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A New Era in Embolic Devices

Novel uses for detachable coils and microvascular plugs and how they are put into practice in the real world.

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Embolotherapy is a major part of today's interventional medicine. Interventional radiologists started implementing different forms of embolotherapy in the 1970s. Since that time, newer methods and devices have been added to our armamentarium for a variety of indications. Some of these products provide temporary occlusion, whereas others have been designed for permanent occlusion.

Indications for embolotherapy include arterial hemorrhage, flow redistribution for oncologic applications, arteriovenous malformations (AVMs), venous disorders (eg, varicocele), pelvic congestion, and portal hypertensive shunts.

The scope of this article is to discuss two of the current products that may provide additional advantages to the interventional radiologist when performing embolization.

THE MVP™ MICRO VASCULAR PLUG

The MVP™ micro vascular plug (Medtronic plc; Figure 1) is currently available in four sizes. As shown in Table 1, the MVP-3Q plug, which has an unconstrained diameter of 5.3 mm, is indicated for 1.5- to 3-mm vessel occlusions and can be delivered through a 0.021-inch microcatheter. The MVP-5Q plug, which has an unconstrained diameter of 6.5 mm, is indicated is for 3- to 5-mm vessel occlusions and can be delivered through a 0.027- or 0.028-inch microcatheter. MVP-7Q, which has an unconstrained outer diameter of 9.2 mm, is indicated for 5- to 7-mm vessels. Lastly, the MVP-9Q plug, which has an unconstrained diameter of 13 mm, is indicated for 7- to 9-mm vessels. The MVP-7Q and MVP-9Q plugs can be delivered through catheters that have an outer diameter of 4 and 5 F, respectively.

In addition to small lumen catheter compatibility, this product has the ability to provide rapid occlusion in a superselective setting. It can be resheathed and provides fast and predictable deployment. Although each plug costs more than a coil, one plug is often sufficient to embolize a vessel, thereby leading to significant cost savings. The num-

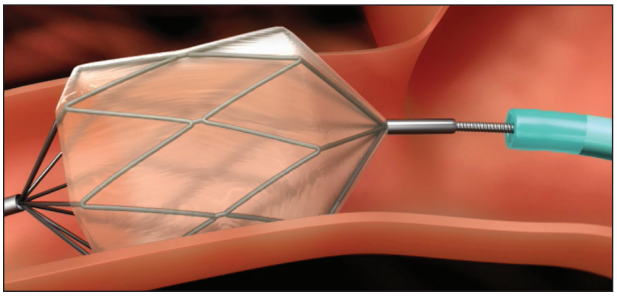

Figure 1. The MVP™ micro vascular plug.

TABLE 1. SIZES AND CATHETER COMPATIBILITY OF THE MVP™ PLUG

Catalog Number	Target Vessel Diameter (mm)	Unconstrained Length (mm)	Maximum Constrained Length* (mm)	Unconstrained Device Diameter (mm)	Minimum Recommended Microcatheter ID for 3Q/5Q and 3US/5US or Catheter OD for 7Q/9Q
MVP-3Q	1.5–3	12	15	5.3	0.021 in
MVP-5Q	3–5	12	16	6.5	0.027 in
MVP-7Q	5–7	16	18.4	9.2	4 F
MVP-9Q	7–9	18	23.4	13	5 F

Abbreviations: ID, inner diameter; OD, outer diameter.
*Maximum constrained length in target vessel diameter range.

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TABLE 2. DIAMETERS, LENGTHS, AND CATHETER COMPATIBILITY FOR THE CONCERTO™ DETACHABLE COIL SYSTEM

Concerto™ Detachable Coil System	Diameter (mm)	Length (cm)	Minimum Microcatheter Compatibility (in)
NV-2-4-Helix	2	4	0.0165
NV-2-6-Helix	2	6	0.0165
NV-2-8-Helix	2	8	0.0165
NV-3-4-Helix	3	4	0.0165
NV-3-8-Helix	3	8	0.0165
NV-4-8-Helix	4	8	0.0165
NV-4-12-Helix	4	12	0.0165
NV-5-15-Helix	5	15	0.021
NV-5-20-Helix	5	20	0.021
NV-6-20-Helix	6	20	0.021
NV-7-30-Helix	7	30	0.021
NV-8-30-Helix	8	30	0.021
NV-9-30-Helix	9	30	0.021
NV-10-30-Helix	10	30	0.021
NV-12-30-Helix	12	30	0.021
NV-14-30-Helix	14	30	0.021
NV-16-40-Helix	16	40	0.021
NV-18-40-Helix	18	40	0.021
NV-20-50-Helix	20	50	0.021

ber of coils needed to occlude a gastroduodenal artery (GDA) is 3.4.[1] The cost of 3.4 detachable coils at $750 per coil is $2,550. In my experience, the GDA was occluded with one plug, leading to significant cost savings.

