## A Practical Approach to Embolotherapy Access and Techniques

Considerations for tool selection in different scenarios.

BY PARAG J. PATEL, MD, AND QUINTON S. KELLY, MD

he drive to create safe and minimally invasive ways of treating disease has led to the development of a wide variety of embolization agents. Amidst the explosion in technology lies a practical approach to the access and delivery of embolotherapy. We present our approach, with particular consideration given to delivery devices and their compatibility with the variety of embolization agents used for the treatment of common pathologies.

After recognizing that a disease process may be amenable to treatment, one of the more challenging aspects of procedural planning is navigating myriad embolics, wires, sheaths, and catheters that are available and selecting those that will facilitate safe and timely access to the targeted vasculature. Embolotherapy is used in a variety of clinical settings, including bleeding complications from trauma, surgery, or inflammation, as well as several applications in nontrauma-related vascular and solid organ disease processes. A few more specific applications include presurgical devascularization of organs and tissues, 1 strategic avoidance of and treatment of stent graft-related type II endoleaks, obliteration of gastric and duodenal varices in patients with portal hypertension,3 improvement of symptoms related to enlarged uterine fibroids, 4 and of symptoms related to abnormally engorged vasculature, such as in pelvic congestion syndrome<sup>5</sup> and varicocele.<sup>6</sup>

There are obvious advantages to managing disease with this minimally invasive approach, not the least of which is the avoidance of surgery and collateral tissue damage. Initially, the approach to these procedures requires selection of an appropriate embolization agent, with consideration given to the size of the target vasculature, the desired permanence of vascular occlusion, and the impor-

tance of achieving or, contrarily, avoiding tissue ischemia.<sup>7</sup>

Having selected an appropriate embolic, the operator must then determine how to deliver it. Table 1 summarizes some of the common clinical scenarios in which embolotherapy is a valuable treatment modality. Commonly selected embolics are included in the context of frequently appropriate access vessels, proximal conduit vessels, access sheath size, angiographic catheter shape, and microcatheter size. Developing an algorithm applicable to every clinical scenario is a futile pursuit, as no two clinical scenarios are identical. However, a general understanding of the principles of embolotherapy and the frequently selected approaches to common scenarios will create a foundation upon which to develop greater confidence and creativity with these procedures.

A survey of these applications demonstrates several trends. For the majority of procedures, multiple embolization agents have been used with similar degrees of success. After an embolic agent has been selected, there is no single acceptable combination of access site, sheath, and catheter for its delivery. Any attempt to distinguish the various sheaths, angiographic catheters, and microcatheters employed in these procedures would be a gross oversimplification. Selection of one device over another is often a matter of operator preference, and the nuances of each device can only be learned through experience.

Generally, an access site is chosen that will provide the safest, shortest, and most anatomically feasible route to the target vasculature given the limits of what our sheaths and catheters can traverse. The common femoral artery (CFA) is typically utilized for access. Sheaths can vary with regard to their inner and outer diameter, length, and rigidity. The inner diameter (ID) of a 4- or 5-F vascular sheath will accommodate the placement and

Clinical Scenario	Embolic Agent	Access Vessel	Access Sheath	Proximal Conduit Vessel	Angiographic Catheter	Microcatheter
Upper Gastrointestinal Bleeding	-Gelfoam -Particles -Coils/microcoils	CFA	5 or 6 F	Celiac artery	-Berenstein -Cobra -Sos -Simmons	Large (0.027 inch) or small (0.018 inch) ID
Lower Gastrointestinal Bleeding	-Gelfoam -Particles -Coils/microcoils -nBCA	CFA	5 or 6 F	-SMA -IMA	-Berenstein -Cobra -Sos -Simmons	Large (0.027 inch) or small (0.018 inch) ID
Visceral/Renal Artery Aneurysms	-Coils/microcoils -nBCA -Amplatzer plug	-CFA -Radial/bra- chial	-5 or 6 F -Renal double curve	-Celiac artery -SMA -IMA -Renal	-Berenstein -Cobra -Sos -Simmons	Large (0.027 inch) or small (0.018 inch) ID
Visceral/Renal Arterial Injury	-Gelfoam -Particles -Coils/microcoils	CFA	5 or 6 F	-Celiac Artery -SMA -IMA -Renal	-Berenstein -Cobra -Sos -Simmons	Large (0.027 inch) or small (0.018 inch) ID
Pelvic Artery Injury	-Gelfoam -Particles -Coils/microcoils	CFA	5 or 6 F	-Hypogastric -External iliac	-Cobra -Roberts uter- ine	Large (0.027 inch) or small (0.018 inch) ID
Splenic Artery Embolization	-Gelfoam -Particles -Coils/microcoils -nBCA -Ethanol	-CFA -Radial/bra- chial	5 or 6 F	-Celiac artery	-Sidewinder -Reverse curve -Cobra	Large (0.027 inch) or small (0.018 inch) ID
Renal Artery Embolization	-Particles -Coils/microcoils -nBCA -Ethanol -Amplatzer plug	-CFA	5 or 6 F	-Renal artery	-Cobra -Sos -Vertebral	Large (0.027 inch) or small (0.018 inch) ID
Uterine/ Ovarian Artery Embolization	-Particles	-CFA	5 or 6 F	-Hypogastric	-Cobra -Rosch IMA -Roberts uter- ine	Large (0.027 inch) ID
Bland Embolization of Liver Tumors	-Particles	-CFA	5 or 6 F	-Celiac artery -SMA	-Cobra -Reverse curve	Large (0.027 inch) or small (0.018 inch) ID
Type 2 Endoleaks	-Coils/microcoils -nBCA -Onyx	-CFA -Direct punc- ture	5 or 6 F	-Aortic branch ves- sels (IMA, Lumbar Arteries)	-Berenstein -Cobra -Sos -Simmons	Large (0.027 inch) or small (0.018 inch) ID
Pulmonary Vascular Malformations	-Coils -Amplatzer plug	-Common femoral vein	7 F	-Pulmonary artery branch	-Long 7-F guiding cath- eter with coaxial 5-F catheter	Typically not utilized

