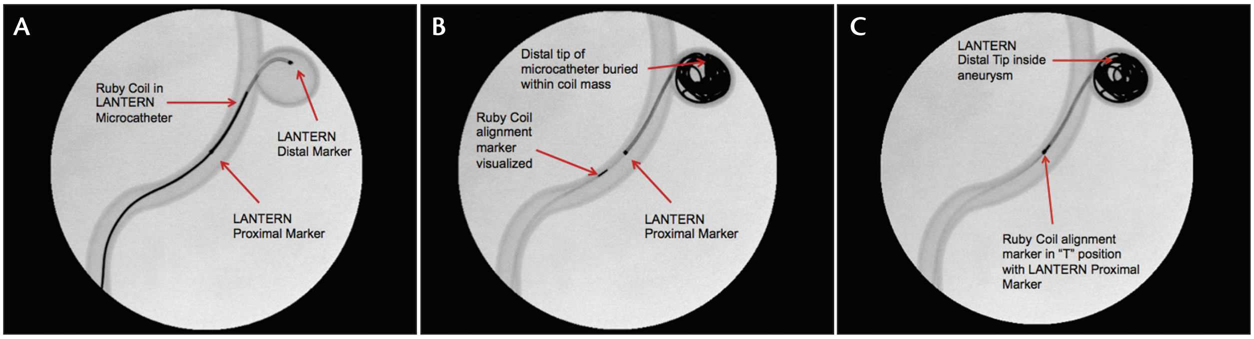

Figure 2. The Ruby Coil advancing through the LANTERN microcatheter. The LANTERN's distal marker and proximal markers are easily identified (A). The coil alignment marker enters the visual field and approaches the LANTERN proximal marker as the Ruby Coil exits the catheter (B). When the coil alignment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

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.

Now with LANTERN, the proximal end of the 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 aneurysm.

CASE REPORT

A woman in her early 60s with Child-Pugh class B ethylic liver cirrhosis was referred to interventional radiology by the hepatology department. The patient was abstinent from alcohol for 1 year and had no ascites and no signs of variceal bleeding. The patient presented with heavy recurrent episodes of hepatic encephalopathy. A CT of the liver and the abdomen was performed, and a large splenorenal shunt with a maximum diameter of 28 mm was detected (Figures 3 and 4). In the interdisciplinary hepatology board, the decision was made to try to occlude this large splenorenal shunt by coil embolisation.

The right common femoral vein was accessed and a short 6-F sheath was introduced. A 5-F diagnostic catheter was placed in the left renal vein, and on angiography, the distal part of the shunt could be visualized, but it was not possible to image the whole shunt by retrograde contrast media injection due to high flow in the large shunt (Figure 5). Based on results from the CT scan, the shunt was very tortuous. A dual-marker microcatheter was inserted into the shunt using a 0.014-inch microwire. When the correct position of the microcatheter was confirmed, embolisation with Ruby Coils was started. From CT imaging, the diameter of the shunt measured 28 mm. A 32-mm X 60-cm standard Ruby Coil was chosen to frame. Although I typically size one-to-one, a slightly larger coil was selected in this scenario because the desired landing zone was tortuous, giving the coils more space. The first coil stayed in place without any

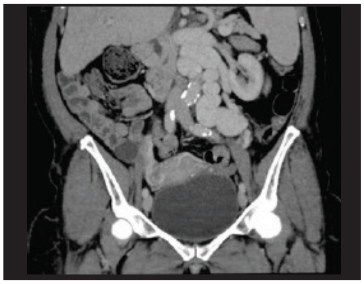

Figure 3. Coronal CT image showing the large splenorenal shunt with widened tortuous vessels.

Figure 4. Axial CT image showing the proximal part of the splenorenal shunt, where the coils are intended to be placed.

