Durable and Efficient Embolisation With Ruby, POD, and Packing Coil

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Penumbra's peripheral embolisation system provides unique tools for durable and efficient occlusions in different applications. The embolisation system is made up of three detachable coil technologies: Ruby Coil, POD (Penumbra Occlusion Device), and POD Packing Coil. All three technologies are large-volume coils, similar in caliber to a 035 coil and deliverable through LANTERN, a high-flow microcatheter (Figure 1).

Each of Penumbra's coil technologies is differentiated by the coil shape and softness. Ruby Coil is a versatile coil that features a three-dimensional shape and is available in Standard and Soft configurations. Standard coils frame aneurysms or vessels, and Soft coils pack densely within or behind a Standard coil. POD is designed to anchor within vessels, which may simplify vessel sacrifice, even in high flow. The distal tip of the device is robust, helping the coil engage the vessel wall. Proximally, the coil becomes softer, allowing the operator to pack densely behind the anchor segment. Finally, Packing Coil has no stated diameter and is designed to densely pack in any size vessel. Like "liquid metal," the 15- to 60-cm Packing Coils pack densely behind a Ruby or POD backstop.

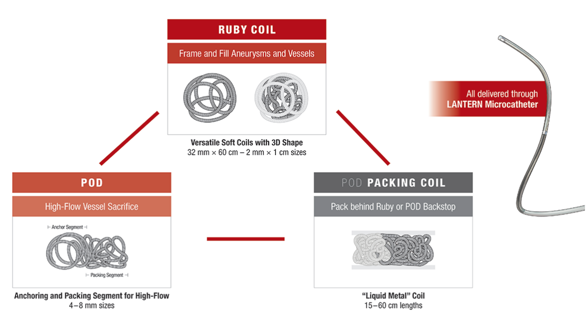

Figure 1. Dedicated embolisation devices for different applications.

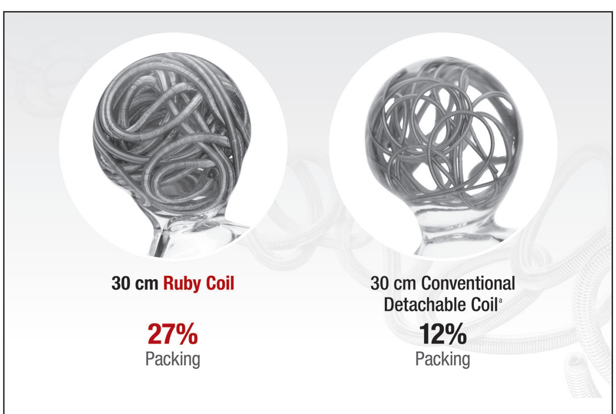

Figure 2. Volume advantage size comparison of a Ruby Coil versus a conventional 0.018-inch coil.*

*a. Concerto™ 3D Coil 8 mm X 30 cm.
7.5-mm glass aneurysm. Photographs taken by and on file at Penumbra, Inc. Tests performed and data on file at Penumbra, Inc. Bench test results may not be indicative of clinical performance. Calculated using AngioSuite packing density calculation tool.

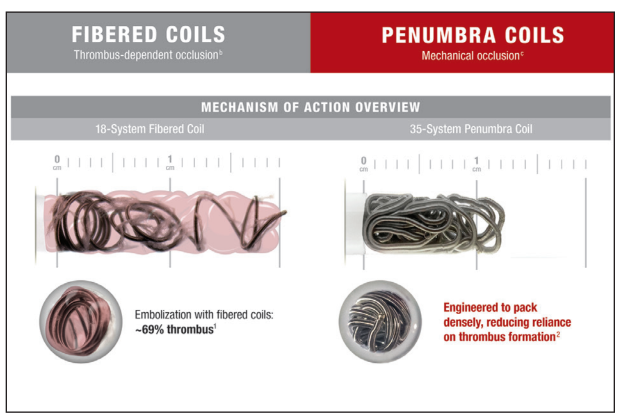

Figure 3. While conventional technology relies on thrombus formation, soft, large-volume coils pack more densely, creating a more durable cross-sectional occlusion.†

†b. Boston Scientific® Interlock® 2D Helical Coil 4 mm X 15 cm in 4-mm glass tube.
c. 30-cm POD Packing Coil delivered through Penumbra LANTERN High-Flow Microcatheter into 4-mm glass tube.

