

Visceral Arterial Embolization

Innovations in new techniques, embolic agents, and delivery systems expand endovascular treatment options for challenging visceral vascular lesions.

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Trascatheter arterial embolization has its origins rooted in the treatment of gastrointestinal hemorrhage.¹ Since gelfoam and autologous clot were first injected into diagnostic catheters to treat bleeding, the types of cases managed with embolization techniques have expanded exponentially. As the technology has advanced so have the embolic agents and delivery systems. Until recently, the only agents available to the interventionist for visceral arterial embolization were pushable coils, embolic particles (such as polyvinyl alcohol [PVA]), and gelfoam. However, a new dawn is rising for endovascular therapeutic procedures in different vascular territories, as newer embolic agents have become available to assist in treating increasingly complex vascular pathologies. These newer embolic agents include detachable bare platinum Microplex microcoils (Microvention/Terumo, Aliso Viejo, CA), coated coils such as hydrogel-coated microcoils (Microvention/Terumo), and liquid agents such as n-butyl cyanoacrylate (n-BCA, Cordis Corporation, Warren, NJ) and Onyx (ev3 Inc., Plymouth, MN). Historically, these tools were reserved for neurointerventional applications. However, through progressive clinical collaborations, their use is being extended beyond the neuroaxis to treat complex vascular pathologies in different vascular locations.

It is through collaboration with our neurointerventionist that our group first began using these embolic agents and techniques for peripheral interventions in 2004. Since that time, we have amassed a large number of cases in which these tools have been applied to complex endovascular interventions (n=79, unpublished data) within a variety of different vascular territories. These agents are particularly well suited for visceral arterial interventions because of the unique technical challenges

encountered in performing embolization in the mesenteric territories. These challenges include the presence of important side branches leading to vital organs, the need to catheterize and deliver embolic agents to small and sometimes tortuous vessels, and the proximity to the aorta of some of these processes. The purpose of this article is to describe our experience in using these tools to treat complex visceral arterial pathologies and to highlight their versatility with several different clinical cases. In many situations, the application of these advanced techniques represented the only possibility of avoiding open surgery due to the location and presentation of the vascular lesion, which often made the risk of using pushable coils or particles prohibitive.

EMBOLIC AGENTS AND DELIVERY SYSTEMS Microcoils

Detachable platinum and hydrogel-coated microcoils have been used to treat intracranial aneurysms² and offer a greater degree of precision than pushable microcoils and, thus, potentially reduce the risk of nontarget embolization, migration, vessel thrombosis, and aneurysm rupture. These microcoils can be carefully placed into the aneurysm or vascular lesion and remain attached until their position and configuration is acceptable to the operator. If their initial location is not acceptable, they can be repositioned or removed. For traditional Guglielmi detachable microcoils, the detachment mechanism is an applied current, which releases the microcoil from the end of a microwire. We have used bare platinum Microplex microcoils, as well as hydrogel-coated microcoils, in performing many of our complex interventions.