THE CONCERTO™ DETACHABLE COIL SYSTEM

The Concerto™ detachable coil system (Medtronic plc; Figure 2) has coils available in diameters ranging from 2 to 20 mm and up to 50 cm in length. A complete list of the available sizes and lengths can be found in Table 2. With a variety of diameters and lengths, this coil system allows for precise and controlled embolization of many different arterial or venous segments. The detachment mechanism is mechanical and highly reliable.

It is important to use an appropriately sized microcatheter to avoid "accordioning" of the coil inside the microcatheter. This is especially important when using 2- or 3-mm–long coils (eg, 2 mm X 8 cm). In our experience, a maximum microcatheter inner diameter of 0.021 or 0.025 inches should be used for smaller-diameter, long-length coils, whereas 0.027- or 0.028-inch inner-diameter microcatheters can be used for larger-diameter coils. The advantages of this coil system include controlled detachment, small microcatheter compatibility, a variety of size options, and excellent softness and conformability.

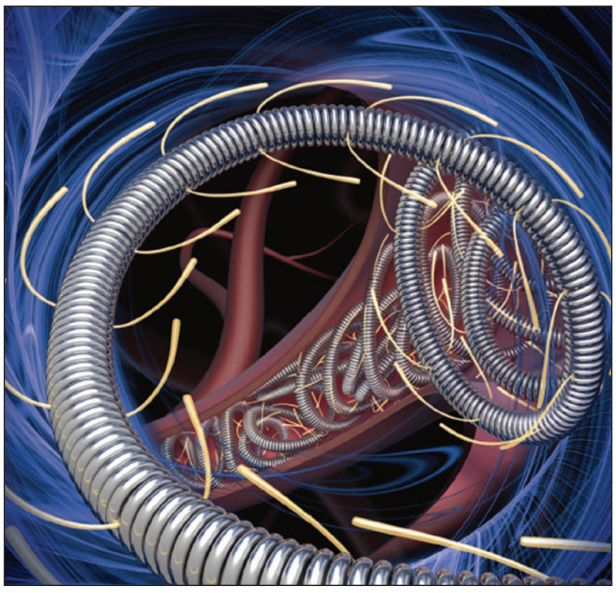

Figure 2. The Concerto™ detachable coils.

CASE 1: TREATMENT OF A HEPATIC ARTERY-TO-HEPATIC VEIN FISTULA SHUNT

A 44-year-old man presented with hepatocellular carcinoma and previous treatment with SIR-Spheres®* microspheres (Sirtex Medical Limited) in the right and left lobes in July and August 2012. He underwent treatment with TheraSphere®* Y-90 glass microspheres (BTG International Inc.) in the right lobe in May 2013 and in the left lobe in April 2013 (superselective treatment of segments 2, 3, and 4B).

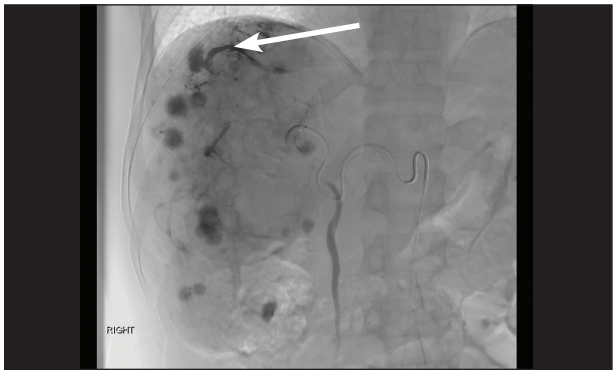

Figure 1. Right lobe angiogram showing multiple hypervascular lesions and right hepatic artery-to-hepatic vein fistula shunting (arrow).

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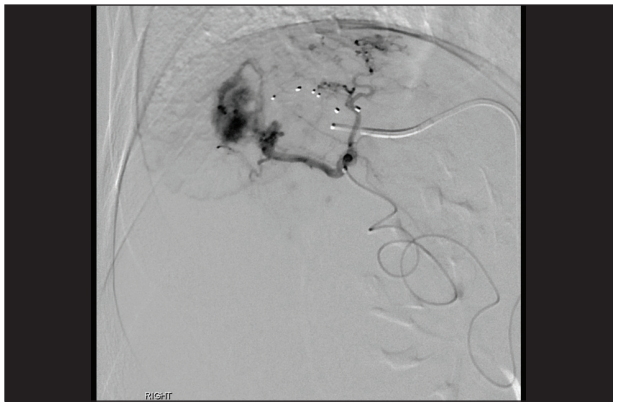

Figure 2. Postdeployment imaging showing no arteriovenous shunting.

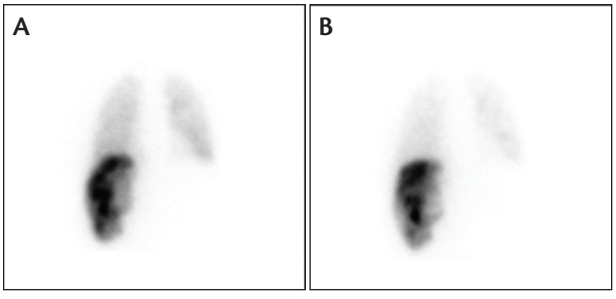

Figure 3. Only 9% residual shunting was seen on subsequent nuclear medicine shunt study.