1. Fohlen A, Namur J, Ghegediban H, et al. Peripheral embolization using hydrogel-coated coils versus fibered coils: short-term results in an animal model. Cardiovasc Intervent Radiol. 2018;41(2):305-312.
2. Yasumoto T, et al. Long-term outcomes of coil packing for visceral aneurysms: correlation between packing density and incidence of coil compaction or recanalization. J Vasc and Interv Radiol. 2013;24(12):1798-1807.

Photographs taken by and on file at Penumbra, Inc. Bench test results may not be indicative of clinical performance. Renderings for illustrative purposes only. Results may vary depending on a variety of patient-specific attributes.

PRODUCT ADVANTAGES AND COST SAVINGS

Penumbra's peripheral embolisation system offers softer coils, longer lengths, and larger volume compared to conventional coil technologies. The volume advantage enables interventionalists to perform embolisations with fewer devices per case, and the extraordinary softness of the coils allows for the delivery of more embolic material to a given landing zone (Figure 2). With more embolic material, there is less reliance on the clotting cascade to generate thrombus within the empty spaces between coil loops (Figure 3).

In both small vessels and large lesions, the increased volumes of Ruby, POD, and POD Packing Coil have the potential to be cost-effective compared to other detachable coils. The larger coil volumes and longer available lengths help reduce the number of coils per case, which may limit case cost and reduce procedure time and radiation exposure.

LUMBAR ARTERY EMBOLISATION PRE-EVAR

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WHY I CHOSE RUBY COIL

- These large-volume, extremely soft coils can be packed very tightly
- They create a full cross-sectional occlusion that does not rely on thrombus formation, potentially leading to a more durable embolisation than fibered coils
- Detachable coils provide more control for safer procedures

