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A Complete Embolization System

The Ruby coil and POD devices.

As data on coil embolization become more robust, so must the tools and technology we use. Penumbra, Inc. has advanced this technology with the Ruby® coil. Ruby's large volume, extreme softness, full control, and long lengths have given interventionists the ability to reduce the number of devices and time needed for cases (Table 1).¹ The Ruby platform is similar in size to the 0.035-inch systems we currently use, but maintains high-flow microcatheter deliverability.

More importantly, we are seeing more data showing a correlation of better long-term outcomes with packing density.^{1,2} The neurovascular space meticulously measures the percent of their aneurysms filled with coils in nearly every case.^{3,4} Recent studies suggest a benefit for this technique in the peripheral anatomy as well.^{1,2} By using large-volume devices that are easily delivered into spaces and vessels that were previously impossible to tightly pack, levels of dense packing can now be achieved.¹

The Ruby coil (Figure 1A) has become our detachable coil of choice for many of the reasons I have previously mentioned. However, there are some situations that are

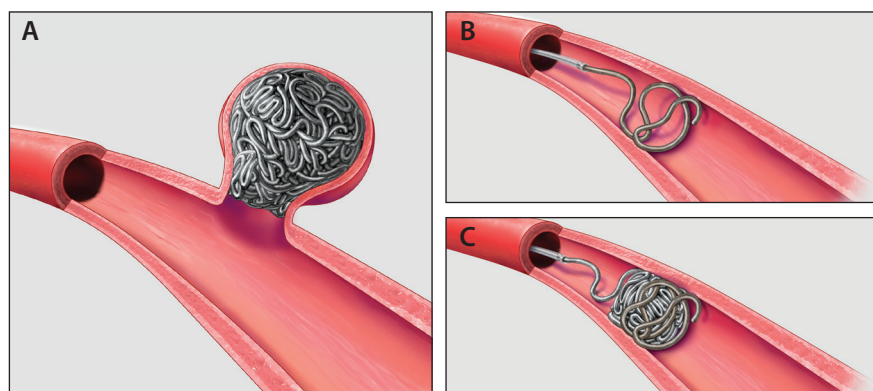


Figure 1. Ruby coil filling in an aneurysm (A). Illustration of the POD™ (peripheral occlusion device) system in use (B, C).

challenging for all coils. High-flow anatomy can negate the ability of coils to catch in the vessel and form their shape. In these situations, we have all developed tricks to get our devices to form.

The new POD™ (peripheral occlusion device) from Penumbra has solved this issue with a very elegant engineering design (Figure 1B and 1C). By adding a secondary stretch-resistant nitinol wire to the distal anchoring segment, POD catches immediately in the vessel. POD then transitions into a softer segment, similar to Ruby and also decreases the shape of its diameter to nest and pack in tightly within the anchor segment (Figure 1C). These two distinct segments allow physicians to embolize high-flow anatomy with less effort and fewer devices.

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TABLE 1. DATA FROM THE ACE STUDY ON RUBY COIL USE

Aneurysms/Malformations	N = 40
Coils deployed per case (median)	6 coils
Fluoroscopy time (mean)	28 min
Packing density (mean)	28%
Peripheral Vessel Sacrifices	N = 28
Coils deployed per case (median)	2.5 coils

1. Teigen C, Moyle H, Patel R, et al. Experience using large volume detachable coils in the peripheral vasculature: preliminary results from the ACE multicenter study. Presented at the 2015 SIR annual meeting, Atlanta, GA; March 2015.
2. 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.
3. Kawanabe Y, Sadato A, Taki W, Hashimoto N. Endovascular occlusion of intracranial aneurysms with Guglielmi detachable coils: correlation between coil packing density and coil compaction. *Acta Neurochir (Wien)*. 2001;143:451-455.
4. Sluzewski M, van Rooij WJ, Slob MJ, et al. Relation between aneurysm volume, packing, and compaction in 145 cerebral aneurysms treated with coils. *Radiology*. 2004;231:653-658.