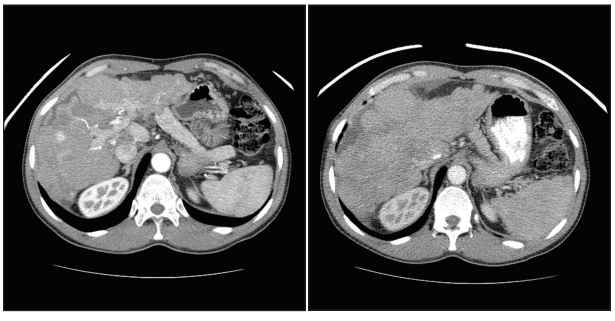

Figure 4. Outcome at 3-month follow-up.

During his most recent follow-up in May 2015, hyperenhancing lesions consistent with current hepatocellular carcinoma were seen. After a thorough discussion of all the available options, he underwent a mapping procedure for repeat radioembolization in January 2015, understanding the risks of repeat treatment and radiation-related complications. However, the hepatic lung shunt fraction was 25.55%. A shunt reduction procedure was planned, and the patient was brought back. Right lobe angiography (Figure 1) showed multiple hypervascular lesions within the right lobe of the liver and also demonstrated right hepatic artery-to-hepatic vein fistula shunting (Figure 1). Access into the right hepatic vein was also achieved.

The arteriohepatic vein fistula/shunt was delineated via arteriography. This hepatic venous outflow was selectively catheterized with a Simmons 2 catheter and a coaxially introduced microcatheter, and successful deployment of an MVP-5Q plug was performed. A second venous branch was also catheterized with a microcatheter, and two MVP-3Q plugs were deployed at the venous end (Figure 2).

Postdeployment arteriography showed no significant angiographic evidence of arteriovenous shunt (Figure 2). A subsequent nuclear medicine shunt study demonstrated only 9% residual shunting, which was reduced from an initial 25.5% shunt (Figure 3). The patient had a complete response to treatment upon subsequent radioembolization with no radiographic evidence of residual disease on follow-up CT scan at 3-month follow-up (Figure 4).

CASE 2: TREATMENT OF A RENAL AVM

A 71-year-old woman was referred to the interventional radiology department after an incidental renal mass was seen on chest CT imaging (Figure 1). A follow-up abdominal CT scan with contrast showed a 3.8- X 3.1-cm, exophytic, solid mass. She was initially referred for a biopsy, but after review by the interventional radiologist, the biopsy was cancelled, and renal angiography was scheduled.

The initial aortogram demonstrated a normal aorta but a large aneurysm involving the left kidney with early filling of the renal vein and inferior vena cava (Figure 2). There was a single right renal artery and three left renal arteries. The known large left renal AVM with an aneurysmal component was identified, and the feeding branch was catheterized.

Selective renal angiography was performed, which confirmed a fully opacified large left renal AVM, confirming the previous findings of main supply by one artery and drainage via one large draining vein. A microcatheter was coaxially introduced and used to selectively catheterize the AVM and the aneurysm itself. The draining vein was also catheterized at this point. Separate venous access was achieved, and a 6-F sheath was coaxially introduced into the left renal vein with the guidance of a Simmons 2 catheter. A microcatheter was then introduced and used to selectively catheterize

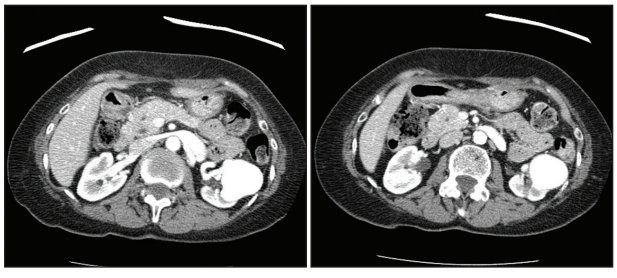

Figure 1. Renal mass discovered via chest CT imaging.

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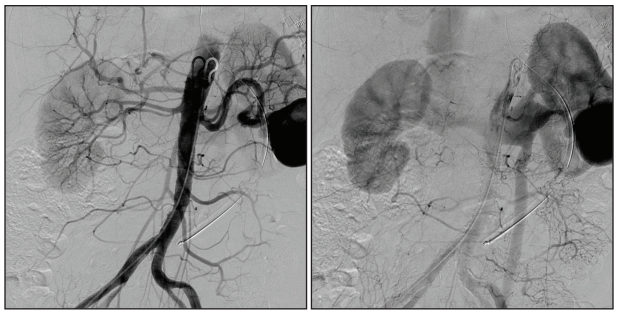

Figure 2. Initial aortogram showing a large aneurysm involving the left kidney with early filling of the renal vein and inferior vena cava.