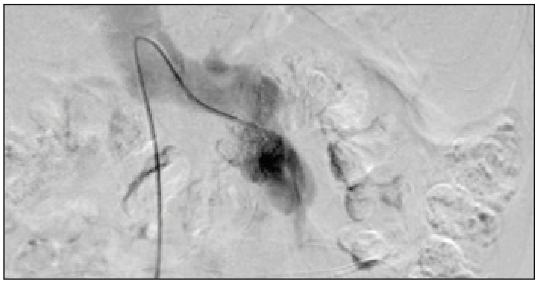

Figure 5. Angiogram of shunt. Despite use of a macrocatheter and high flow, it is not possible to visualize the shunt by retrograde contrast media injection.

dislocation. After framing the space, smaller-diameter soft coils where then selected to both concentrically fill and pack. The result was a complete occlusion of the splenorenal shunt (Figures 6 and 7). Confident coil deployment was aided by the dual-marker band. The dual-marker band system allowed for deployment of coils even when the catheter tip was not buried in the coil mass.

The intervention was completed without any complications, and the patient left the hospital the next day. At 3- and 6-month follow-up, the patient had no additional occurrences of hepatic encephalopathy, and there were no signs of ascites or variceal bleeding.

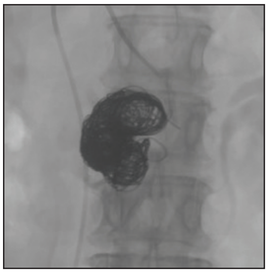

Figure 6. Final angiogram of the shunt after embolisation showing excellent packing density.

Figure 7. Final angiogram showing no flow in the splenorenal shunt during contrast injection in the left renal vein (enlarged insufficient ovarian vein is visible).

DISCUSSION

Dual-marker coils deliver microcatheters allow me to easily deliver large-volume Ruby and POD Coils to distal and tortuous anatomy. The multiple transition zones and soft atraumatic tip helps the catheter to effortlessly track over the wire. The coil-wound construction and high-flow lumen allow for longer and larger-volume coils to be delivered to even the most distal vessels and aneurysms, promoting more durable, longer-lasting embolisations. Now with LANTERN, I can more easily visualize the catheter allowing for even more precise coil placement.

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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]

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, lowering the rate of recanalization that I experienced with conventional technology. The following case shows an example of why tight packing in vessels is important for long-term occlusion.

CASE REPORT

A man in his early 70s presented to our clinic with hypoxemia and polycythemia due to recurrent bleeding. He had a previous diagnosis of hereditary hemorrhagic telangiectasia (Osler-Weber-Rendu syndrome type 2) and pulmonary arteriovenous malformation (AVM) located in the lower left lobe, which had been embolised 3 years prior with fibered coils. The fistula had recurred, requiring re-embolisation.

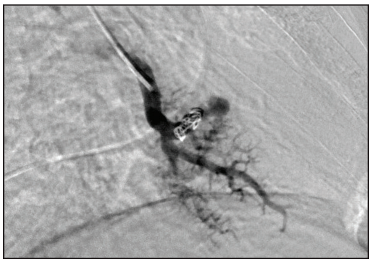

Figure 1. Supraselective pulmonary arteriogram showing recanalization of previously placed fibered coils.

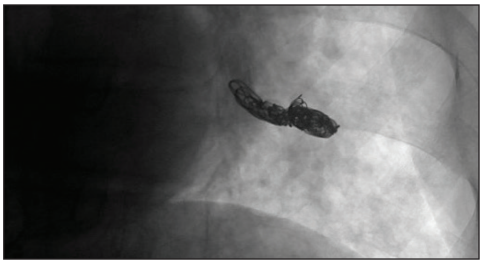

Figure 2. Fluoroscopic image of the thorax showing tighter packing of POD and POD Packing Coil compared to previously placed fibered coils.

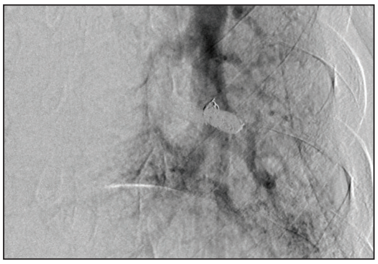

Figure 3. Postembolisation pulmonary arteriogram with no evidence of permeability of the arteriovenous fistula.