Manufacturer Name	Access Sheath	Commonly Targeted Conduit Vessels	Size (F)	Length (cm)	Comments
Biotronik	Fortress	CFA/iliac artery	4	45–100	Shaped dilator and precurved sheath designed to facilitate stability in "up and over" lower extremity interventions. Thin wall design. Designed to limit need for vascular closure devices.
Cook Medical	Flexor Shuttle (Shuttle Select System)	Head and neck (carotid artery)	5-8	80-110	Popular for achieving stability in head and neck interventions. Can be paired with specially designed coaxial Slip-Cath hydrophilic catheters (several tip configurations) to simplify access and minimize device exchanges.
	Flexor Ansel	-Visceral applications -CFA/iliac artery	5–12	45–110	Gentler curves. Multiple available configurations (multipurpose, straight, renal double curve, etc.).
	Flexor Raabe	-Visceral applications - CFA/iliac artery	4–9	55-90	Can be "cold formed" into variety of shapes depending on conduit vessel anatomy leading to target vasculature.
	Flexor Balkin	-Visceral applications -CFA/iliac artery	5.5–8	40–45	Manufactured with 180° curve. Stabilizes access across the aortic bifurcation for contralateral iliac artery or limb interventions.
Covidien	The Sheath	-Visceral applications -CFA/iliac artery	7–8	55	Noted for ease of use and wide variety of applications.
Penumbra, Inc.	Neuron Delivery Catheter (several subtypes)	-Head and neck (carotid artery) -Visceral appli- cations -CFA/iliac artery	5-8	95–115	Engineered with multiple transition points and tapered shaft (eg. 6-F proximal, 5-F distal), thus highly flexible and ideal for navigation of tortuous anatomy for robust distal target vessel support.
Terumo Interventional Systems	Pinnacle Destination Guiding Sheath	-Visceral appli- cations -CFA/iliac artery	5-8	45–90	Highly visible ("triple radiopacity"). Noted for ease of use and wide variety of applications. Multiple available configurations (multipurpose, renal double curve, hockey stick, etc).

Manufacturer Name	Microcatheter	Endhole ID (inch)	Recommended Guidewire (inch)	Length (cm)	
Boston Scientific Corporation	Direxion Torqueable Microcatheter	0.021	0.018	105, 130, 155	
	Direxion HI-FLO Torqueable Microcatheter	0.027	0.021	105, 130, 155	
	Renegade Microcatheter	0.021	0.018	130, 150	
	Renegade HI-FLO Microcatheter	0.027	0.018	105, 115, 135, 150	
	FasTracker 325 Microcatheter	0.024	0.018	105, 135, 140	
Codman Neuro	Prowler Select Plus	0.021	0.018	150	
(Johnson & Johnson)	Prowler Plus	0.021	0.018	110, 135, 150	
	Prowler 27	0.027	0.018	150	
	Transit Microcatheter	0.021	0.018	135, 150	
	Rapidtransit Microcatheter	0.021	0.018	75, 155, 175	
Cook Medical	Cantata 2.5	0.021	0.018	100, 110, 135, 150	
	Cantata 2.8	0.025	0.021	100, 110, 135, 150	
	Cantata 2.9	0.027	Maximum 0.025	100, 110, 135, 150	
Covidien	Marksman 27	0.027	0.023	105, 135, 150	
Merit Medical Systems,	Maestro	0.020, 0.024, 0.027	0.021	110, 130, 150	
lnc.	EmboCath Plus	0.028	0.025	100, 135	
Penumbra, Inc.	PX Slim	0.025	0.014	150	
	Velocity	0.025	0.014	160	
Reverse Medical	ReVerse 21 Microcatheter	0.021	0.018	150	
	ReVerse 27 Microcatheter	0.027	0.025	150	
Terumo Interventional Systems	Progreat $\Omega$	0.027	0.025	110, 130	
	Progreat 2.7	0.025	0.021		
	Progreat 2.4	0.022	0.018		