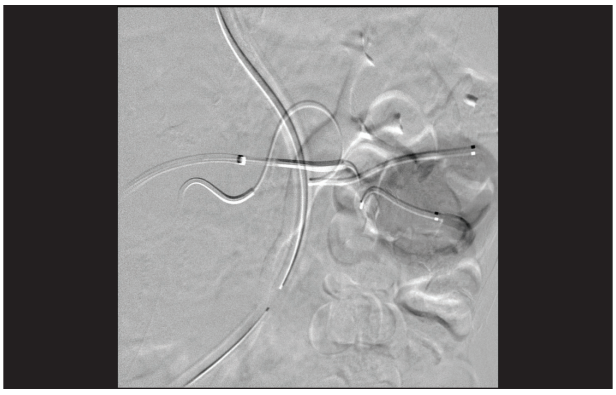

Figure 3. Two microcatheters within the aneurysm via arterial and venous accesses.

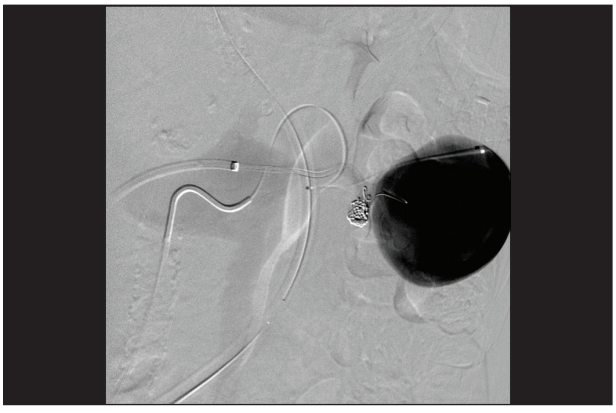

Figure 4. A 7-mm X 30-cm Concerto™ detachable coil was placed but not detached at the venous outflow.

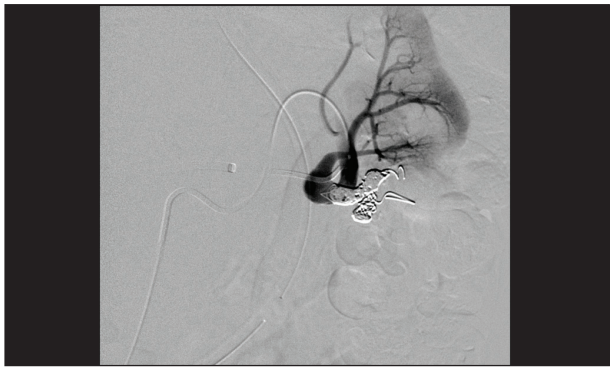

Figure 5. Final angiogram showing complete flow occlusion to the aneurysmal segment after seven Concerto™ detachable coils were deployed to the inflow of the AVM.

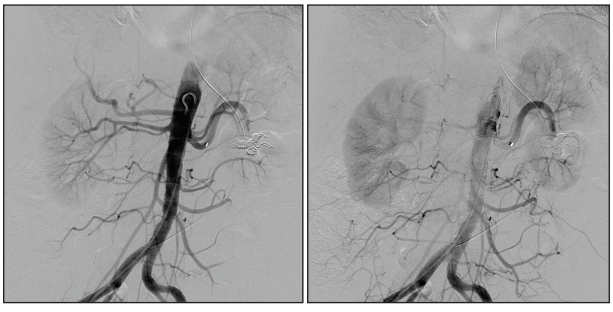

Figure 6. Excellent angiographic result with complete occlusion of the AVM with preserved perfusion of the upper and lower kidney poles.

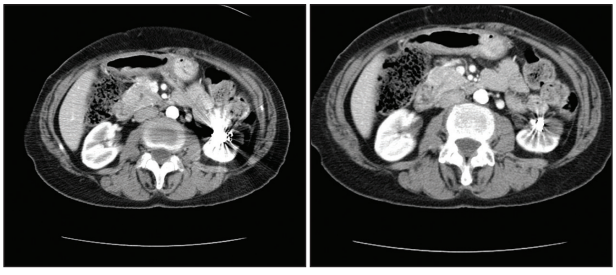

Figure 7. Follow-up CT scans at 1 year showing nearly complete aneurysm resolution and no evidence of AVM.

the draining vein and, finally, the aneurysmal portion of the AVM itself via the draining vein. At this point, two microcatheters were within the aneurysm via arterial and venous accesses (Figure 3).

There was concern for possible migration of the coils due to high flow immediately after deployment. To prevent this potentially serious complication, a 7-mm X 30-cm Concerto™ detachable coil was placed into the venous outflow of the AVM and aneurysm (Figure 4). The coil was left in place without detachment. With the venous outflow secured to prevent any migration from the arterial side, a total of seven Concerto™ detachable coils (ranging in size from 4 X 10 mm to 7 X 30 mm) were then deployed to the arterial inflow of the AVM and aneurysm (Figure 5).

