

Chapter 8

Fundamental Techniques in Endovascular Treatment

W. Austin Blevins and Peter A. Schneider

1 Endovascular Revolution

Endovascular procedures are an integral part of the practice of vascular surgery. Advances over the last 4 decades, and particularly over the last 20 years, have changed the scope of vascular practice and the treatment of vascular disease. Endovascular techniques were initially only useful in patients with less severe anatomical patterns of disease (e.g., focal stenosis of the iliac or superficial femoral artery). The evolution of techniques, equipment, and attitudes has yielded the current situation in which endovascular intervention is viewed as a reasonable first approach and/or alternative in the treatment of most vascular lesions. Developments in catheters, guidewires, stents, endografts, distal protection devices, and CTO devices and advancing knowledge about how to use them offer promise for further advancements in the next few years.

W.A. Blevins, M.D.
Kaiser Permanente Medical Group, Honolulu, HI, USA

P.A. Schneider, M.D. (✉)
Division of Vascular Therapy, Hawaii Permanente Medical Group,
Kaiser Foundation Hospital, 3288 Moanalua Road, Honolulu, HI 96819, USA
e-mail: Peter.schneider@kp.org; peterschneidermd@aol.com

The role of endovascular procedures continues to evolve as new technology is developed and long-term data on procedure outcomes become available. In general, endovascular procedures are less morbid and patients have shorter recovery periods. This early benefit should be weighed against long-term outcomes, as well as the need for additional interventions and more frequent surveillance following endovascular procedures. In many cases endovascular interventions have drastically changed the treatment of specific lesion as is the case with iliac angioplasty and stenting, largely replacing open aortofemoral bypass. The distribution of endovascular and open cases varies from one institution to another. At our facility, arterial revascularizations are comprised of endovascular techniques in 70% of cases and open surgery is used in 30%. Open surgery is used for aneurysm patients with short or otherwise unsuitable necks, carotid stenosis patients who do not qualify for stents, and the majority of patients with branch vessel disease and lower extremity disease, including critical limb ischemia due to tibial occlusive disease.

2 Patient Selection for Endovascular Evaluation

1. Clinical Evaluation—In general, patient selection for endovascular repair is dependent upon specific factors, such as the severity of the clinical problem, the fitness of the patient for surgery, and the anatomic morphology and pattern of the vascular lesions. Much can be learned about these factors at the bedside using history, physical exam, and a handheld Doppler.
2. Duplex Ultrasound—Inexpensive and usually readily available, noninvasive screening tool for identification of luminal narrowing and changes in flow velocity. This modality is operator dependent and vascular labs are required to periodically standardize their results against angiographic studies. When integrated into vascular practice and performed by technologists who understand the treatment options, this tool can significantly streamline the evaluation of patients by indentifying levels and severity of disease prior to treatment.
3. CTA—Improvement in the quality of CT scanners and the ability to create 3D reconstructions of lesions have replaced diagnostic angiography in many practices. This modality provides additional

information about the characteristics of the arterial wall (degree of calcification) as well as anatomic relationships to surrounding structures and can be used with success for case planning. This has been particularly valuable in planning stent-graft treatment of all types of aneurysms.

4. **MRA**—Similar to CTA, MRA is a noninvasive modality providing excellent soft tissue imaging. MRA is more expensive and its use is limited by the presence of a pacemaker, metal implants, or claustrophobia. Details about lesion morphology can be obtained with newer MRA programs.
5. **Angiography**—Excellent confirmatory tool of other imaging modalities, though typically redundant from a strictly diagnostic standpoint. Conventional angiography continues to have utility in emergencies such as acute limb ischemia, mesenteric ischemia, and for diagnostic dilemmas. An angiogram is usually performed to plan or to guide vascular repair.