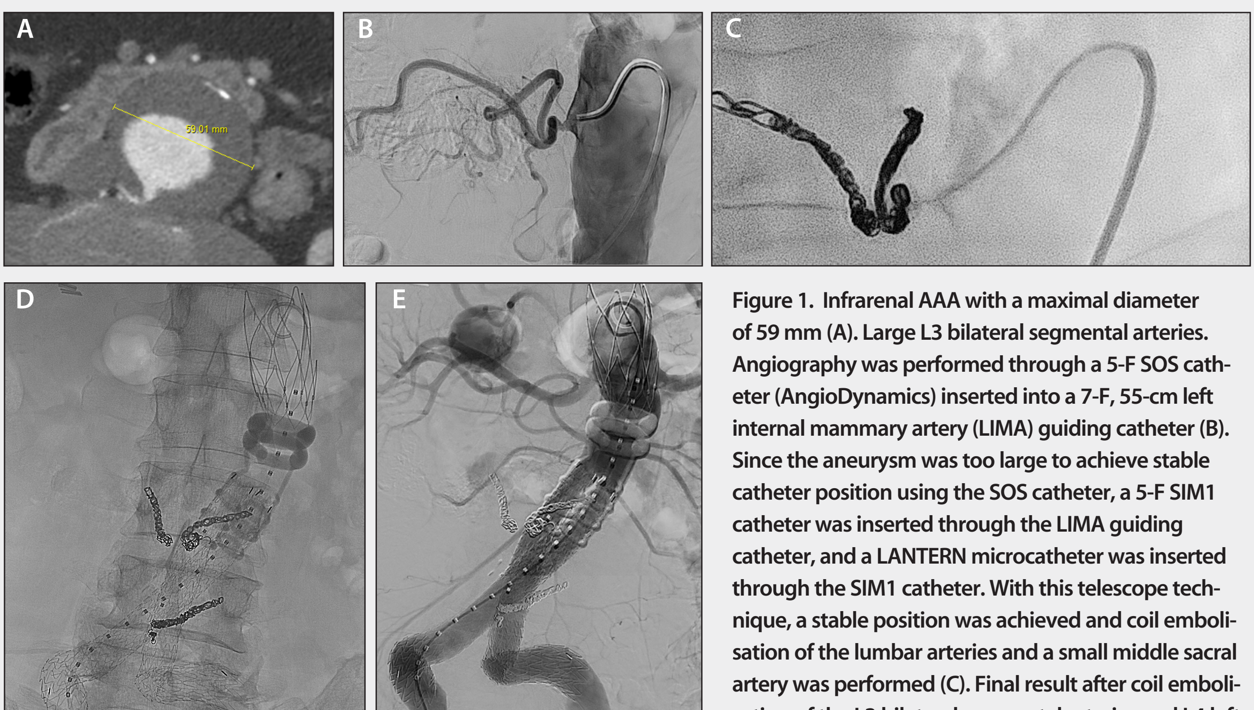

Figure 1. Infrarenal AAA with a maximal diameter of 59 mm (A). Large L3 bilateral segmental arteries. Angiography was performed through a 5-F SOS catheter (AngioDynamics) inserted into a 7-F, 55-cm left internal mammary artery (LIMA) guiding catheter (B). Since the aneurysm was too large to achieve stable catheter position using the SOS catheter, a 5-F SIM1 catheter was inserted through the LIMA guiding catheter, and a LANTERN microcatheter was inserted through the SIM1 catheter. With this telescope technique, a stable position was achieved and coil embolisation of the lumbar arteries and a small middle sacral artery was performed (C). Final result after coil embolisation of the L3 bilateral segmental arteries and L4 left segmental artery and a small middle segmental artery. Implantation of an Ovation stent graft was performed during the same session without any endoleak on completion angiography (D, E).

The significance of type II endoleaks after stent graft implantation for abdominal aortic aneurysms (AAAs) is controversial. Whereas most specialists would consider type II endoleaks to be rather benign, others are concerned by their unknown natural history. Once type II endoleaks appear and lead to sac enlargement, their treatment can be frustrating. Selective closure of the feeding arteries is often impossible after endovascular aneurysm repair (EVAR), and typically only unselective sac embolisation can be performed, which may not lead to the desired clinical results. Therefore, some specialists have started to use coil embolisation to occlude potential feeding side branches before EVAR. We have adopted this idea and went through a learning curve regarding the optimal technique and technology to achieve effectiveness with as little radiation time and dose as possible. In the beginning, we mainly used 0.021-inch-compatible pushable microcoils and vascular plugs (when possible) to close lumbar arteries and the inferior mesenteric arteries. Recently, we changed to large-volume Ruby Coils through the LANTERN 2.6-F microcatheter.

CASE STUDY

A 69-year-old man presented with a large asymptomatic infrarenal AAA. On CT, the inferior mesenteric artery appeared to be occluded. The bilateral L3 lumbar arteries as well as the left L4 lumbar artery seemed to be of rather small diameter (Figure 1A). However, on angiography, the diameter of the lumbar arteries measured > 3.5 mm by quantitative angiography (Figure 1B), and the small middle sacral artery appeared to be patent. Coil embolisation was performed using a telescope technique with final insertion of a LANTERN microcatheter using two 4-mm X 20-cm Standard Ruby Coils per lumbar artery and a smaller Ruby Coil for the middle sacral artery (Figure 1C). During the same session, an Ovation stent graft (Endologix) was implanted percutaneously after local anesthesia and preloading of Perclose ProGlide closure systems (Abbott) in both common femoral arteries. Final angiography showed a good result without any endoleaks (Figure 1D and 1E).

DISCUSSION

Currently, we are analyzing our results with preemptive coil embolisation of segmental arteries and the inferior mesenteric artery before EVAR. It is our impression that we may be able to reduce the procedure time and, as a result, also reduce the radiation dose of this procedure. Additionally, we may be able to improve the efficacy of closing the side branches by using large-volume Penumbra coils instead of standard pushable microcoils.