Repeat angiography showed good exclusion of the aneurysm and the AVM, and at that time, the venous coil was detached. Final angiography was performed through a microcatheter positioned within the proximal renal artery, which showed complete occlusion of flow to the aneurysmal segment (Figure 5). Final angiography was also performed through a flush catheter from the aorta to assess for collateral flow to the aneurysm and also to assess the overall residual renal parenchymal enhancement. This confirmed an excellent angiographic

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result with complete occlusion of the AVM and preserved perfusion of the upper and lower poles of the kidney (Figure 6).

Follow-up CT imaging at 1 year (Figure 7) showed almost complete resolution of the aneurysm, no evidence of the AVM, and normal kidney function with full preservation of the renal parenchyma.

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CASE 3: PEDIATRIC GASTRODUODENAL ARTERY EMBOLIZATION

By Frank Hao, MD; Daniel Powell, MD; and Vladimir Sheynzon, MD

The incidence of acute significant upper gastrointestinal bleeding in critically ill children has been reported to be 0.4% to 1.6%. Etiologies include ulcers, portal hypertension, or coagulation disorders. Endoscopic intervention is the gold standard in treating upper gastrointestinal bleeding, with rebleeding usually managed with repeat endoscopic intervention. Other options include transcatheter arterial embolization (TAE) or surgical management when the hemorrhage is unsuccessfully controlled endoscopically.[1]

TAE can be performed using various embolization agents including coils. Direct artery occlusion utilizing an Amplatzer™* vascular plug (St. Jude Medical, Inc.) in the gastroduodenal artery (GDA) has been described to be more effective in target vessel occlusion compared to coil embolization.[2] However, use of the Amplatzer plug is technically challenging in small, tortuous vessels.

The MVP™ plug was developed for use with a microcatheter. The MVP™ plug is a self-expanding occlusive device with an ovoid detachable nitinol exoskeleton that is partially covered with polytetrafluoroethylene along its base. It is deliverable through a 0.021- or 0.027-inch microcatheter. The MVP™ plug is connected to a 0.018-inch nitinol pusher wire and is capable of controlled detachment. The primary advantages of this device include the ability to resheath and to navigate through small and tortuous vessels through standard microcatheters.

In the following section, we describe the first case of GDA occlusion in a pediatric patient utilizing the microvascular plug system.

CASE DESCRIPTION

A 7-year-old boy had a history of refractory Hodgkin's lymphoma after matched unrelated donor bone marrow transplantation and peripheral blood stem cell boost complicated by skin and enteric graft-versus-host disease. He presented with diarrhea and dehydration secondary to *Salmonella* Enteriditis and hemophagocytic syndrome, later decompensating into septic shock. An abdominal and pelvic CT scan demonstrated diffuse small bowel wall hyperemia consistent with graft-versus-host disease, and his course was further complicated by melena and hematemesis. He was initially managed via supportive red blood cell and platelet transfusions and a proton pump inhibitor drip.

However, an upper endoscopy was performed for persistent bleeding, which demonstrated patchy and erythematous mucosa with stigmata of bleeding found in the second and third portions of the duodenum, as well as in the stomach. Sites of active bleeding were controlled with argon, bipolar cautery, and epinephrine injection. Despite these measures, the patient had persistent hematemesis and melena with poor response to further blood transfusions. A repeat upper endoscopy showed significant bleeding from duodenal ulcers within the second and third portions that could not be controlled via cautery.

Angiography was requested. Empiric embolization was planned based on the endoscopic findings to decrease the arterial blood inflow pressure head to the ulcers, allowing the platelet clots to form, unless bleeding was readily identified during angiography. After achieving right common femoral arterial access, a 5-F Sos catheter was advanced through a sheath, and the celiac artery was catheterized. Celiac arteriography was performed and did not show extravasation. A 2.8-F Progreat®* catheter (Terumo Interventional Systems) and a 0.016-inch Fathom™* wire (Boston Scientific Corporation) were used to catheterize the GDA, and a focused diagnostic gastroduodenal arteriogram was performed without evidence of active extravasation (Figure 1). Prophylactic embolization was then performed using an MVP-3Q plug (indicated for 1.5- to 3-mm vessel diameters), which was deployed within the GDA spanning the superior pancreaticoduondenal artery trunk and embolizing down to the level of the right gastroepiploic artery origin. Complete occlusion was demonstrated without encroachment on the hepatic artery, as shown on completion angiography (Figure 2). No evidence of bleeding (such as extravasation or pooling) was seen.