The hydrogel-coated microcoil is now available as the

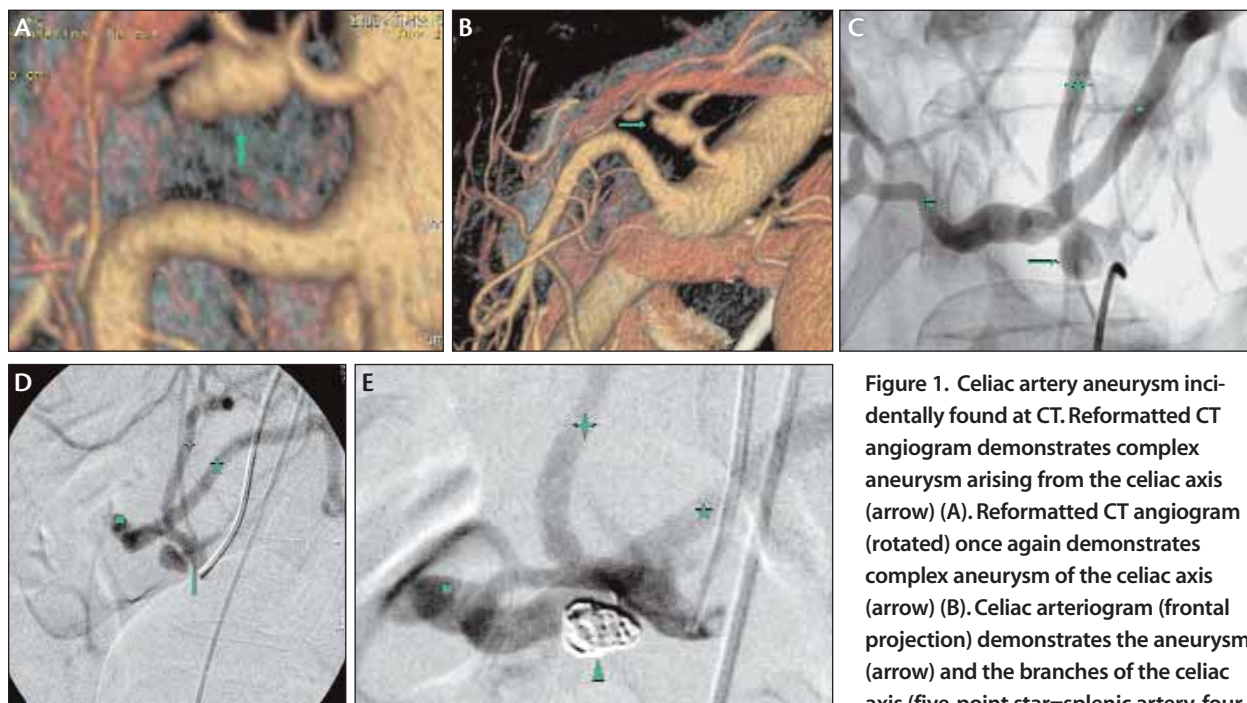


Figure 1. Celiac artery aneurysm incidentally found at CT. Reformatted CT angiogram demonstrates complex aneurysm arising from the celiac axis (arrow) (A). Reformatted CT angiogram (rotated) once again demonstrates complex aneurysm of the celiac axis (arrow) (B). Celiac arteriogram (frontal projection) demonstrates the aneurysm (arrow) and the branches of the celiac axis (five-point star=splenic artery, four-point star=left gastric artery, crosshair=common hepatic artery) (C). Celiac digital subtracted arteriogram (DSA) in lateral projection demonstrating the fairly narrow neck of the aneurysm arising from the inferior aspect of the celiac artery just proximal to branch vessels (see Figure 1C symbols) (D). Completion celiac DSA demonstrating exclusion of the aneurysm after placement of detachable hydrogel-coated microcoils. Note complete preservation of side branches and no coil extending beyond the aneurysm into the celiac artery (E).

Azur microcoil (Terumo Medical Systems, Somerset, NJ) for peripheral use. The hydrogel coating consists of a polymer that expands six to seven times the original volume of the bare coil when placed into blood, thus offering the advantage of excluding more volume with potentially fewer microcoils placed. The deployment of the detachable microcoil is precise and, admittedly, once the interventionist is exposed to this degree of performance, it is difficult to return to standard, older technology (ie, pushable microcoils). Fibered metal detachable microcoils are also available in the form of the Interlock microcoil (Boston Scientific Corporation, Natick, MA), which detaches once the microcoil is pushed out of the microcatheter completely. Consequently, the Interlock microcoil cannot be retracted once it leaves the end of the microcatheter, in contradistinction to the Azur and Microplex detachable microcoils. Many of our cases could only be performed by using the precision of the truly retractable and detachable microcoil because of the location of side branches with respect to the aneurysm neck and the high-flow nature of arteriovenous fistulas and malformations (Figure 1).

Liquid Embolics

n-BCA is FDA approved for preoperative obliteration of intracranial arteriovenous malformations. However, it has been used as an off-label device for many years. As a liquid embolic agent, it offers several advantages over the other agents mentioned with respect to precision, penetration, and permanence. It is mixed with ethiodized oil,

which retards polymerization. The ratio of the n-BCA to the ethiodol will govern the polymerization rate, flow characteristics, and viscosity of the glue. Typically, the range of concentrations for use is between 20% and 50%. To achieve these concentrations, 1 mL of n-BCA can be mixed with anywhere from 1 to 4 mL of ethiodol. The lower acrylic concentration usually is reserved for slower flow situations and more distal penetration. The higher concentration is preferred for rapid polymerization in high-flow situations to avoid nontargeted embolization of normal arterial vascular territories or draining veins. Before injecting the n-BCA, it is necessary to flush the microcatheter with glucose solution to avoid polymerization from contact with ionic solutions such as saline or contrast. When injecting n-BCA, the interventionist has to be aware of the distal extent of penetration allowable and the proximal level that the glue can be safely refluxed to avoid occluding important side branches. The interventionist also has to be careful so as to remove the microcatheter while aspirating before full polymerization