exchange of selective angiographic catheters of different shapes and sizes used in these procedures.

The angiographic catheter suggestions included in Table 1 should be considered as a starting point when attempting to gain access to the targeted proximal conduit vessel. Additionally, guide sheaths and guide catheters, which are typically stiffer and more resistant to bending or buckling, are useful in situations where there is difficulty maintaining access to a particular artery (for example, using a renal double curve sheath to facilitate and stabilize access to the splenic or renal arteries).8 There are several manufacturers that have engineered variations of these commonly used sheaths. There is a steady introduction of new access technology, all striving for safer, more stable access. A sample of several specialty sheaths that facilitate access to target vascular territories in the majority of embolotherapy applications are summarized in Table 2. Note that their use in vascular territories may extend beyond the particular applications for which they were designed. Kink resistance, trackability, and soft, atraumatic tips are universally adopted manufacturing qualities.

For embolotherapy, a coaxial or often a triaxial system is created. The targeted proximal conduit vessel is selected either with an angiographic catheter or a specialty sheath. An angiographic catheter may then be advanced through a specialty sheath more distally toward the targeted anatomy. Once the target has been selected, a microcatheter is chosen for superselectivity and delivery of the designated embolic agent. As a general rule, catheters should not be advanced into vessels with diameters less than twice the catheter's diameter in order to avoid focal occlusion of the vessel or diminished antegrade flow. This problem is largely avoided with the use of microcatheters.

The microcatheters used in interventional radiology have tip shapes that range from straight to 90° of angulation and are advanced in a coaxial technique through the angiographic catheter to facilitate selection of more peripheral vessels within the targeted vascular territory. Microcatheters can navigate narrow or tortuous vasculature for more distal, selective deployment of embolic agents, thereby minimizing the potential for embolization of nontarget vessels. A catheter of appropriate size, length, and compatibility with the desired embolic is chosen for the specific procedure.

Currently available embolics can be categorized into proximal occluding agents (macrocoils, microcoils, plugs); distal occluding agents (particles such as polyvinyl alcohol and microspheres); liquids, and glues (alcohol, SDS, n-butyl cyanoacrylate [n-BCA], and ethylene-vinyl alcohol copolymer), which can be used for proximal and distal

occlusion; and temporary occluding agents (gelfoam, thrombin). While the approach to a target may be identical, the selected embolic agent or combination of agents may differ depending on the level, degree, and permanence of vascular occlusion. For example, splenic artery embolization performed to control extrasplenic hemorrhage typically requires more peripheral, generalized embolization with particles or gelfoam, although splenic infarction is more likely to occur. <sup>10,11</sup> Splenic artery embolization for control of intrasplenic hemorrhage typically requires delivery of coils or microcoils more proximally within splenic artery branches, in principle achieving hemostasis by reducing inflow pressure to target vasculature while simultaneously preserving collateral circulation and minimizing the potential for splenic infarct. <sup>12</sup>

A vascular target is always considered in the context of its surrounding vascular territory. Once a vessel has been selected distal to (thus excluding) nontarget vasculature, proximal occlusion of the vessel can be achieved (as with coils and plugs), or the body's native hemodynamics will carry particulate embolic agents more peripherally (as with gelfoam, particles, liquids, and glues) to achieve hemostasis with the desired degree of permanence.

The body's ability to develop collateral vessels in the setting of a proximal vessel embolization leaves open the possibility (and likelihood) of vessel reconstitution distal to the site of embolization, thereby revascularizing the target. This can be advantageous or a potential pitfall. In the treatment of gastrointestinal bleeding, collateral vessels grant the ability to achieve hemostasis by selecting culprit arteries at the level of the vasa recta without causing bowel infarct.13 However, in the treatment of vascular malformations, proximal vascular occlusion is ineffective due to eventual formation of distal collaterals. Additionally, subsequent treatment embolization attempts are made more difficult or impossible. Proximal occluding devices (coils or plugs) can be appropriate for fistula-like malformations, such as pulmonary or renal arteriovenous malformation. End arterial organs, such as the kidney, are poorly collateralized, increasing the importance of superselective embolization to avoid nontargeted tissue necrosis.