PULMONARY ARTERIOVENOUS MALFORMATION

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WHY I CHOSE PENUMBRA LARGE-VOLUME COILS AND LANTERN

- The coils are easy to use and can provide a durable and cost-effective solution
- **LANTERN:** Can provide great visibility and maximum support in challenging anatomy

PROCEDURAL APPROACH

In our institution, procedures are performed under local anesthesia because it allows us to obtain direct feedback from the patient with respect to potential procedural complications and the ability to provide respiratory instructions, which facilitates the access of target vessels and optimizes imaging and characterization of pulmonary arteriovenous malformations (PAVMs). After the common femoral vein is accessed with a 6-F introduction sheath, a 6-F hooked pigtail catheter is used to pass through the heart and select the right or left main pulmonary artery. Subsequently, embolisation is performed with a triaxial system consisting of a 6-F, 90-cm multipurpose guiding catheter; a 4-F, 125-cm multipurpose diagnostic catheter (0.038-inch); and the LANTERN microcatheter (straight or 45°).

The choice of coils depends on the morphology of the PAVM. In a simple PAVM, distal embolisation is pursued using either a single POD or a POD in combination with a POD Packing Coil. When there is a branching artery close to or coming from the sac, the sac itself is embolised with a POD by matching the device size to the sac diameter. For example, a 6-mm sac can be occluded with a POD8 and, if indicated, an additional proximal coil nest with POD Packing Coil(s). Sac embolisation is also performed in tortuous anatomy in combination with large feeding arteries. In this case, one or two framing coil(s) will be placed in the sac to

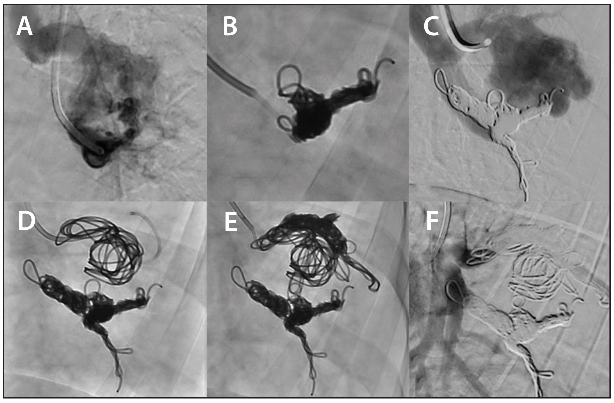

Figure 1. Coil embolisation of a complex PAVM. A smaller feeding artery is primarily embolised with two 60-cm POD Packing Coils (A–C). The larger feeding artery with high flow is embolised after one 18- X 57-cm Standard Ruby Coil is placed in the sac to act as a stopgate (D, E). Next, the feeding artery is embolised with two 60-cm POD Packing Coils (F). The POD Packing Coils have a typical branching configuration as a result of prolapsing into branching arteries, some of which are not visible on the diagnostic angiogram.

act as a backstop and additional coiling is performed. The typical combination of coils will be Standard Ruby Coils in the sac and POD Packing Coils for additional embolisation (Figure 1D–F). In complex PAVMs without the risk of coil dislodgement, embolisation is performed as close to the nidus as possible while occluding the side branches as well. For this, POD Packing Coils will be used (Figure 1A–C). The proximal coil nest then consists of one or two POD Packing Coils (30–60 cm), depending on the length of the landing zone. PAVMs with a low risk of coil dislodgement can be treated with POD Packing Coils only. Because of the shapeless form of this coil, it has the ability to prolapse into small arteries originating from or

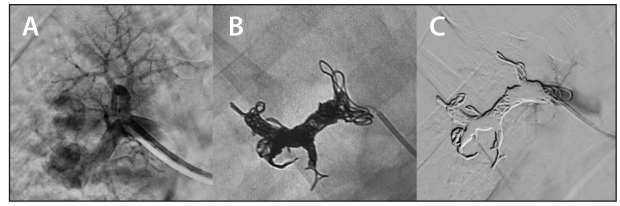

Figure 2. Multiple subsegmental arteries supplying the PAVM (A). Branching configuration of POD Packing Coils (B). Final result after embolisation with two 60-cm and one 45-cm POD Packing Coils (C).

close to the sac (Figure 2), thereby potentially reducing the chances of perfusion after embolisation.