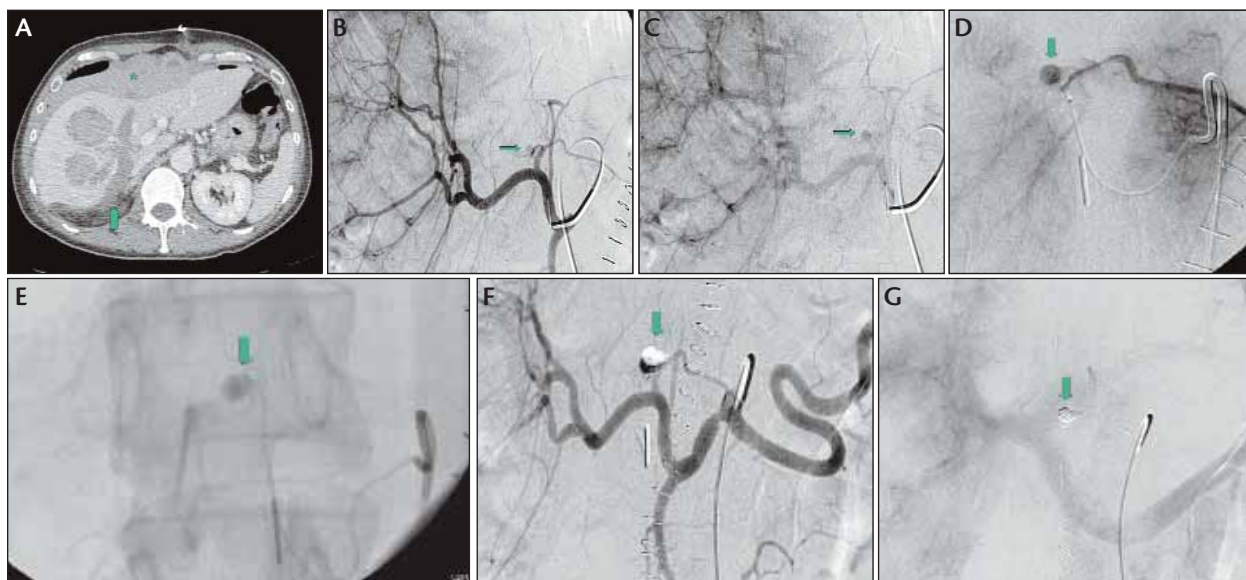


Figure 2. Intraoperative hemorrhage after intraoperative radiofrequency ablation (RFA) of hepatic tumor. Contrast-enhanced CT axial image demonstrating large intraoperative hemorrhage (star) and hepatic laceration (arrow) after RFA of right hepatic neoplasms (A). Hepatic DSA demonstrating a pseudoaneurysm from a left hepatic arterial branch supplying segment 4 (arrow) (B). Hepatic DSA (capillary phase) demonstrates persistent contrast in the left hepatic pseudoaneurysm (arrow) (C). Superselective left hepatic DSA demonstrates the pseudoaneurysm (arrow) and its relationship with the hepatic artery (D). Superselective injection of 0.3 mL of 30% n-BCA into the pseudoaneurysm (arrow) after selective catheterization with the microcatheter. Celiac DSA demonstrating complete exclusion of the hepatic pseudoaneurysm with n-BCA as subtracted defect (arrow) remaining within the pseudoaneurysm (F). Celiac DSA (portal phase) demonstrating no contrast filling into the pseudoaneurysm (arrow) (G).

occurs; otherwise, the catheter cannot be retrieved.

We have found the use of n-BCA to be particularly helpful in permanently occluding pseudoaneurysms and as an adjunct in the exclusion of aneurysms in conjunction with detachable microcoils. The microcoils occupy most of the volume and provide a framework for polymerization. The combination of the microcoils and the liquid embolic ensures that virtually no filling of the aneurysm or pseudoaneurysm is possible. Additionally, with experience, n-BCA can also be applied to other locations that traditionally have been treated with other embolic agents. Accurate deposition and permanent occlusion results in a high degree of safety and efficacy that make it a preferred agent (Figure 2).

Delivery Systems

Technological innovations have led to the development of lower-profile, hydrophilic microcatheters and softer, smaller microwires than traditional .018-inch systems. These smaller-caliber delivery systems allow one to navigate tortuous anatomy and to go more distally than before to achieve a more focal occlusion at the site of pathology, thus resulting in targeted focal obliteration. These delivery systems can only be used in conjunction with liquid embolic agents or detachable

microcoils because they are too small to accommodate traditional embolic agents, such as particles or pushable microcoils. Some examples of microcatheters we currently employ include the Prowler (Cordis) at the .014-inch level and the Echelon (ev3) at the .01-inch level. Some examples of microwires we find useful in navigating tortuous distal vessels include the Silver Speed (.014- and .01-inch, [ev3]), as well as the miniscule Mirage (.008-inch, [ev3]).