Access was achieved via the right common femoral vein with a 5-F introducer sheath. Selective catheterization of the arterial branch was performed with a 5-F diagnostic catheter. A pulmonary arteriogram showed recanalization of the previous fibered coil (Figure 1).

The afferent artery was selected using a dual-marker microcatheter, and the 6-mm vessel was densely packed with POD6 and a 30-cm POD Packing Coil (Figure 2). Much higher packing density was observed compared to the previously recanalized fibered coil mass. A final angiogram was performed showing total occlusion of the AVM. (Figure 3).

DISCUSSION

Pulmonary AVMs are an important cause of cerebral ischemic events, brain abscesses, systemic infections, hemoptysis, and processes linked to hypoxemia. Hereditary hemorrhagic telangiectasia is a genetic disorder that affects approximately 200 out of 1,000,000 individuals, and approximately one-third of patients develop pulmonary AVMs. In general, AVMs > 3 mm require treatment. Follow-up studies have shown > 25% index of recanalization in AVMs that had initially resolved, hence the importance of correct packing of coils. POD allows for correct distal anchoring of the device without the need to oversize the coil, and the complement of POD Packing Coil leads to effective occlusion of the internal lumen.

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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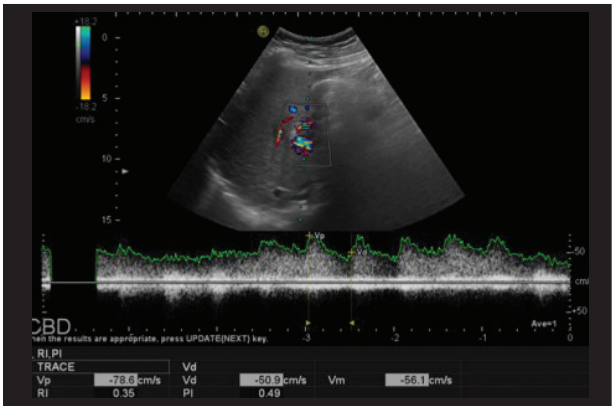

Figure 1. Follow-up ultrasound demonstrating dampened flow within the transplant artery (RI, 0.3–0.35)

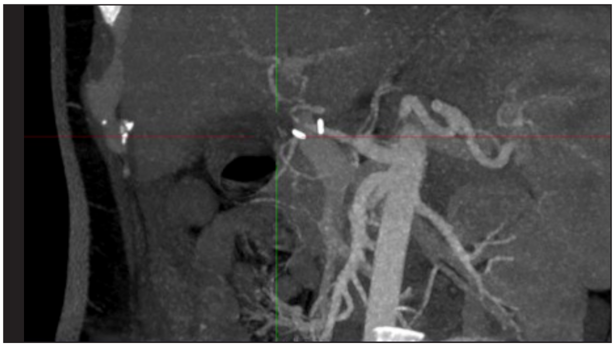

Figure 2. CT demonstrating a small hepatic artery and possible underfilling.

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

Like Ruby, POD has a predictably 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.

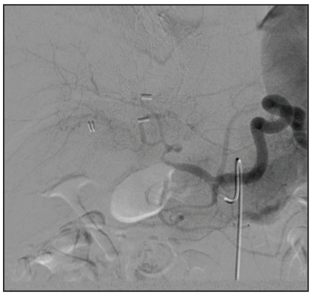

Figure 3. A diagnostic angiogram confirming small and tortuous hepatic artery branches. There was reduced flow within the arteries due to stealing from the spleen. Note most of the contrast in the dynamic phase flowed into the spleen and enhanced the splenic parenchyma.

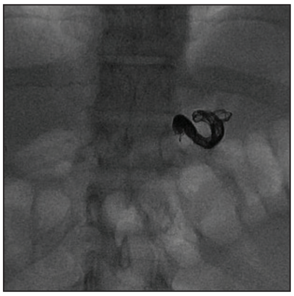

Figure 4. Postembolisation angiogram showing placement of POD and soft Ruby Coils in a proximal position within the splenic artery.