DISCUSSION

When embolising a PAVM, the aim is to occlude the feeding arteries as close to the sac as possible. Compared to plugs, this is relatively easy to achieve with a triaxial system, which enables easy navigation with both the 4-F diagnostic catheter and the microcatheter in combination with an 0.018- or 0.014-inch guidewire. When using coils to embolise high-flow vascular malformations, the challenge is to prevent dislodgement and subsequent nontarget embolisation. The Penumbra Coils are detachable and rely on the dense packing characteristics to occlude the vessel. The large-diameter Standard and Soft Ruby Coils and POD have the potential to enable secure anchoring in either the sac or distal feeding artery even in high-flow situations. The POD has a unique configuration with a distal anchoring segment and a soft proximal segment, which may enable effective occlusion with only one coil. The POD Packing Coil, sometimes referred to as "liquid metal," is designed to be shapeless and soft and can provide dense coil configurations. In addition, because of the long available lengths of up to 60 cm, a limited number of coils is necessary, which can make treatment cost-effective as well.

RENAL ARTERY ANEURYSM VIA RADIAL ACCESS

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A 50-year-old-woman presented with an incidental CT finding of a right renal hilar aneurysm without thrombus (Figure 1). The aneurysm sac measured 15 X 19 mm. The procedure was performed under fluoroscopy via left radial access with a 6-F sheathless guide catheter. The right renal artery was catheterized with a 6-F guiding catheter. Selective angiography of the

WHY I CHOSE RUBY COIL AND LANTERN

- **Ruby Coil:** Available in a very large range of Standard and Soft configurations for framing and filling aneurysms
- **LANTERN:** Marker band system enables precise coil deployment

renal vascular system confirmed an aneurysm deriving from the main renal artery with the neck at its bifurcation (Figure 2). Selective catheterization of the inferior branch originating from the neck of the aneurysm was performed with a 2.6-F straight-tip LANTERN high-flow microcatheter, and a 0.014-inch hydrophilic wire was placed. With the same microcatheter and another 0.014-inch wire, the aneurysm was catheterized. Two Standard Ruby Coils (20 mm X 60 cm and 18 mm X 57 cm) were placed in the sac (Figure 3). Then, two Soft Ruby Coils (12 mm X 40 cm and 10 mm X 35 cm) were introduced until the sac was optimally obliterated. Only four coils were needed to exclude this aneurysm. An angiogram was obtained to confirm that the aneurysm was correctly embolised and the side branches were still patent (Figure 4). The microcatheter and protection wire were then removed without any coil displacement or branch obstruction (Figure 5). Parenchymal perfusion of the kidney was optimal at the end of the procedure (Figure 6).

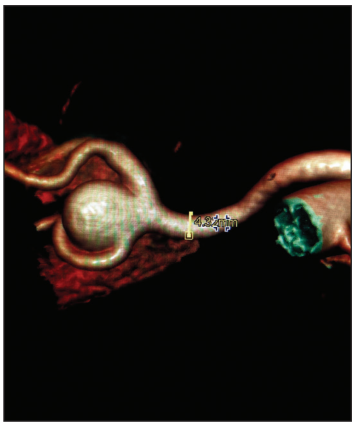

Figure 1. Volume-rendering CT reconstruction of the renal aneurysm showing the neck at the bifurcation.

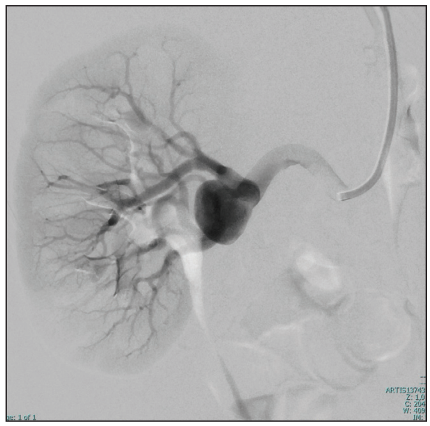

Figure 2. Selective angiogram of the right renal artery showing a hilar aneurysm with a renal artery branch arising from the proximal part of the neck.