VISCERAL ARTERY ANEURYSMS

Visceral aneurysms are uncommon but, when ruptured, are associated with a high mortality rate.³ Visceral aneurysms comprise both true and false aneurysms, with the clinical history and location of the aneurysm determining the probable etiology. The splenic artery is the most common location of true aneurysms.⁴ These aneurysms may grow and rupture, particularly in women during pregnancy. Other less common sites of true aneurysms include the hepatic, celiac, gastroduodenal, and superior and inferior mesenteric arteries. False aneurysms, or pseudoaneurysms, more commonly present with hemorrhage requiring urgent intervention. Pseudoaneurysm formation can be secondary to surgery, malignancy, or inflammatory processes, such as pancre-

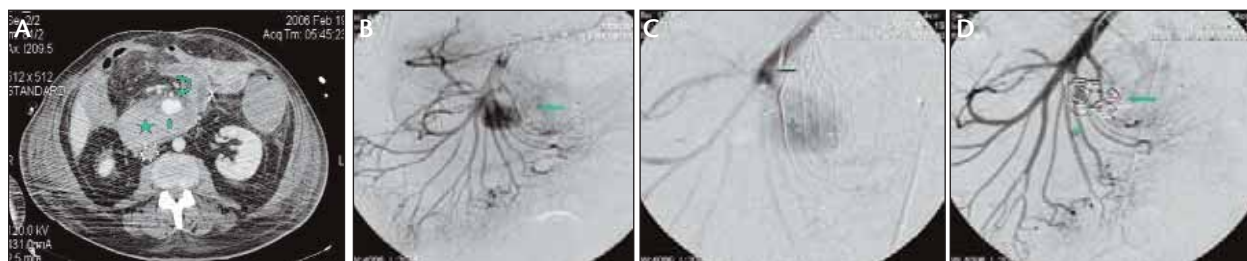


Figure 3. Intraoperative hemorrhage from jejunal pseudoaneurysm secondary to postoperative intra-abdominal abscess. Contrast-enhanced CT axial abdominal image demonstrates a large mesenteric hematoma (star) and pseudoaneurysm (small arrow) posterior to a branch of the superior mesenteric artery (SMA) (curved arrow) (A). SMA DSA demonstrates large pseudoaneurysm arising from branch of SMA (arrow) (B). Superselective DSA demonstrating catheterization of pseudoaneurysm (star) with a neck that is located at the origin of a jejunal artery (C). SMA DSA after embolization with detachable platinum and hydrogel-coated microcoils demonstrating no further filling into the pseudoaneurysm (arrows) and preservation of all jejunal branches (D).