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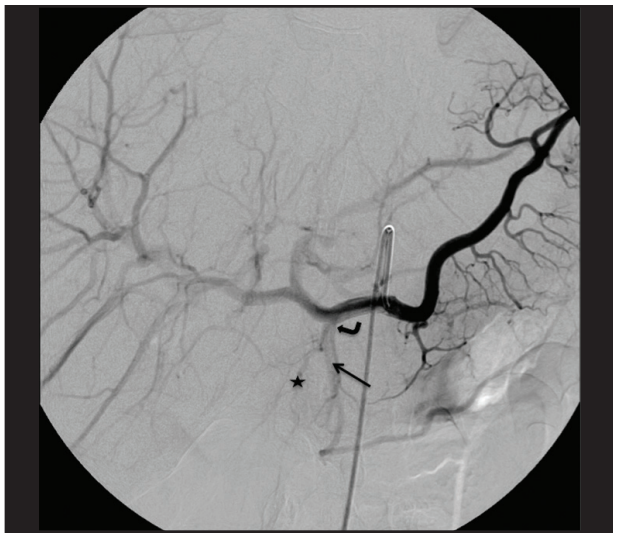

Figure 1. Digital subtraction angiography of the celiac axis shows the GDA (arrow) with its right gastroepiploic and pancreaticoduodenal artery continuations (star). Note the overlap of the left hepatic artery branches (curved arrow).

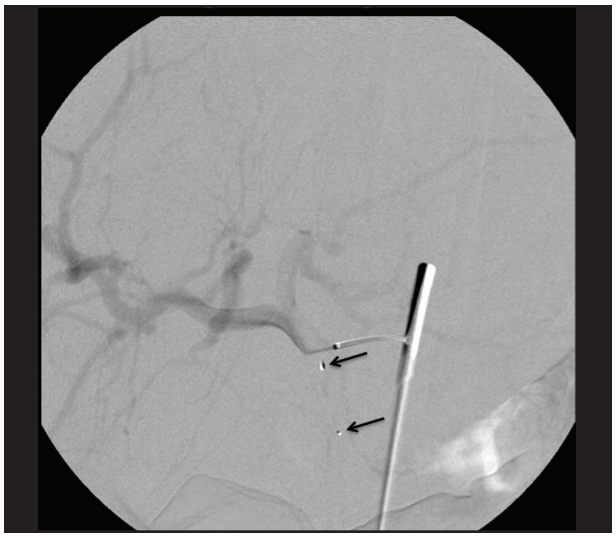

Figure 2. Digital subtraction imaging showing successful occlusion of the GDA with the MVP™ plug, which is visualized by its radiopaque markers at each end (arrows), and good opacification of the proper hepatic artery.

DISCUSSION

TAE of the GDA represents a safe and effective method in managing massive ulcer bleeding.[3] A retrospective study of 117 patients with a high risk of rebleeding after initial endoscopic hemostasis who underwent prophylactic TAE of the GDA showed rebleeding in 11% and a major complication rate of only 4%, resulting in a decreased need for multiple transfusions of packed red blood cells.[3]

The main drawback of coil embolization is the quantity and time needed to achieve immediate and stable vessel occlusion, as well as the possibility for coil migration or recanalization.[4] Use of the MVP™ plug allows for immediate and stable target vessel occlusion. A two-center pilot study by Pellerin et al in 14 patients showed successful navigation, deployment, and occlusion of tortuous and small (1- to 3-mm diameter) vessels ranging from the right gastric, pancreaticoduodenal, and hepatic segment IV arteries. Only one microvascular plug was used per target artery.[5] Additional cases have shown the MVP™ plug to be effective in pathologies ranging from posttraumatic head/neck bleeding, carotid-cavernous or vertebral-vertebral fistulas, and stump emboli after carotid dissections, as well as vessel occlusion in small arteries such as the proximal sphenopalatine artery or precavernous internal carotid artery, without evidence of procedural complications such as plug migration or vessel recanalization.[6]

To our knowledge, this is the first report documenting the use of a microvascular plug for a pediatric vascular case. This case illustrates the potential efficacy of the MVP™ plug in occluding small and torturous arteries in pediatric patients. Although devices like the MVP™ plug cannot completely replace the use of coils, it may simplify embolization and may make the procedure fast and easy in certain cases.

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CASE 4: SPLENIC ARTERY EMBOLIZATION

By John J. Park, MD, PhD, and Jinha M. Park, MD, PhD

A 46-year-old man with cholangiocarcinoma, who was previously treated with systemic chemotherapy followed by liver-directed Y90 radioembolization for progressive liver disease, was evaluated and treated for thrombocytopenia associated with hypersplenism. Two years earlier, his splenic volume was 159 mL, and his platelet counts were normal. At the time of consultation, the patient's spleen had significantly enlarged, with a volume of 1,182 mL (Figure 1), and his platelets ranged from 60 to 70 K/µL, precluding him from further chemotherapy. Furthermore, given his declining performance status (ECOG 1–2) and need to minimize any significant treatment delays, the decision was made to proceed with main splenic artery embolization to treat the hypersplenic thrombocytopenia.[1,2]

The outpatient procedure was performed under moderate sedation using a right common femoral access approach. A 5-F Lev1 catheter was initially used to access the celiac artery. Due to corkscrew tortuosity of the midsplenic artery, the Lev1 catheter was exchanged for a 5-F angled Glidecath®* (Terumo Interventional Systems), which was used to further select the distal main splenic artery segment. The artery was 6.9 mm in diameter at this location (after calibration; Figure 2). At this point, an MVP-7Q plug was advanced with ease across the corkscrew segment and positioned along the distal main splenic artery. Predetachment angiography was performed using a Y-connector hemostatic valve (BigEasy™, Medtronic plc), showing the microvascular plug in a slightly proximal location (Figure 3). After resheathing the device and reposition-