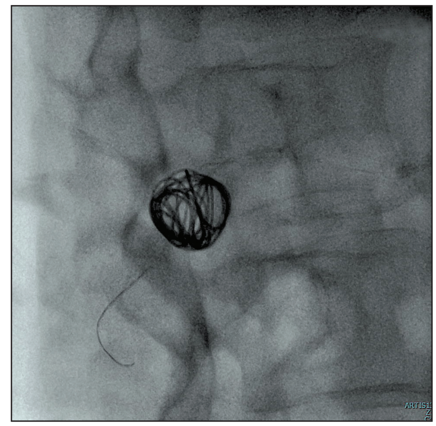

Figure 3. A 0.014-inch hydrophilic protection wire was placed in the inferior branch of the renal artery and the first Ruby Coil (20 mm X 60 cm) was placed in the aneurysm, creating a solid frame.

Figure 4. Angiogram showing the complete embolisation of the aneurysm with patent branches. The microcatheter (in the sac) and the protection wire (in the inferior branch) are still in place.

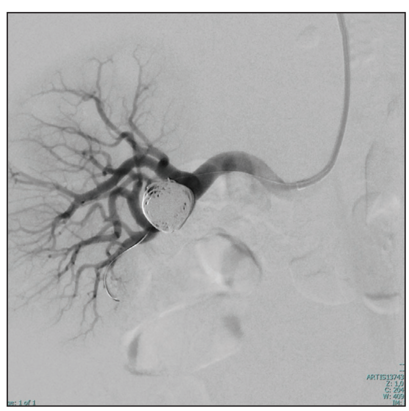

Figure 5. The LANTERN microcatheter was removed from the aneurysm without any coil displacement.

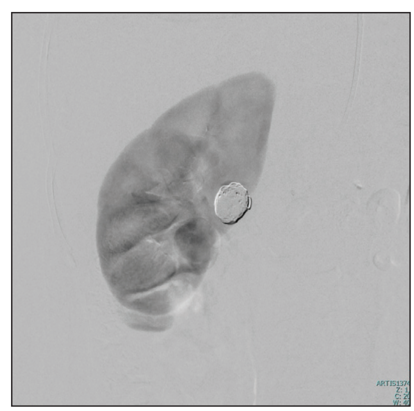

Figure 6. The 0.014-inch protection wire was removed. There was no need to stent the inferior branch because patency was maintained by the stable three-dimensional shape of the Ruby Coil frame. Only four Ruby Coils were needed to exclude the aneurysm. Optimal parenchymal perfusion of the kidney was demonstrated.

GASTROINTESTINAL BLEEDING

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WHY I CHOSE RUBY COIL

- The large volume and long lengths enable fast and easy embolisation
- The softness allows for a dense pack, which can minimize recanalization

A 70-year-old man presented to a tertiary referral center with increasing abdominal unwellness and back pain over several weeks. CT revealed a mass between the pancreatic head and the duodenum. Endoscopic biopsy identified the tumor as a poorly differentiated adenocarcinoma of the major duodenal papilla. The patient received successful pylorus-preserving pancreaticoduodenectomy (PPPD) clarifying the staging of a pT3b pN1 cM0 G3 tumor.

Fifteen days after successful surgery and normal initial course, he developed an abscess in the region of the pancreatic anastomosis, likely resulting from an anastomotic leakage. The leaking of activated pancreatic juice caused peripancreatic collections and an intraabdominal abscess. On the same day, percutaneous drainage was placed at the pancreatic-digestive anastomosis, which produced approximately 100 mL per day over the next few days.

A week after drainage placement, the patient developed an upper gastrointestinal bleeding with hemorrhagic shock. Multiphase CT revealed active bleeding at the biliodigestive anastomosis into the jejunum arising from an aneurysm of the right hepatic artery with a maximal diameter of 8 mm. These aneurysms are common complications based on autodigestion and destruction of the tissues surrounding the leaking pancreatic anastomosis including vessels, most commonly the hepatic artery.