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Our institution treats a large number of visceral aneurysms. Along with data from the Japanese study that looked at embolic therapy in peripheral anatomy,¹ our own experience with the ACE trial has proven that higher packing densities create a more confident long-term occlusion.²

CASE REPORT

The patient presented with a 2-cm splenic artery aneurysm with a very wide neck. Initially, it was believed that a stent would have to be placed across the neck of the aneurysm and then crossed with a microcatheter to complete the coil embolization. Due to the high level of control with the Ruby coil, we decided to first see if a framing coil would stay in the aneurysm without the use of a stent. A 5-F diagnostic catheter was advanced over a 0.035-inch wire into the splenic artery. A PX Slim™ microcatheter (Penumbra, Inc.) with a 45° shape was then advanced into the aneurysm over a 0.016-inch wire (Figure 1). The first coil (24 mm X 57 cm standard) was deployed. After two to three manipulations, the entire length of the coil framed the aneurysm very nicely (Figure 2). Five additional Ruby coils were placed in the aneurysm to achieve a packing density of 24.8%. There was no filling of the aneurysm observed during the final angiography (Figure 3). Six-month CT follow-up showed a stable occlusion (Figure 4).

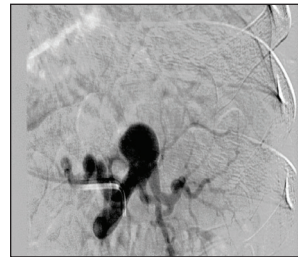


Figure 1. Advancement of the PX Slim microcatheter into the aneurysm.



Figure 2. The coil framing the aneurysm.



Figure 3. Final angiogram.

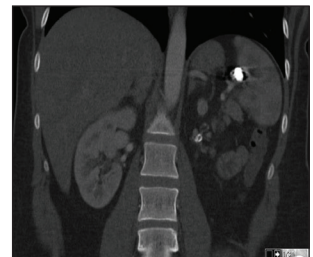


Figure 4. Six-month follow-up CT scan demonstrating stable occlusion.

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.
2. Teigen C, Moyle H, Patel R, et al. Experience using large volume detachable coils in the peripheral vasculature: preliminary results from the ACE multicenter study. Presented at the 2015 SIR annual meeting; Atlanta, GA; March 2015.



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Our institution has been using Ruby coils for a number of years. The reduction in time and number of devices has been remarkable over other coils on the market. Older technology, although helpful in the past, needs improvement to stay relevant in today's coil embolization procedures. Recently, POD was introduced to our institution, and it has added an extremely valuable tool to our repertoire.

Splenic arteries are both very tortuous and high flow, which can create a challenging emboliza-



Figure 1. The 6-mm splenic artery pre-embolization.



Figure 2. The splenic artery after deployment of the 6-mm POD.



Figure 3. The splenic artery after deployment of the POD and one Ruby coil.

tion case. Although plugs are an option, they tend to fall into two categories: (1) larger plugs that are difficult to track and deliver or require much larger access systems, and (2) microplugs that are more deliverable, but do not tolerate high flow or

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deployment in curved anatomy. One cannot know if these devices will migrate with the high flow until after they are detached. The combination of POD and Ruby coils creates a trackable, efficient, and effective system for high-flow arterial embolization.

Two cases of splenic artery embolizations performed with a combination of POD and Ruby coils are detailed in the following case reports.

CASE REPORT 1

The patient required a splenic artery embolization due to a traumatic injury. A 5-F Cobra catheter with a 0.035-inch Glidewire (Terumo Interventional Systems) was used to access the celiac artery and, subsequently, the splenic artery. A 2.6-F PX Slim microcatheter with a 45° angle was advanced over a 0.016-inch wire. Measurement after splenic artery angiography revealed the artery to be 6 mm (Figure 1), therefore, a POD 6 was chosen. The device was anchored in the vessel on the first deployment and was detached (Figure 2). A soft Ruby coil was

packed behind the POD (Figure 3). After detachment, angiography was performed through the PX Slim microcatheter, and no flow was observed distal to the coil mass.

CASE REPORT 2

A second case was performed in a very similar fashion to Case 1. After one POD 6 and one 6-mm X 30-cm soft Ruby coil was deployed, angiography was performed through a PX Slim microcatheter.

Again, no contrast was observed distal to the coil mass upon completion angiography (Figure 4).



Figure 4. The splenic artery after POD and Ruby coil treatment.



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The number of complex cases being performed by interventionists continues to increase. Because of this, the importance of finding tools to reduce procedure times, increase efficiency, and limit or reduce costs is also increasing. One of these new tools is the Ruby coil. This coil offers a wide variety of diameters and lengths of up to 60 cm. The softness of the coil allows it to rapidly take shape within the targeted anatomy and also enables the coil to be densely packed. Both of these qualities increase the speed of the procedure by decreasing the amount of manipulation of the coil, and the dense packing and lengths of the coil decrease the number of coils that are often required.