3 Diagnostic Angiography

1. **Access**—Access site selection should take into consideration the proximity to the site of interest, the possibility of intervention, and the risk of complications. The goal is to utilize the smallest entry method that provides safe and effective access. Large caliber transfemoral percutaneous access (>12Fr) can be obtained now that closure devices are available. Percutaneous brachial access can be obtained up to 7 Fr, but beyond that, consider open arterial exposure. The most commonly utilized sites for diagnostic angiography are the femoral, brachial, and radial arteries (Table 8.1).
2. **Femoral**—This is the most common and versatile access site. Access can be either retrograde (pointed superiorly toward the aortic bifurcation and against the direction of flow) or antegrade (pointed inferiorly toward the foot and in the direction of flow).
 - (a) **Landmarks**—Identify the inguinal ligament (running between the anterior superior iliac spine and pubic tubercle). Optimal CFA access is 1–2 cm inferior to the inguinal ligament. Caution should be used when using the groin crease as a landmark as this is often displaced distally, especially in obese patients.

Table 8.1 Percutaneous access site selection

| Puncture site | Approach | Arteries that can be interrogated | Discussion |
|---------------------|------------|---|---|
| Femoral | Retrograde | Aorta and its branches | This is the most common access and can be used to access any arterial bed from the coronary and cerebral to the tibials |
| Femoral | Antegrade | Ipsilateral infrainguinal | Best approach for a distal tibial or pedal intervention, usually not required for diagnostic angiography. Contraindicated when there is inflow disease or the patient is obese |
| Brachial/ radial | Retrograde | Aorta and its branches including coronary and cerebral arteries | Any vascular bed can be visualized, but it can be a challenge to perform tibial and pedal angiography because of the long distance involved. Brachial puncture has a slightly higher risk |

- (b) Fluoroscopy—Identify the femoral head. The CFA usually passes over the medial portion of the femoral head inferior to the inguinal ligament and is the area where arterial access should be obtained. Puncturing the artery proximal to the femoral head is too proximal and will likely result in access of the external iliac increasing the risk of retroperitoneal hematoma.
- (c) Palpate—Pin the artery between the index and middle fingers of your nondominant hand and use the dominant hand to pass the needle. Ultrasound guidance may be utilized to confirm the relationship to the profunda femoris and inguinal ligament.
- (d) Technique—The angle of approach is typically 45° or steeper. Only the anterior wall of the artery is punctured and a guide-wire passed once pulsatile return is obtained. Once wire access is obtained, confirm the position with fluoroscopy, remove the access needle, and introduce the access sheath/dilator over the

wire. Flush the side port of the sheath after aspirating until return of blood in the syringe to remove air.

3. Brachial—This is an alternate choice of access for patients with unfavorable femoral anatomy or previous femoral bypass procedures. The left arm is preferred because right arm access results in crossing both carotid artery ostia increasing the risk of stroke. Brachial access provides for easier access of down-sloping mesenteric vessels. Treatment of lesions distal to the superficial femoral artery is limited due to the distance traversed and the lengths of available sheaths, catheters, and balloons.
 - (a) Landmarks—The brachial artery is usually superficial and easily palpable along the medial arm proximal to the antecubital fossa.
 - (b) Technique—A steeper angle of approach is recommended. Wire access and sheath placement are performed similar to femoral access. Following removal of the sheath, meticulous hemostasis is mandatory. Hematoma at a brachial access site can result in median nerve compression.
 - (c) Duplex USG—Provides useful visualization to access the brachial artery.
4. Radial—This site is typically reserved for diagnostic angiography of cardiac vessels but may also be used for other types of diagnostic angiography.

4 Venography

1. Venography has largely been replaced by venous duplex in the diagnosis of deep venous thrombosis (DVT). Utility of venography still exists for thrombolytic therapy of acute venous thrombosis as well as to define anatomy for venous bypass or valve reconstruction. Venography is also performed in the evaluation of iliac vein obstruction in preparation for reconstruction and also gonadal vein reflux in pelvic congestion syndrome.
2. Diagnostic venography consists of ascending and descending studies. Ascending venography requires distal access (distal great saphenous or vein of the dorsum of the foot) with infusion of contrast oriented toward the vena cava. The patient should be

placed in 30°–45° reverse Trendelenburg without weight bearing (no footboard). The superficial and deep systems can be visualized. Once images are obtained of the leg, the table is returned to the horizontal position and the leg elevated to obtain pelvic images. More proximal access (the popliteal vein) is usually used for catheter-directed thrombolytic therapy. Descending venography consists of accessing the contralateral femoral vein using an up and over technique to position a flush catheter in the proximal femoral vein. The patient is placed in reverse Trendelenburg and is asked to do a Valsalva maneuver to increase intra-abdominal pressure and decrease return to the vena cava. Contrast boluses are administered to assess valvular competence. Contrast flows distally and through incompetent valves.