The patient was immediately brought into the angiography suite. Angiography was performed, confirming a right hepatic artery aneurysm (Figure 1). The tip of a microcatheter was carefully placed within the aneurysm. Utilizing high-pressure rinsing, an 8-mm X 35-cm Soft Ruby Coil was deployed into the aneurysm (Figures 2 and 3). Thus, hemostasis was achieved. The entire time of intervention was 25 minutes. A follow-up CT was performed, which showed the coil in the completely filled aneurysm next to the patent hepatic artery (Figure 4), and the patient was discharged from the hospital 16 days after coiling and a last surgical procedure to restore the pancreatic anastomosis.

Figure 1. Angiogram of the celiac trunk revealing an aneurysm in the right hepatic artery; two surgical clips are in close vicinity.

Figure 2. Selective angiogram with the tip of the microcatheter placed within the aneurysm of the right hepatic artery revealing contrast material extravasation into the anastomosed jejunum and the bile duct.

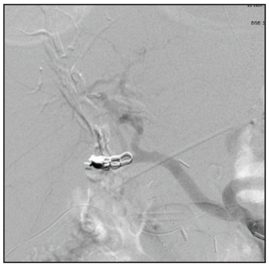

Figure 3. Angiogram after successful coiling of the right hepatic artery aneurysm using one 8-mm X 35-cm Soft Ruby Coil. However, the last two turns of the coil could not be placed completely within the aneurysm.

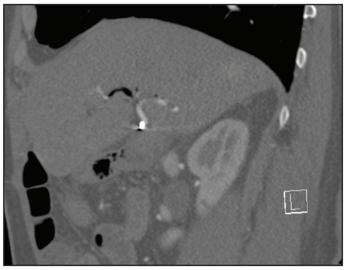

Figure 4. Oblique-sagittal reformat CT shortly before the patient was discharged from the hospital showing the coil in the completely filled aneurysm next to the patent hepatic artery.

TYPE II ENDOLEAK

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WHY I CHOSE RUBY COIL

- They are large-volume coils (0.020-inch in diameter, almost like macrocoils, and up to 60 cm in length) that allow efficient embolisation of the aneurysmal sac
- May be easy to handle, can be precise during positioning, and can be time saving
- Their dense packing is designed to lead to a durable occlusion

A 72-year-old man was referred to our department for treatment of type II endoleak (Figures 1 and 2). Two years previous, he underwent endovascular aneurysm repair for an aortic aneurysm with a maximum diameter of 5.4 cm.

Under local anesthesia, a 5-F sheath was inserted into the right common femoral artery and aortography was performed. The aneurysmal sac was primarily supplied by a branch of the deep circumflex iliac artery and secondarily by the inferior superficial epigastric artery (Figure 3), which likely supplied the obturator artery through a corona mortis anastomotic arch in a retrograde way and finally the aneurysmal sac. With a 4-F angled angiographic catheter, we catheterized the deep circumflex iliac artery and advanced a 2.6-F, 125-cm microcatheter over a 0.021-inch microwire all the way to the aneurysmal sac (Figure 4). Then, we started filling the aneurysmal sac with only eight Penumbra Ruby Coils (one 10 mm X 35 cm, four 8 mm X 60 cm, two 6 mm X 30 cm, and one 6 mm X 20 cm) (Figures 5–7). Despite the expected difficulty of advancing coils so distally through such a tortuous artery, the deployment of Ruby Coils was easy and quick. Additionally, the packing of the aneurysmal sac was ideal. The arteriogram revealed immediate and complete thrombosis of the sac, and there was no need to catheterize the other (and likely more complex) feeding artery, given that the latter revealed stasis of contrast media (Figure 8). The patient was discharged the next day without any complications. ■

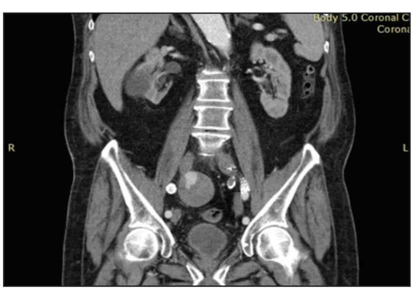

Figure 1. Arterial phase, coronal CTA showing the aneurysmal sac (5.4 cm) and its partial filling with contrast media.