When the coil is used with the PX Slim microcatheter, other advantages of the system become easily recognizable. The coil has a black marker on the attached pusher, and when this marker enters the microcatheter, the coil is approximately 10 cm from the tip of the microcatheter. This limits the amount of radiation, both to the operator and the patient, as the coil does not have to be followed through the entire catheter under fluoroscopy. Besides the added



Figure 1. Preprocedural imaging showing a type I endoleak with retrograde flow into a false lumen after complete aortic remodeling in the thoracic aorta.

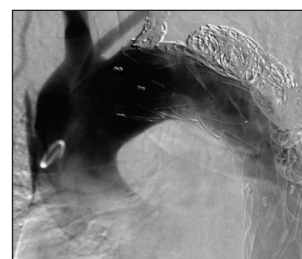


Figure 2. Postprocedural imaging showing complete embolization of the endoleak.

length of the coil, the mechanical detachment system design is an easy, simple pull of the trigger, as well as reliable in comparison to other detachable coils that have a slow and sensitive detachment or are not truly detachable.

The coil does not require any preparation and can be introduced into the microcatheter right out of the pouch. Recently, I used the Ruby coil in an interesting case, which is described in the following case report.

CASE REPORT

A 66-year-old woman with a type B aortic aneurysm was treated with a thoracic endovascular stent graft. She had a small type IA and B endoleak, with

antegrade and retrograde flow into the false lumen. We achieved access with 4-F sheaths from the left brachial and femoral arteries. A PX Slim microcatheter was advanced through the left subclavian artery and into the false lumen proximally (Figure 1).

The Ruby coil was delivered through the PX Slim microcatheter with a 90° angle. The exceptional control and softness of the Ruby coil allowed for coiling of the short proximal landing zone of the left subclavian artery and false lumen. The coil packed tightly

against the aortic graft, eliminating the proximal type IA endoleak. With the longer lengths and larger diameter of these coils, we were able to embolize the endoleak and 38-mm false lumen with three 20-mm X 60-cm Ruby coils (Figure 2).

By our estimates, it would have taken more than 10 conventional detachable 0.018-inch coils for a similar result. Unlike plug devices, the coil was able to fill even the small spaces between the left subclavian artery and the graft.



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The Ruby coil was recently approved in Europe and has been used in our institution during the last year. We have found that the biggest advantage of this coil is its ability to quickly pack aneurysms and vessels with a high level of density that may allow for more stable long-term occlusion.

CASE REPORT

A 77-year-old man was scheduled for CT angiography of his thorax due to a suspect finding on a chest x-ray with an unclear mediastinal broadening (tumour vs vascular). CT angiography showed a 4.2-cm pseudoaneurysm with a volume of approximately 23 mL in the ascending aorta near the aortic root (Figure 1). The cause of this pseudoaneurysm was unclear, and because surgical therapy with replacement of the ascending aorta was not possible due to an altered clinical condition of the patient, he was sent to the interventional radiology department for minimally invasive treatment.

The ascending aorta was accessed via a femoral approach using a 5-F multipurpose catheter (Figure 2). Via a 2.4-F microcatheter, standard fibered 18 microcoils (with an actual diameter of 0.012 inch) were placed in the aneurysm (Figure 3). The peripheral parts of the aneurysm were sufficiently filled with coils, and the central parts were only relatively loose. Nevertheless, the intervention was terminated because it was assumed that the fibers would help the central parts thrombose.

On a CT scan 3 days later, the aneurysm was still perfused, but again, it was assumed that the aneurysm

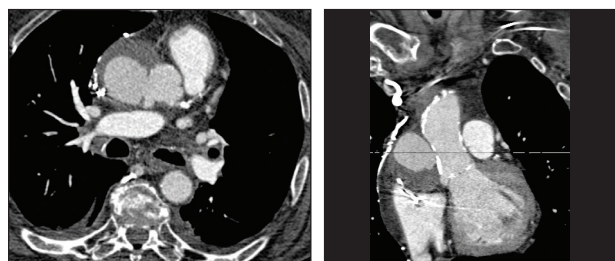


Figure 1. CT images of a 4.2-cm pseudoaneurysm.