5 Contrast Injectors

1. Power Injectors—Power injection is required to opacify large volume arteries such as the aorta. Settings can be adjusted to perform angiography of smaller vessels as well. Caution should be used when there is a risk of damaging the artery. Don't use power injection when the tip of the catheter is within the lesion, when the tip is within an aneurysmal segment with thrombus, when the tip is oriented against the wall of the artery, or if there is redundancy (slack) in the catheter.
 - (a) Use of the power injector. The reservoir is loaded with contrast that may be full strength or dilute (e.g., 25% or 50%). The extension tubing is sterile and the line is purged of air when connecting to the angiographic catheter.
 - (b) Settings—Pressure, Rate of rise, Volume administered per second, total to be delivered. These settings reflect the vascular bed to be interrogated and the catheter through which it is to be administered. A multi-sidehole flush catheter can be used to high pressure (800–1,000 psi). Evaluation of the aorta requires larger volume: 30 ml for the aortic arch and 20 ml for abdominal aorta. End hole diagnostic catheters are used at lower pressure (250–500 psi) and volume (3–5 ml per second). The rate of rise is used in smaller branch arteries such as carotid or renal to permit the pressure of injection to increase slowly (e.g., over 0.5 s).

2. **Hand Injection**—Fast and simple. Useful in smaller caliber vessels, when the required volume of contrast is less than 10 ml or in low flow vessels. This approach is usually employed when using an end hole diagnostic catheter.
3. **Types of iodinated contrast**
 - (a) **Nonionic versus Ionic**—Nonionic contrasts are used today and most are iso-osmolar or slightly hyperosmolar and this significantly reduces discomfort. Incidence of anaphylaxis is similar between the two. A high iodine concentration improves visibility.
 - (b) **Osmolarity**—Iso-osmolar agents are preferred. Better tolerated by the patient and result in less physiologic damage.

6 Basic Equipment for Angiography

1. **Needles**—No. 18 straight angiography entry needle; the lumen is adequate to pass a 0.035 in. diameter guidewire into the vascular system. Coaxial Micro puncture set (Cook, Inc., Bloomington, Indiana, USA)—21-gauge needle with a 0.018 in. guidewire and a 4 or 5Fr dilator.
2. **Access Sheaths**—A standard access sheath has a side port for the administration of medications or contrast. Measured based on their ID (inner diameter), 4Fr to 7Fr sheaths are used most commonly for peripheral interventions with larger sheaths required for stent-grafts. Most angiography is performed with 4 or 5Fr catheters and sheaths. A standard access sheath for diagnostic angiography is 12–15 cm in length. Sheaths that support interventions may be obtained up to 110 cm in length.
3. **Guidewires**—Diameter ranges from 0.014 to 0.038 in. Lengths range from 145 to 300 cm. The length of the wire must be long enough to cover the cumulative distance from the access site to well beyond the lesion as well as the length outside the patient to support the longest catheter that is required for the procedure (65 to 145 cm). Access wires should have a floppy tip and be atraumatic. Multiple characteristics including stiffness (support), coating, tip shape, and steerability need to be kept in mind. General types of guidewires are listed below. Guidewire handling skills are included in Table 8.2.