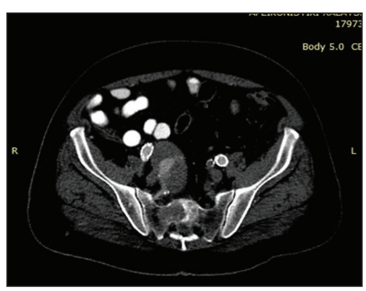

Figure 2. Arterial phase, axial CTA showing the aneurysmal sac and its partial filling with contrast media.

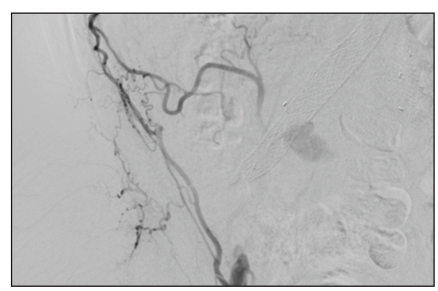

Figure 3. Visualization of the aneurysmal sac after arteriography of the deep circumflex iliac artery.

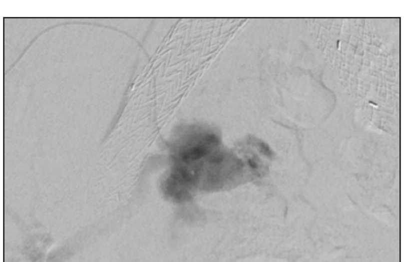

Figure 4. Advancement of the microcatheter into the aneurysmal sac.

Figure 5. Placement of the first Ruby Coil (10 mm X 60 cm) directly into the aneurysmal sac.

Figure 6. Packing of the aneurysmal sac with Ruby Coils.

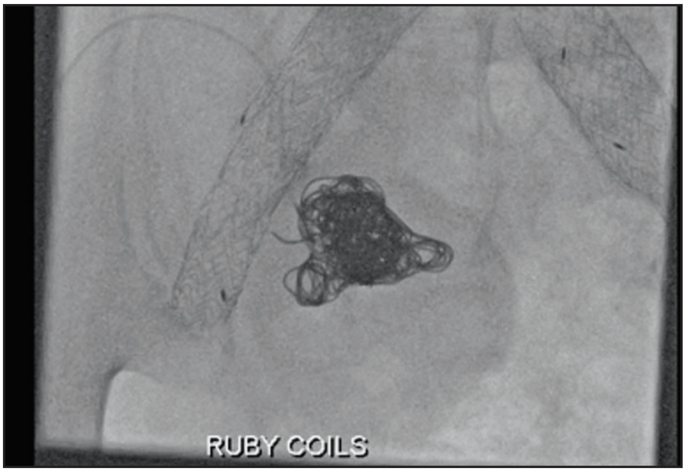

Figure 7. Final image of the aneurysmal sac filled with Ruby Coils.

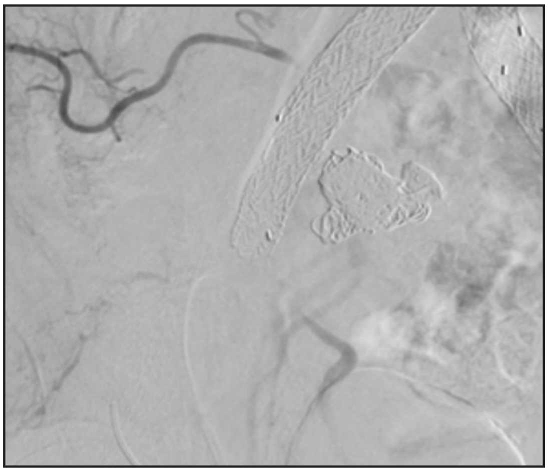

Figure 8. Late arterial phase CTA showing stagnation of the contrast media in the right deep circumflex iliac artery as well as in the right obturator artery (supplied by the right inferior superficial epigastric artery through the corona mortis anastomotic arch). The image demonstrates optimal packing and total occlusion of the aneurysmal sac, helping decrease the chances of retrograde filling from the other supplying arteries.

Drs. van den Heuvel, Balestriero, and Ptohis and Prof. Dr. med. habil. Abolmaali were compensated in association with this article.

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.