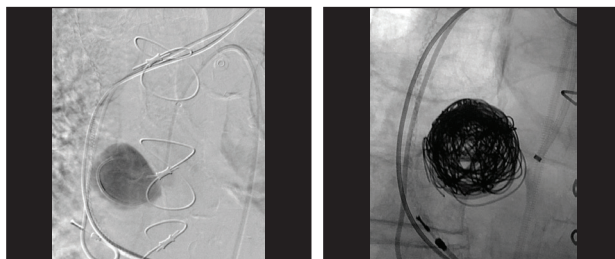


Figure 2. Angiography through the 5-F diagnostic catheter reveals a 4.2-cm aneurysm.

Figure 3. The aneurysm is packed as tightly as possible with conventional 0.012-inch fibered coils.

would thrombose during the next few days (Figure 4). Another CT scan was performed 2.5 months later, the aneurysm was still perfused, and a second small pseudoaneurysm was detected in the distal ascending aorta (Figure 5). This new pseudoaneurysm was approximately 14 mm in diameter with a 7-mm neck. Again, the decision was made to employ minimally invasive treatment of the small pseudoaneurysm.

The ascending aorta was approached with a 5-F Sidewinder II catheter (AngioDynamics), and a PX Slim 90° microcatheter was placed in the aneurysm. One 18-mm X 57-cm standard coil and one 16-mm X 50-cm soft Ruby coil were placed in the new pseudoaneurysm (Figure 6). With only two coils, the result was satisfying, especially given the wide neck. Although the packing density was not very high, the long loops across the

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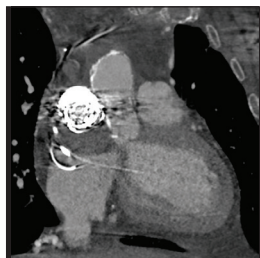


Figure 4. A CT scan at 3 days postprocedure shows the aneurysm is still filling.

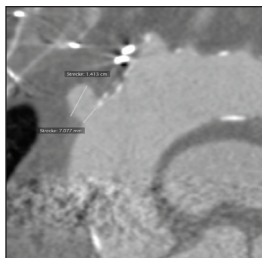


Figure 5. A CT scan at 2.5 months shows the original aneurysm is still filling and uncovered a small 14-mm pseudoaneurysm.

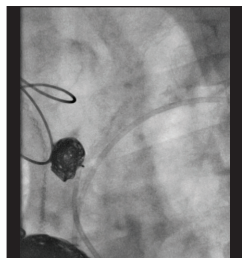


Figure 6. The 14-mm pseudoaneurysm was treated with two Ruby coils.

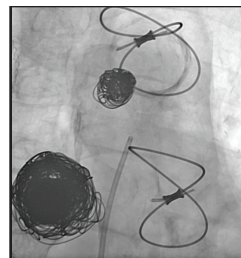


Figure 7. Eleven long Ruby coils were used to complete embolization of the 4.2-cm aneurysm.



Figure 8. Final angiogram shows complete exclusion of both pseudoaneurysms after Ruby coiling.

neck were sufficient to protect the aneurysm. Because the large pseudoaneurysm was still perfused, as seen on imaging, a 5-F Sidewinder II catheter was placed at its entrance point. The length of its tip was optimal to reach a stable position. The peripheral parts were not perfused because the packing density was high there, and the central part of the aneurysm showed contrast media still filling. Again, the PX Slim microcatheter was placed in the aneurysm, and 11 Ruby coils were placed in the aneurysm.

Comparing the images before (Figure 4) and after (Figure 7) coil placement, a significantly higher packing density can be seen in the central part of the aneurysm after adding 11 more coils (6 m in total length). The final angiogram shows complete exclusion of both aneurysms in the proximal and distal ascending aorta

(Figure 8). The intervention was completed without complications.

DISCUSSION

This case shows that packing density is crucial for successful aneurysm treatment. The Ruby coils have the ability to provide successful embolization of large aneurysms, as their diameter is significantly larger compared to other microcoils. Moreover, the maximum length of the Ruby coils is 60 cm, which allows for a fast procedure with a smaller number of coils compared to standard microcoils, which, in general, are shorter and thinner.

The softness of the Ruby coils allows us to place them where the much stiffer fiberoptic device would be unable to be deployed.