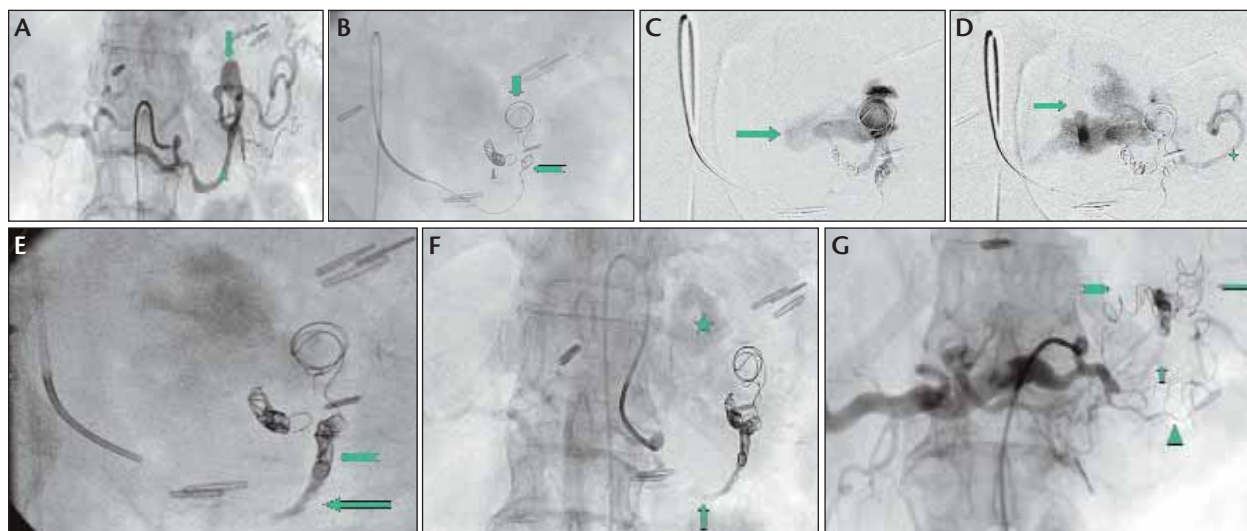


Figure 4. Massive upper gastrointestinal hemorrhage uncontrolled with endoscopy in a patient with metastatic esophageal carcinoma. Celiac arteriogram demonstrating pseudoaneurysm (arrow) arising in the midportion of the splenic artery (star) (A). Embolization of the outflow (triangle), pseudoaneurysm (vertical arrow), and inflow (horizontal arrow) vessels with detachable hydrogel-coated microcoils (B). Extravasation of contrast from pseudoaneurysm (arrow) indicating pseudoaneurysm rupture. At this point during the procedure, the patient developed massive hematemesis (C). Delayed image during embolization demonstrating massive hemorrhage from the ruptured pseudoaneurysm (arrow) (D). Further embolization with hydrogel-coated microcoils (rounded arrow) and 0.6 mL of 30% n-BCA (straight arrow). The glue was mixed emergently while the microcoil was being placed (E). Completion celiac DSA demonstrating occlusion of the pseudoaneurysm and splenic artery at the level of n-BCA (arrow) with no further extravasation noted. The patient immediately stopped bleeding clinically with stabilization. Note pooled residual contrast in the fundus of the stomach from the hemorrhage (star) (F). Celiac arteriogram 2 months later for recurrent upper gastrointestinal hemorrhage demonstrates persistent occlusion of the splenic artery at the n-BCA (short vertical arrow) with collateral vessels extending to reconstitute the distal splenic artery. Note the microcoils have changed position and migrated, underscoring the importance of the glue in performing pseudoaneurysm embolization, due to the potential malleability of the surrounding soft tissues (G).

atitis or intra-abdominal infection.⁵ With an increase in hepatic interventions and instrumentation, iatrogenic hepatic pseudoaneurysms are becoming increasingly common.⁶ Other locations for pseudoaneurysm formation include the splenic artery, the gastroduodenal artery, and even in mesenteric branches.⁷

The location and size of the aneurysm usually governs the therapy for elective repair. Some advocate treating all symptomatic visceral aneurysms, aneurysms in women of gestational age, and aneurysms >2 cm in size.⁸ However, there are instances in which bleeding and rupture necessitate emergent treatment, regardless