CASE REPORT

A man in his early 20s underwent liver transplantation for primary sclerosing cholangitis. He received a full-size graft from a donor after circulatory death, and biliary construction was performed with duct-to-duct anastomosis. The patient initially had a good post-transplant recovery and was discharged home on post-transplant day 13.

Three weeks after transplant, the patient's liver function deteriorated. Ultrasound confirmed that the deterioration of the liver was a result of dampened flow in the hepatic artery with a resistance index (RI) of 0.3 to 0.35 (RI immediately after transplantation 0.63) (Figure 1).

At the time of the intervention, angiography revealed small and tortuous liver graft vessels and possible underfilling (Figures 2 and 3). To drive blood flow to the hepatic artery and prevent hepatic artery thrombosis, a proximal splenic artery embolisation was performed.

The splenic artery was accessed with a microcatheter coaxially through a diagnostic catheters. Into the tortuous 8-mm splenic artery, POD8 was deployed. The POD8 anchored within the vessel despite high flow, then soft Ruby Coils were delivered, forming a dense metal occlusion (Figures 4 and 5).

The final angiogram showed complete proximal embolisation of the splenic artery and significant increase of flow into the transplant hepatic artery (Figure 6). There was some collateral flow to the spleen via short gastric vessels. The collaterals opened soon after embolisation and allowed the spleen to continue to be perfused, with the hope of preventing loss of splenic function. The patient made a good post-procedure recovery with improved liver function and was discharged home.

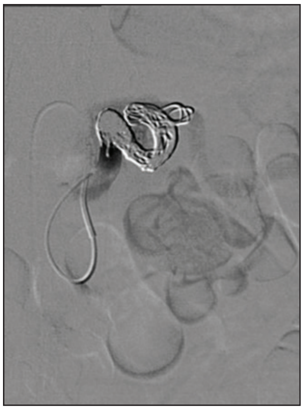

Figure 5. Postembolisation angiogram showing tight packing with no flow through the coil mass.

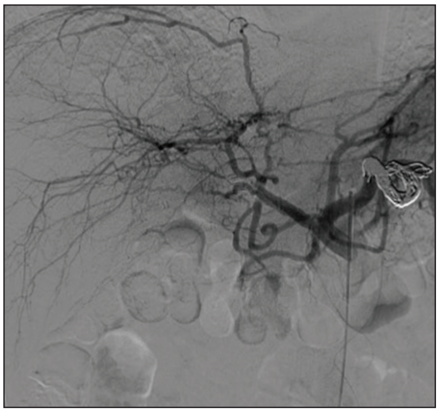

Figure 6. The final angiogram demonstrating significant increase in flow within the hepatic artery branches. Note that contrast is visible in the distal hepatic artery branches, which was not present previously. Proximal embolisation of the splenic artery and several short gastric collaterals filled the spleen.

DISCUSSION

I have performed many cases with both the POD and Ruby Coil and have noticed a significant decrease in procedure time and complexity in embolisation of the splenic arteries. The main advantage of the POD is that it allows accurate proximal anchoring within the high-flow splenic artery, especially in tortuous vessels. The Ruby Coils then allow tight packing behind the POD Coil, which results in good embolisation and cessation of flow within these vessels.

In this case, the POD prevented distal migration of the coils into the splenic hilum and nontarget embolisation. The ability to retract and reposition the coils allows tight and accurate coil formation, which in turn allows flow to continue via collaterals to the spleen and prevention of loss of splenic function.

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POD Packing Coil has changed how I perform vessel sacrifice. When sacrificing a vessel, I initially place a Ruby Coil or POD as a backstop. With a backstop coil placed, I then use POD Packing Coil. With POD Packing Coil, an ultrasoft and shapeless high-volume coil, secondary coil selection is simplified. 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 devices.

The following case shows the softness of the POD Packing Coil and its ability to pack in vessels with variant diameter. Because of the small diameter of the target vessel and the desire to embolise distally, a backstop coil was not placed in this specific case.