Table 8.2 Guidewire Handling Skills

1. Wet the guidewire with heparin–saline solution
 2. Introduce the tip of the guidewire through the entry needle hub
 3. Use fluoroscopic guidance when advancing a guidewire, especially when encountering lesions
 4. Maintain hand control of the guidewire until you are certain it is secure in the artery
 5. Don't force the guidewire
 6. Rapid incremental advancement of the wire increases the chance of kinking the wire or inadvertent passage into a branch
 7. Caution when the guidewire tip encounters the lesion
 8. Shape the guidewire tip by running a metal clamp over the tip of the wire while holding the wire between the clamp and your thumb
 9. Have a torque device available for steerable guidewires
 10. Pin the wire during exchanges and when advancing catheters. Remove any slack from the wire without withdrawing the guidewire
 11. Use a pin and pull technique to remove catheters to ensure that the tip of the wire does not migrate
 12. Wipe the wire with heparin–saline after each exchange
 13. Ensure intraluminal position of the wire before passing any endovascular device
 14. Handle a hydrophilic coated wire with a pincer grasp (between the thumb and forefinger)
 15. Place a towel over the end of the guidewire outside of the patient to prevent the wire from falling off the table. A shodded clamp can also be used for wire identification when using a buddy wire technique (two wires through the same access sheath)
 16. Contamination of the wire requires removal of the wire or cutting contaminated end of the wire, provided adequate length remains for exchange
 17. Place a catheter over the guidewire when additional stiffness or pushability is needed
 18. Exchange a kinked or bent wire
 19. Do not give up wire access! Leave the guidewire in place until the procedure is finished
 20. The way the guidewire feels as it advanced and the appearance using fluoroscopy give clues to optimal handling of guideiwres and can only be learned on the job
-

- (a) Workhorse/general use: This is typically a medium support guidewire with a soft, somewhat floppy and atraumatic tip.
- (b) Exchange: Stiff guidewire that can be used to help straighten anatomy and assist passage of a sheath or a larger endovascular device.

Table 8.3 Catheters in endovascular practice

| Catheter type | Catheter | Function | Length |
|---------------|--|--|---------------------|
| Flush | Pigtail | Aortography | 65, 90 cm |
| | Tennis racket | | |
| | Omni-flush | | |
| Exchange | Straight | Exchange guidewires | 70, 100 cm |
| Selective | Simple curve (bend at tip) or complex curve (complex bend or reverse curve at tip) | Assist cannulation, support guidewire, and are used for crossing the lesion; complex curve catheters are used for cannulation challenging or tortuous carotid arteries | 40, 65, 100, 120 cm |

- (c) **Steerable:** A steerable guidewire allows a 1:1 turning ratio between the shaft of the wire and the tip. A common steerable guidewire is the Glidewire which also has a hydrophilic coating. The smaller caliber guidewires can typically be shaped at the tip to adjust the degree of curvature.
- (d) **CTO:** These are smaller caliber guidewires (0.014 or 0.018 in.) that have a stiff shaft and a relatively stiff tip for use in a chronic total occlusion.
4. **Catheters—**Measured based on their OD (outer diameter). A 5 Fr OD catheter fits into a 5 Fr ID sheath. A variety of lengths (40—120 cm) and shapes may be obtained. Catheters may have a single hole at the tip for contrast administration or there may be multiple side holes plus an end hole (Table 8.3).
- (a) **Flush:** Multiple side holes, straight or rounded head shapes, used for administration of contrast into large arteries, like the aorta.
- (b) **Selective:** Single end hole, multiple head shapes. The shape of the catheter tip may be specialized to a specific task, such as cannulating the carotid or renal arteries. These specially shaped catheters are also integral to supporting cannulation in difficult situations.
- (c) **Exchange:** Single end hole, straight. These are used to exchange the guidewire, typically to insert a stiffer exchange guidewire in preparation of an endovascular intervention.
- (d) **Infusion:** Multiple side holes, straight, used for thrombolytic therapy.

References

1. Schneider PA. Endovascular skills. 3rd ed. New York: Informa; 2009. p. 1–471.
2. Hodgson KJ, Hood DB. Endovascular diagnostic. In: Cronenwett JL, Johnston KW, editors. Rutherford's vascular surgery. Philadelphia, PA: Saunders; 2010. p. 1262–76.
3. Singh H, Cardella JF, Cole PEH, et al. Quality improvement guidelines for diagnostic arteriography. Society of Interventional Radiology Standards of Practice Committee. *J Vasc Interv Radiol.* 2003;14:S283–8.
4. Neequaye SK, Aggarwal R, Van Herzeele I, et al. Endovascular skills training and assessment. *J Vasc Surg.* 2008;47:1008–11.
5. Dotter CT, Rosch J, Robinson M. Fluoroscopic guidance in femoral artery puncture. *Radiology.* 1978;127:266–7.