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Rendu-Osler-Weber syndrome (or HHT [hereditary hemorrhagic telangiectasia]) is an autosomal dominant disorder characterized by the development of multiple arteriovenous malformations. Pulmonary arteriovenous malformations (PAVMs) may cause life-threatening hemoptysis or hemothorax, if their rupture occurs, or paradoxical embolism with stroke or cerebral abscess for right-to-left shunting, especially in patients present-

ing with diffuse pulmonary involvement. Most PAVMs are high-flow shunts and can be simple, with only one afferent feeding artery and draining vein, or complex, with more than one supplying arteries. Percutaneous embolization, feasible when done by an experienced interventionist, has become the treatment of choice due to its safety and efficacy.

CASE REPORT

A 50-year-old woman affected by Osler-Weber-Rendu syndrome presented with the sensation of shortness of breath and decreased arterial oxygen saturation. She underwent previous percutaneous PAVM embolization at another center 10 years earlier. Transthoracic contrast echocardiography showed an increased number of microbubbles in the left cardiac cavities, and CT angiography revealed the appearance of multiple bilateral PAVMs and residual flow in some of the treated malformations. The patient was admitted for elective percutaneous bilateral PAVM embolization.

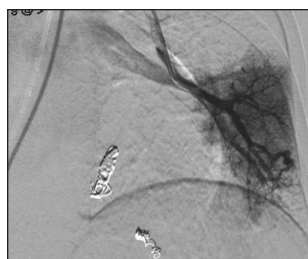


Figure 1. Initial angiogram reveals multiple PAVMs in the lung.



Figure 2. Selective angiography through a PX Slim microcatheter reveals a 6-mm target.

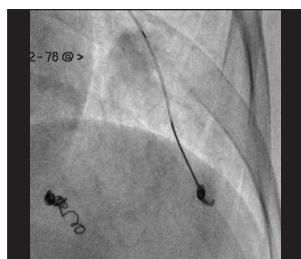


Figure 3. Standard Ruby coils (6 mm X 30 cm) were deployed.

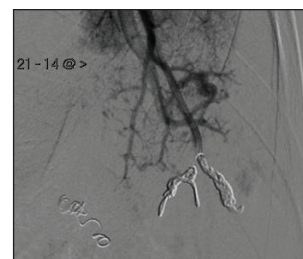


Figure 4. Additional Ruby coils were deployed into other branches.

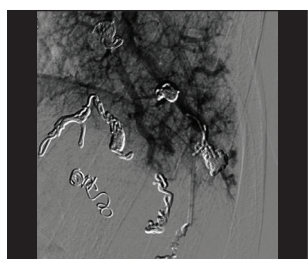


Figure 5. Final angiogram after coil embolization shows no flow distal to coils in the left side of the lung.

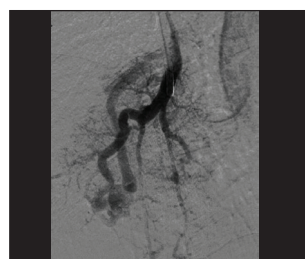


Figure 6. Selective angiogram of the right lung reveals additional PAVMs.



Figure 7. Coil embolization performed with the PX Slim microcatheter and Ruby coils.

Ultrasound-guided right femoral venous access was performed, and a 5-F, 110-cm pigtail catheter helped confirm bilateral PAVMs (Figure 1.). The afferent pulmonary arteries of these malformations were successfully catheterized with a high-flow microcatheter (Figure 2), sparing the adjacent normal pulmonary arteries, and were embolized with large-volume detachable coils (Ruby; Figures 3–7). No procedure-related complications occurred. Technical success was achieved, as demonstrated by the exclusion of the treated PAVMs at CT follow-up.

DISCUSSION

Ruby coils have a controlled mechanical detachment mechanism, which enables us to deliver and

reposition the coil until the final desired position is achieved. Their compatibility with high-flow microcatheters allows for high-quality imaging and then coiling without being forced to switch to smaller microcatheter systems. The high volume, long length, and softness produce very densely packed networks of coils that do not migrate despite very high antegrade flow and create confident long-term mechanical occlusion. Ruby large-volume coils provides us the opportunity to be very quick and accurate, which is especially important when treating multiple PAVMs in the same session. Considering that these are often young patients, it is important to note that Ruby coils also allow reduced x-ray exposure and the amount of contrast medium needed.



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The following cases were our first experience with two new embolization devices by Penumbra, Inc. POD was used to anchor in the vessel while soft Ruby coils were used to create an extremely dense coil mass that mechanically occluded the artery. The aim of our embolization procedures was to minimize blood loss during splenectomy.

CASE REPORT 1

A 46-year-old man was admitted to the hospi-

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Figure 1. Angiogram of the celiac axis demonstrates splenic flow. The diameter of the vessel to be embolized has been measured as part of the standard procedure.