CASE REPORT

A woman in her mid 20s presented to the emergency department with acute left-sided flank and back pain. She had previously undergone percutaneous renal

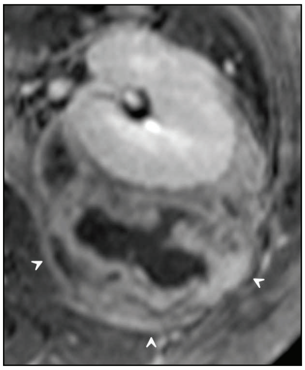

Figure 1. Contrast-enhanced MRI of a large perirenal hematoma (arrowheads).

Figure 2. Contrast-enhanced MRA showing a pseudoaneurysm (asterisk) in the middle part of the left kidney.

Figure 3. Angiography confirmed a pseudoaneurysm (asterisk) in the middle part of the left kidney.

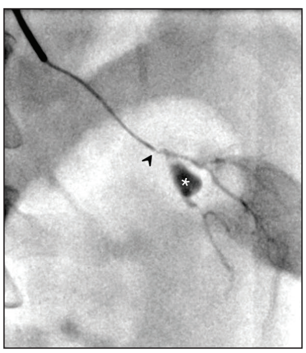

Figure 4. Superselective catheterization of the pseudoaneurysm (asterisk) arising from a subsegmental renal artery with a high-flow microcatheter (catheter tip, arrowhead).

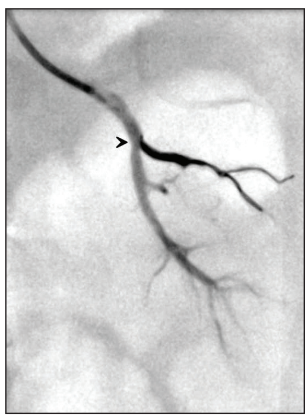

Figure 5. The 30-cm POD Packing Coil conformed to the variant vessel diameter, fully occluding the target vessel in one device.

Figure 6. Final angiogram showing complete embolisation with now flow beyond coil mass.

biopsy for evaluation of systemic antineutrophil cytoplasmic antibody–positive vasculitis and progressive renal impairment (serum creatinine, 1.4 mg/dL). Biopsy-related bleeding (hemoglobin, 6 mg/dL) was suspected and confirmed by MRI (Figure 1). In addition to a large perirenal hematoma, a pseudoaneurysm with a diameter of approximately 1 cm and an arteriovenous fistula were identified (Figure 2).

After informed consent, the patient was referred for endovascular embolisation. The left renal artery was accessed using a 5-F, 100-cm diagnostic catheter, which was configured in the aortoiliac bifurcation. Angiography confirmed a pseudoaneurysm in the middle part of the kidney (Figure 3). A high-flow microcatheter was advanced superselectively into the subsegmental and feeding interlobar artery (Figure 4). Because of the target vessel's small diameter and our desire to embolise as distally as possible, a 30-cm POD Packing Coil was selected. The shapeless POD Packing Coil conformed to the variant vessel diameter. The volume allowed for the embolisation of the entire vessel in just one device. (Figure 5). The second interlobar artery feeding the false aneurysm was occluded in the same fashion using a 60-cm POD Packing Coil. To complete the embolisation, a 45-cm POD Packing Coil was delivered proximally (Figure 6). The final angiogram demonstrated complete occlusion of the feeding vessels with perfect fitting and packing of the three coils deployed into the subsegmental arteries, very similar to glue-like behavior. There was no flow into the pseudoaneurysm.

DISCUSSION

In life-threatening situations fast and confident vessel occlusion is essential. After first deploying a POD or Ruby Coil, POD Packing Coil's soft and shapeless design allows for very tight packing in any vessel without needing to size. The ability to pack more densely with a soft coil is essential for a durable cross-sectional occlusion. Additionally, the shapeless design allows for much longer coils to be delivered to the smallest vessels, significantly reducing the number of coils needed for complete occlusion. ■

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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.