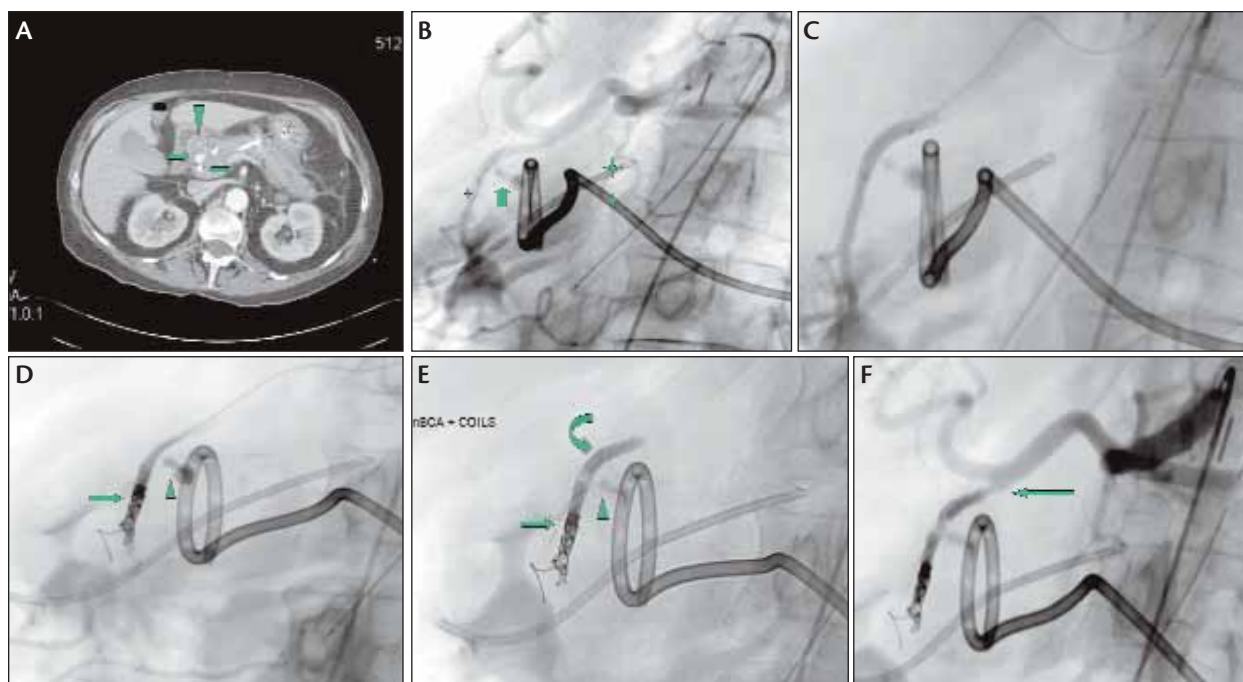


Figure 5. Upper GI hemorrhage secondary to gastroduodenal pseudoaneurysm associated with pancreatic pseudocyst drainage catheter. Contrast-enhanced CT axial abdominal images demonstrate the pseudoaneurysm (straight arrow) in relation to the drainage catheter (rounded arrow) and the gastroduodenal artery (triangle) (A). Celiac arteriogram demonstrating the pseudoaneurysm (arrow) arising from the gastroduodenal artery (GDA) (small four-point star). Note the drainage catheter (five-point star) and a pancreatic duct stent (larger four-point star) (B). Superselective gastroduodenal arteriogram again demonstrating the pseudoaneurysm with a small neck (C). Interval arteriogram after embolization of the distal gastroduodenal artery with hydrogel-coated microcoils (arrow) to prevent collateral reperfusion from the SMA. There is filling of contrast noted into the pseudoaneurysm (triangle) (D). Photospot image after embolization of proximal GDA (curved arrow) and pseudoaneurysm (triangle) with 0.6 mL of 40% n-BCA. Note the microcoils (straight arrow) (E). Postembolization celiac arteriogram demonstrates filling of the origin of the GDA with amputation at the level of the n-BCA (arrow). No filling into the GDA or pseudoaneurysm was demonstrated on the SMA injection as well (F).

of size, because aneurysms <2 cm may rupture as well. For a ruptured true aneurysm, open surgery may be necessary to perform aneurysmectomy and reconstruction, but operative mortality can be high (eg, 10%–25% for splenic artery aneurysms).⁹ If the patient can be stabilized, endovascular therapies, such as embolization or stent graft placement, are possible. However, the presence of branch vessels and tortuosity of the mesenteric vessels do not often lend themselves to stent graft placement due to the large delivery systems required. For a pseudoaneurysm, if one is able to catheterize the outflow vessel, coil embolization of the outflow and subsequently the inflow branches has been the standard therapy in preventing reperfusion via collateral pathways. However, there are instances in which the location at a branch point makes this risky. At our institution, the need for precise, controllable deployment to achieve focal, segmental occlusion using very small delivery systems has driven the use of advanced detach-

“If the patient can be stabilized, endovascular therapies, such as embolization or stent graft placement, are possible.”

able platinum and hydrogel-coated microcoils for extremely challenging vascular lesions, both in the elective and the emergent settings.

Many pseudoaneurysms will present with rupture, leading to gastrointestinal hemorrhage. Frequently, these patients have undergone endoscopy, which cannot always control the bleeding source. Furthermore, many patients who present with bleeding pseudoaneurysms often have significant comorbidities, such as a “hostile abdomen,” metastatic carcinoma, or pancreatitis, which make the morbidity and mortality of open surgical inter-