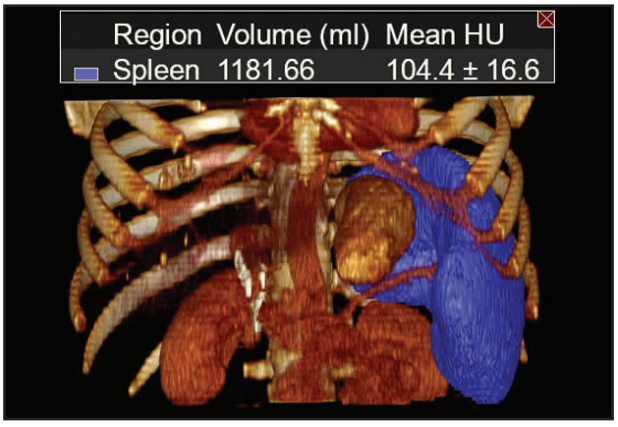

Figure 1. CT volume rendering of the spleen (blue) with measured volume included.

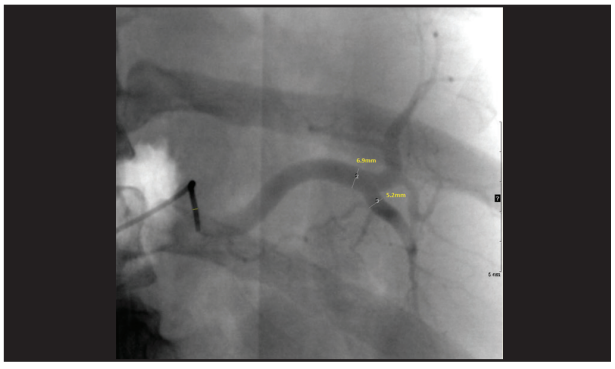

Figure 2. Nonsubtracted splenic artery angiogram with distal artery diameter measurement.

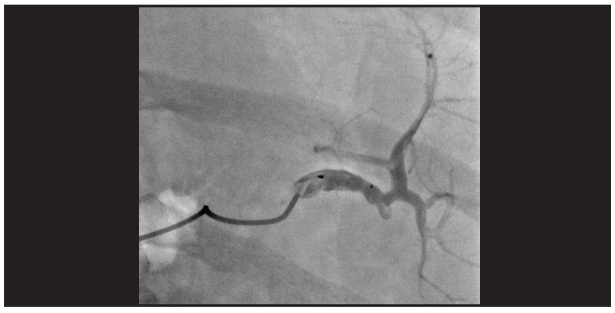

Figure 3. Predetachment angiogram of the vascular plug demonstrating a slightly proximal position. The plug was subsequently resheathed and repositioned in a more optimal position.

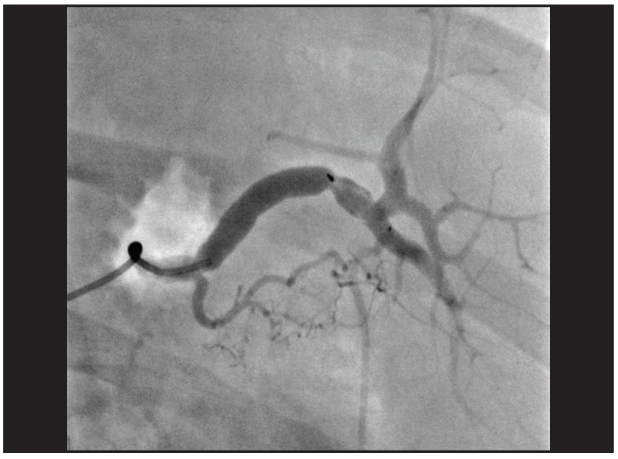

Figure 4. Immediate postdetachment angiogram of the MVP™ plug within the distal main splenic artery.

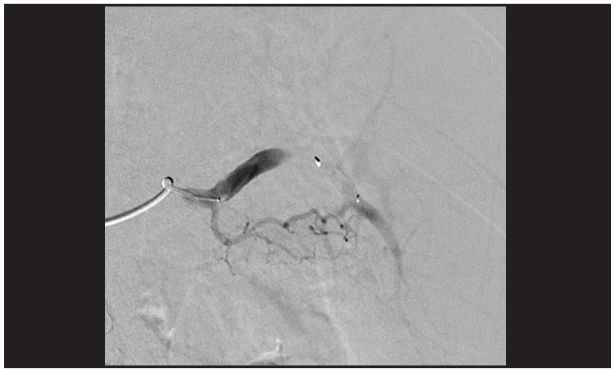

Figure 5. Final angiogram showing complete occlusion of the distal main splenic artery with cross-collateralization of the intrasplenic artery branches noted via the pancreatic branches.

ing to a more optimal location, the plug was detached, and angiography was immediately performed (Figure 4). Serial angiography at selected time points were then performed until complete vessel occlusion was achieved (Figure 5). Postprocedure, the patient recovered per standard protocol. At his 2-week follow-up clinic visit, the patient was re-evaluated, and his platelet counts had increased to 153 K/µL.