Figure 2. A high-flow 2.8-F microcatheter (Progreat, Terumo Interventional Systems) is placed in the splenic artery at the level of the coil deployment.

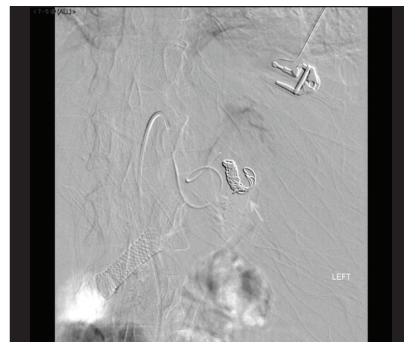


Figure 3. POD 6 has been successfully placed. Note the tight packing (arrow).



Figure 4. POD 6 and an 8-mm X 30-cm soft Ruby coil (arrows) are shown tightly packed together.



Figure 5. Postembolization angiogram shows complete occlusion of the splenic artery with no flow beyond the coils (arrow).



Figure 6. Angiogram of the celiac axis demonstrates the splenic artery and blood flow.

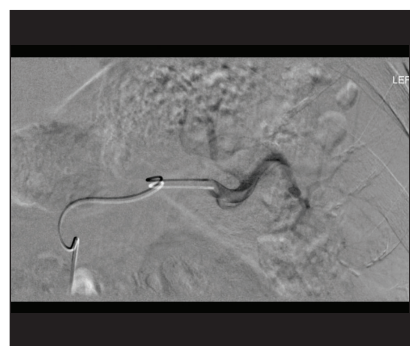


Figure 7. Selective angiogram of the splenic artery is shown with a high-flow 2.8-F microcatheter in place and ready for coil deployment.



Figure 8. POD 8 and an 8-mm X 60-cm soft Ruby coil (arrows) are shown tightly packed.



Figure 9. Postembolization angiogram shows complete occlusion of the splenic artery with no flow beyond the coils (arrow).

tal with severe acute chronic pancreatitis. A CT scan had shown a moderately large subcapsular splenic collection and infarct. Splenectomy was planned, and the surgical team had requested splenic artery embolization to reduce intraoperative blood loss. Selective and subangiography were performed through the celiac axis and splenic artery before embolization. The diameter of the vessel to be embolized was measured. The first device deployed was a POD 6 device (50 cm), the distal part of which acts as an anchor. This was followed by a soft Ruby coil (8 mm X 30 cm). Complete occlusion of the splenic artery was achieved, as seen on the final angiographic runs. Figures 1 through 5 demonstrate the tight packing and occlusion of blood flow beyond the coils after embolization.

CASE REPORT 2

A 47-year-old male man was admitted with acute pancreatitis. He was also found to have a suspicious pancreatic head mass. He was to undergo a Whipple procedure (pancreatoduodenectomy)

along with a splenectomy. Preoperative splenic artery embolization was requested by the surgical team to reduce intraoperative blood loss. An embolization technique similar to that used in Case Report 1 was used. A POD 8 device (60 cm) was placed followed by a soft Ruby coil (8 mm X 60 cm) to achieve tight packing and complete occlusion of the splenic artery, as demonstrated in Figures 6 through 9.

DISCUSSION

Both cases demonstrate the technical success of occlusion when using these new devices. The control afforded by these devices allowed for precise placement. The anchoring properties of POD help us to utilize the entire length of the device because it catches in the vessel immediately. The large volume, long length, and softness of both devices allow for a rapid occlusion. Although the artery does thrombose, occlusion does not rely on this mechanism. The mechanical cross-sectional occlusion lends itself to a very stable embolization.

Conclusion



Our institution has a great deal of experience with the Ruby coil. This new technology has allowed us to maintain microcatheter access while delivering large-volume coils that are similar in size to 0.035-inch coils. It is a little-known fact that the 0.035-inch coils we use today are actually 0.021 inch in diameter. Ruby coils are 0.020 inch and are therefore similar to the volume of macrocoils but can be delivered through a high-flow microcatheter.

With new data coming out about packing density and its effects on long-term outcomes, a tool that can quickly and densely pack may become more important. Now, with the addition of POD, we have a solution for high-flow anatomy. POD anchors in the vessel, despite high flow, and then quickly transitions into a soft segment that can pack in very densely. These two systems work seamlessly together and add truly valuable tools to our embolization practice. ■

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