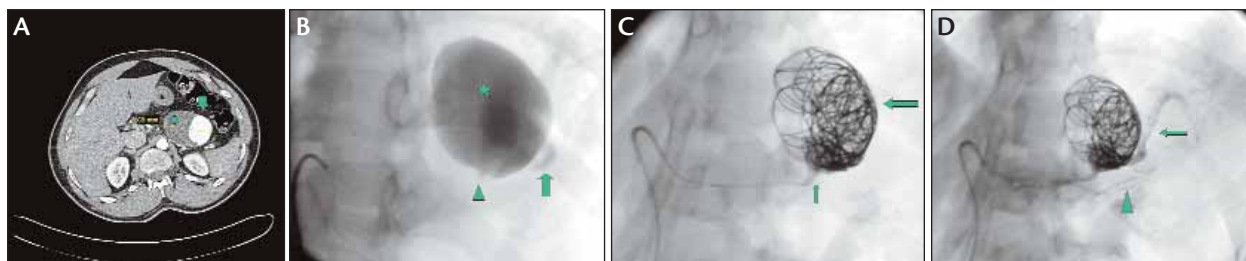


Figure 6. Large splenic artery pseudoaneurysm in a patient who fell off a bicycle 3 years earlier and complained of abdominal “fullness.” The patient was transferred from an outside institution after failed attempted endovascular embolization. Contrast-enhanced CT axial abdominal image demonstrating a large partially thrombosed splenic artery pseudoaneurysm with contrast (arrow) and thrombus (circle) noted. The pseudoaneurysm measured approximately 7 cm in size (A). Splenic arteriogram demonstrating inflow from the main splenic artery (triangle), filling into the aneurysm (star), and outflow into the distal splenic artery (arrow). Attempts at catheterizing the outflow branch were unsuccessful at the outside institution and ours. The patient was transferred specifically for the application of advanced embolization techniques (B). Embolization with detachable platinum and hydrogel-coated microcoils (horizontal arrow) and 1.1 mL of 40% n-BCA (vertical arrow). The microcoils were intentionally packed preferentially toward the base near the inflow and outflow branches. The glue filled the interstices of the microcoils, thus effectively sealing the pseudoaneurysm shut (C). Postembolization completion splenic arteriogram demonstrates complete occlusion of the pseudoaneurysm with no further filling. Note the pancreatic collaterals (triangle) that reconstitute the distal splenic artery with flow preserved to the spleen (D). The patient was able to avoid splenectomy, distal pancreatectomy, and reconstruction surgery. This case underscores the importance of sealing the outflow vessel.

vention prohibitive.

Although pushable coils have been successful in treating these lesions historically, one cannot always catheterize the outflow artery to achieve distal exclusion. In addition, the pushable coils can migrate or perform unpredictably, turning a simple case into a complex one with additional time spent attempting to retrieve a migrated coil. Pushable coils, with their inability to be repositioned, are particularly troublesome as their deployment approaches an important side branch or the parent vessel supplying the lesion because placement is less controllable and predictable. We have termed this the *one more coil* syndrome. When lesions are near the origin of the mesenteric branches or there are vital branches to preserve this becomes a major risk and limitation of this older, more traditional technology. Complications such as migration, thrombosis, or the inability to close the target vessel have been described.⁷ The risk of coil migration is reduced when using detachable microcoils because the microcoil is not released unless it is in a satisfactory position (Figure 3). Although migration can occur after release, it is unlikely if the lesion is in a low-flow vascular territory and proper coil sizing is utilized.

For high-flow lesions, the benefits of the detachable microcoil are even greater in minimizing coil migration and embolization into another vascular bed. We have applied a double microcatheter, single arterial puncture site technique to minimize the risk of migration of the coil mass in the setting of high flow and have previously

reported this technique in the setting of treatment of an aortic pseudoaneurysm with detachable hydrogel-coated microcoils.¹⁰ We have used this technique to overcome wide-neck aneurysms but have also reported it in the setting of high-flow pulmonary arteriovenous malformations.¹¹

In the setting of massive uncontrollable hemorrhage, the ability to embolize rapidly with n-BCA and detachable microcoils proved to be extremely useful (Figure 4). Although we have reserved their use in the past for complex interventions, we have found these agents valuable and versatile, even for technically less challenging cases, in order to minimize risk and facilitate precise, complete, and permanent segmental endovascular closure. The durability of the closure is more certain because these agents are very unlikely to reperfuse given the ability to tightly pack the microcoils together and fill any interstices with the liquid agent. Perfusion through bare metal coils can be demonstrated on angiography, even at times remote from the initial embolization procedure.¹² Furthermore, so-called permanent agents, such as PVA particles, can recanalize.¹³ The hydrogel-coating of microcoils expands, thus adding an extra level of insurance against recanalization and reperfusion through increased volume and density packing (Figure 5).

SPLenic EMBOLIZATION

There are a variety of clinical indications for embolization of the splenic artery. Proximal splenic