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CASE 5: SPLENIC ARTERY EMBOLIZATION AFTER SPLENIC TRAUMA

By Jason W. Mitchell, MD, MPH, MBA

A 16-year-old girl with no previous medical history presented with a grade III splenic laceration that resulted from a motor vehicle collision. She also suffered nondisplaced pelvic fractures. After a short period of conservative management, a repeat CT scan 48 hours after presentation showed an increased number of parenchymal splenic pseudoaneurysms, so splenic angiography and possible embolization was requested. The patient was brought to the angiography suite for treatment, and a 5-F sheath was placed in the right common femoral artery. A 5-F Sos catheter was used to select the celiac axis and splenic artery. Splenic angiography demonstrated multiple small pseudoaneurysms (Figure 1), with no active extravasation. The splenic artery measured 5 cm proximally (Figure 2). The Sos catheter was exchanged for maneuverability in the splenic artery for a 5-F angled Glidecath, and an MVP-7Q plug was deployed in the proximal splenic artery, with immediate occlusion of the vessel, which was confirmed on postembolization angiography (Figure 3). ■

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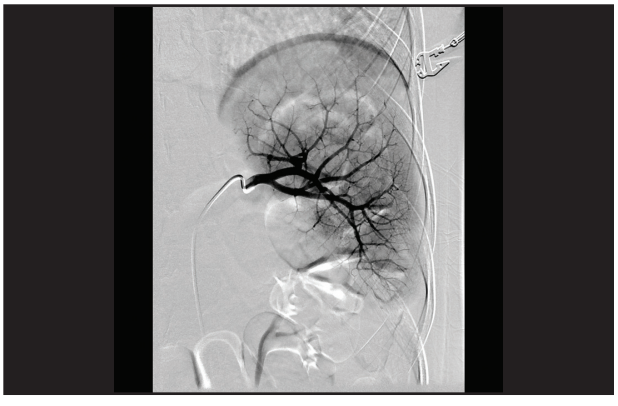

Figure 1. Multiple small splenic pseudoaneurysms.

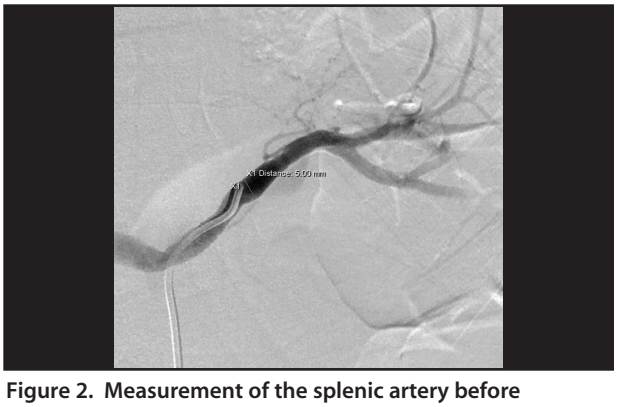

Figure 2. Measurement of the splenic artery before embolization.

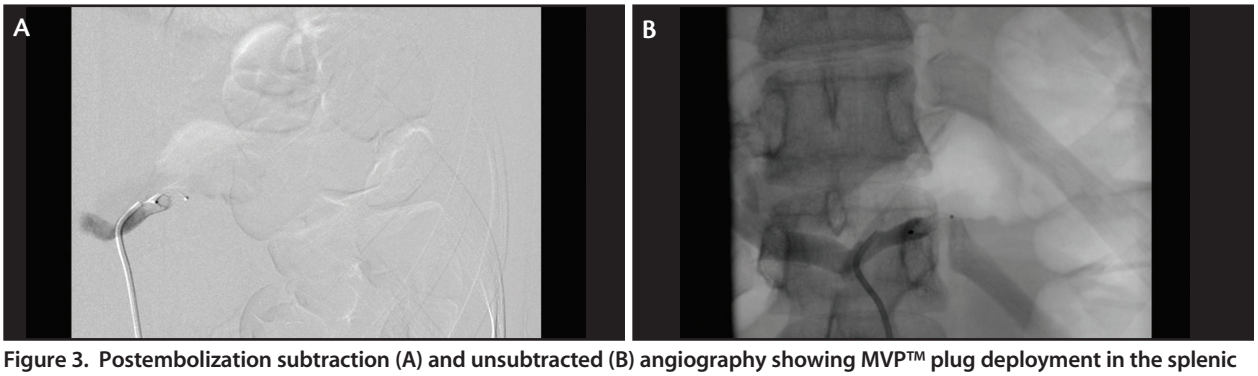

Figure 3. Postembolization subtraction (A) and unsubtracted (B) angiography showing MVP™ plug deployment in the splenic artery with immediate occlusion of the vessel.