There are several technical considerations to keep in mind when selecting an appropriate microcatheter for embolotherapy. There is a spectrum of microcatheter outer diameters and IDs that range from 0.015 inch (Asahi Corsair, Asahi Intecc USA, Inc., Santa Ana, CA) to much larger, although for the purposes of this article, the range of sizes has been simplified to IDs that are large (approximately 0.027 inch) or small (approximately 0.018 inch). Some microcatheters are available as a packaged system with a microwire-preloaded microcatheter

(eg, Fathom-16 or Transend-14, Direxion, and Direxion HI-FLO preloaded systems, Boston Scientific Corporation, Natick, MA).

As the ID of the catheter decreases, the ability to transmit more viscous or concentrated solutions of particles is significantly reduced. Polyvinyl alcohol and particles are significantly more difficult to inject through microcatheters with small IDs. Particles < 700 microns will generally function through microcatheters with IDs of 0.021 inch. However, particles > 900 microns typically require use of traditional angiographic catheters (0.038 inch) to allow for smooth delivery and to prevent clumping or occlusion within the catheter lumen.<sup>14</sup> For similar reasons, microcatheters with large IDs are recommended for gelfoam injections. Pushable microcoils and some detachable microcoils (eg, Interlock coils, Boston Scientific Corporation) should be deployed through microcatheters with small IDs (0.021 inch or less) to avoid having the coil inadvertently deploy within, and thereby become thronged within, the lumen of larger microcatheters. The Ruby line of detachable coils (Penumbra, Inc.), specially designed for peripheral applications, has diameters similar to the 0.035-inch macrocoils such as Nester or Tornado (Cook Medical, Bloomington, IN) but can be delivered through some larger-diameter microcatheters. There are vascular plugs that can be deployed through microcatheters with 0.021- and 0.027inch IDs (MVP-3 and MVP-5, Reverse Medical, Irvine, CA). However, the majority of large vascular plugs are delivered through guide sheaths or guide catheters, with intermediate sized plugs (up to 8 mm) delivered through standard angiographic catheters (Amplatzer vascular plugs, St. Jude Medical, St. Paul, MN). Generally, manufacturers of embolic particles, coils, plugs, etc publish recommended minimum IDs for catheter delivery based on size. Thus, it is important to check the compatibility of the selected embolic with the microcatheter ID before any procedure.

Select embolic agents are only compatible with certain microcatheters. Ethylene vinyl alcohol copolymer (Onyx liquid embolic system, Covidien) and n-BCA (Trufill DCS, Codman Neuro [Johnson & Johnson], Raynham, MA) are two of the most commonly used liquid embolics. Both agents are difficult to use compared to other embolics and are dangerous in inexperienced hands due to the extensive technical considerations and methods required for their use.15

The microcatheters utilized for delivery of n-BCA must be flushed with 5% dextrose solutions to prevent polymerization of the agent in the microcatheter. The transit time in the selected catheter must also be considered, with different ratios of the n-BCA, tantalum powder, and ethiodized oil varying the polymerization time of the agent. Also, the microcatheter must be removed immediately

after delivery of the n-BCA, and the microcatheter tip evaluated for tip fracture.

Although these agents can be delivered through microcatheters with both large and small IDs, catheter compatibility is a concern, and it is important to verify that the catheter selected to deliver these agents will withstand the high pressures associated with their delivery (Onyx) and not trigger polymerization within the catheter or degrade with contact (n-BCA). The n-BCA-compatible microcatheters (Prowler, Transit, Rapidtransit [Codman Neuro]) and Onyx-compatible microcatheters (Marathon, Rebar, Ultraflow, Echelon [Covidien]) are clearly recommended by their respective manufacturers. Not all microcatheters are designed or appropriate for embolotherapy applications. Excluding those microcatheters specific to delivery of Onyx, a sample of commonly used microcatheters for embolotherapy procedures are listed in Table 3.

There has been immense growth in the field of embolotherapy over the past decade. The number and sophistication of new embolics and the tools to deliver them continues to increase. As the role of embolotherapy expands in a variety of clinical scenarios, an understanding of the basic principles and techniques used for access and treatment will facilitate more successful outcomes.

Parag J. Patel, MD, is an interventional radiologist and Assistant Professor of Radiology and Surgery at Froedtert and The Medical College of Wisconsin in Milwaukee. He has disclosed no financial interest related to this article. Dr. Patel may be reached at papatel@mcw.edu.

Quinton S. Kelly, MD, is an incoming interventional radiology fellow at Froedtert and the Medical College of Wisconsin in Milwaukee. He has disclosed no financial interest related to this article.

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