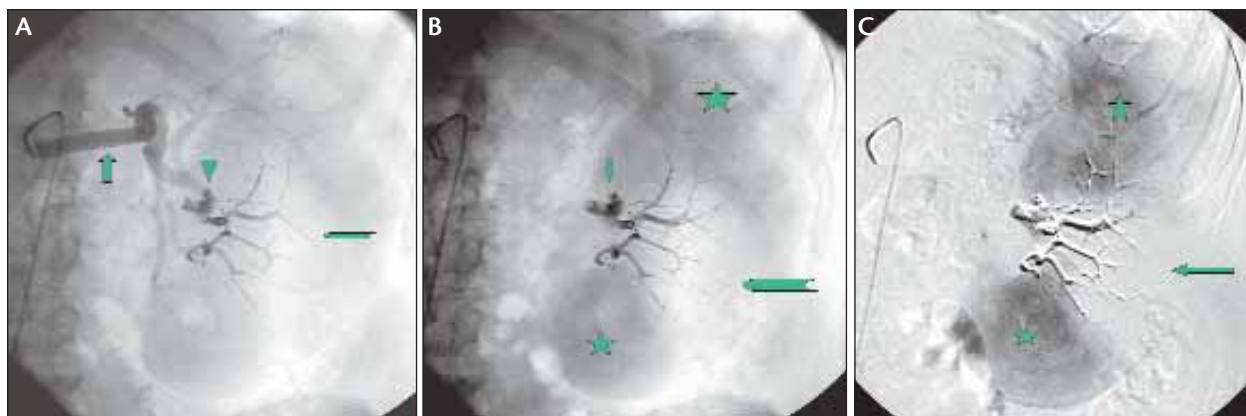


Figure 7. Partial splenic embolization for hypersplenism and thrombocytopenia. Postembolization splenic arteriogram demonstrates the main splenic artery (vertical arrow) with segmental occlusion of midpole branches of the spleen with n-BCA (horizontal arrow) and detachable hydrogel-coated microcoils (triangle). Approximately 1.5 mL of 30% n-BCA was used total (A). Splenic arteriogram (capillary phase) demonstrating infarction of the embolized midspleen (round arrow) and preservation of the upper and lower pole splenic parenchyma (stars). Vertical arrow depicts the microcoils (B). Splenic DSA once again highlights the preserved spleen (stars) and infarcted midspleen (arrow). The patient's platelet count rose from 40,000/ μ L to 110,000/ μ L after embolization (C).

artery embolization is a well-established, effective therapy in the management of splenic trauma.¹⁴ However, if focal splenic pseudoaneurysms can be demonstrated either in the traumatized parenchyma or near the hilum, they can be selectively embolized with n-BCA or other embolic agents distally. Given these new agents, we now prefer to perform the embolization distally, in a more targeted, focal fashion, if possible. This ability to target pathology so precisely still enables the interventionist to preserve splenic perfusion while minimizing the risks of rebleeding, infarction, and abscess formation.

Splenic aneurysms lend themselves readily to the use of advanced embolization agents and techniques. The endovascular option may allow one to avoid the morbidity of open surgery. Surgery may require, in addition to aneurysm resection and reconstruction, removal of the spleen and/or even the distal pancreas.⁴ Detachable coils and n-BCA expand the types of cases that can be treated without open surgery. Splenic infarction rates after embolization have been reported to be as high as 44%.¹⁵ We have had a successful experience using these advanced embolic agents and techniques in the spleen. Precise placement and preservation of side branches makes clinically important splenic infarction less likely. The combination of tightly packed, coated microcoils and liquid embolic agents affords complete, precise segmental occlusion of aneurysms. This technique should minimize the risk of persistent perfusion or recanalization of aneurysms and pseudoaneurysms treated (Figure 6).

Splenomegaly and hypersplenism present further

opportunities to apply endovascular techniques toward the goal of safer patient care. Preoperative embolization prior to splenectomy minimizes intraoperative blood loss.¹⁶ Partial splenic embolization can be performed to increase platelet counts in patients with hypersplenism and sequestration.¹⁷ We have found n-BCA and detachable microcoils to be useful agents for both indications (Figure 7).

CONCLUSIONS

Embolization for complex visceral arterial pathologies is a safe and effective therapy. However, a special consideration in the mesenteric vascular territory includes the presence of important branch vessels that supply vital adjacent structures such as the bowel, liver, pancreas, and spleen. Preservation of these branches can be challenging or impossible with pushable coils. In addition, perfusion can remain despite the presence of bare coils. Advanced techniques using detachable platinum and hydrogel-coated microcoils and n-BCA address most of the limitations of previously utilized agents.

With more experience and widening indications and availability of these agents, more complex cases should become amenable to endovascular therapy, thus obviating the need for open surgical repair. We envision that the widespread use of these techniques will lead to a paradigm shift in the way these challenging cases are managed. More cases are likely to be successfully treated using an endovascular approach, with a lower complication rate and a more durable result than those reported with more conventional embolic agents.

Furthermore, we have found these advanced techniques to be extremely useful beyond the visceral territories, facilitating embolization to treat pulmonary and renal vascular pathologies, as well as embolization for aortic aneurysm disease in both preoperative planning and postoperative endoleak management. ■

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