Advances in Angiography and Their Impact on Endovascular Therapy

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Abstract

Transvascular therapy has progressed rapidly due to improvements in imaging equipment and endovascular devices. Interventional fluoroscopic equipment and portable machines are able to produce high-resolution digital images in well-lighted procedure rooms.

Catheters and guidewires are now available in a variety of shapes, diameters and lengths, allowing entry into distal, small, and tortuous vessels. This in turn permits targeted local therapy of tumors and bleeding sites, as well as endovascular treatment of diseased vessels.
Key Words: Angiography, endovascular therapy.

IMPROVEMENTS IN IMAGING and endovascular diagnostic and therapeutic devices such as catheters, guidewires, balloons and stents have promoted the growth of endovascular and transvascular therapy.

Imaging in the Modern Interventional Suite

Basic Room Design

The design of dedicated interventional suites has progressed with the realization that these rooms will function as operating rooms. In fact, many procedures performed in interventional rooms in the radiology department may be more complex and potentially more dangerous than those performed in the traditional operating room. For this reason, interventional radiology rooms are constructed with adequate space for procedure tables, Mayo stands and other equipment. In addition, there must be adequate space for anesthesia staff and their equipment. These rooms are now designed with wall suction and appropriate gas lines. Many rooms are "OR compatible," meaning that the floors, ceiling and cabinets meet operating room specifications. In addition, the number of air exchanges per minute must meet local health code standards. Electrocardiography, pulse oximetry, and blood pressure monitoring may be done only in rooms where conscious sedation or anesthesia is administered.

Most major X-ray manufacturers have designed their rooms so that the gantry of the unit can be placed at the head of the table or on either side of the table. This assures easy access to either groin for femoral artery and/or vein puncture, as well as access to the neck for transjugular procedures. In addition, the TV monitors are usually placed on a movable track system, which allows them to be moved to either side of the table for viewing. Finally, many of the imaging controls are at tableside, allowing manipulations such as shutter control, image size adjustment, roadmapping and filming to be performed by the physician (1).

Fluoroscopy

The replacement of conventional fluoroscopy with image intensification coupled to a TV chain has permitted fluoroscopically guided procedures to be performed in a lighted room. This has added an element of comfort for the operator as well as increased safety for the patient. The use of image intensification has also decreased the amount of X-ray exposure necessary to produce an adequate real-time image. The dose of radiation to both the patient and operator also has been decreased with the advent of better collimation and pulsed fluoroscopy (2,

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3). This has become more important as procedures using fluoroscopic techniques have become longer. Nevertheless, it is important to keep track of total fluoroscopic time. Reports have appeared of radiation-induced skin burns related to long procedures such as transjugular intrahepatic porto-systemic shunting (TIPS), cardiac catheterization, etc. (4 – 6).

One cannot overemphasize the importance of high-quality fluoroscopic equipment that is coupled to TV chains in which the resolution of the monitors is 1,024 lines. This affords excellent resolution which allows visualization of very small catheters and guidewires as well as clear imaging of small vessels.

Roadmapping is a technique built into most new interventional imaging systems. This allows the operator to visualize the course of a catheter and/or wire through a previously opacified vessel, the image of which is stored and displayed on a TV monitor. This technique facilitates the catheterization of specific branches without the need for guidewire removal or repeated injections of contrast material to define catheter position.

Image Recording

Until recently, most angiography rooms were equipped with some sort of rapid film changer. To continue filming usually required moving the patient over the film changer, where a second-ceiling mounted X-ray tube was used to make the film exposures. This proved cumbersome, and catheters were often dislodged during movement of the patient. The problem was overcome by mounting the film changer next to the image intensifier in such a fashion that it could be moved into place without moving the patient. In such systems, the same X-ray tube is used for fluoroscopy and film exposure. These film changers are still available as an option for most interventional rooms. However, film changers are rarely used nowadays, because of the time and expense associated with conventional film processing and because of the availability now of digital imaging techniques.

The newer digital angiography equipment provides resolution that is quite acceptable for all vascular procedures. Thus, most new rooms have digital subtraction angiography as the standard means of recording vascular images. These rooms also have software that allows the images to be post-processed. Techniques such as pixel shifting allow misregistration artifacts to be eliminated. Subtraction can be done in real time or the bony background can be restored when indicated. Brightness and contrast controls allow image improvement to be controlled by the physician or technician. Finally, the images are stored and archived in a digital format, thus eliminating the problem of lost films.

Portable C-arm fluoroscopic units, which are now also available, allow most of these techniques to be employed in the operating room or at the bedside.

Ultrasound Guidance

Many interventional rooms have the available option of an integrated ultrasound unit. Some interventionalists use units which can be moved from room to room. These can be used to "find" vessels to puncture, particularly veins. The internal jugular vein is a common site for venous access procedures, inferior vena cava filter placement, and pulmonary arteriography. The complication of inadvertent carotid artery puncture and pneumothorax are all but eliminated when ultrasound guidance is used.

Small dedicated ultrasound units are also useful for performing percutaneous nephrostomy, abscess drainage, peritoneal catheter insertion and thoracentesis of loculated collections.

Computed Tomography and Magnetic Resonance Imaging

Computed tomography (CT) and magnetic resonance imaging (MRI) are increasingly useful in the management of patients with vascular disease (7).

Needles and Entry Systems

Needles

Vessels are usually punctured using "single-wall" or "double-wall" needles. The single-wall needle has no stylet, so that when the vessel is punctured, blood returns as the needle enters the lumen. Using it provides the advantage of avoiding the puncture of the posterior wall of the target vessel. However, it is not uncommon to traverse the vessel and not get blood return. This probably results from the anterior wall of the vessel collapsing against the posterior wall as the puncture is being performed. For this reason, it is important to withdraw a single-wall needle slowly, while looking for blood return. Using the single-wall needle also has the disadvantage of making guidewire exchange more difficult, since there is no stylet to replace while a new wire or one of different shape is obtained.

The "double-wall" or Seldinger needle has a stylet, which actually punctures the vessel. Once the stylet is removed, one is left with a blunt cannula tip in the vessel. The major disadvantage of using this needle is that there is a puncture in the posterior wall of the vessel, which may be a site for bleeding, particularly in patients with coagulation disorders or hypertension. However, one can perform a single-wall puncture with this needle in 20–30% of cases when the maximum pulsation of the vessel is transmitted to the hand holding the needle. A short thrust at this site will allow an anterior-wall-only puncture.

Micropuncture Sets

Micropuncture sets come as 4 or 5F systems. The vessel is punctured with a 21-gauge needle through which an 0.018 inch guidewire is advanced. The needle is removed and the micropuncture sheath is advanced over the wire into the vessel. The 0.018 inch wire and the inner sheath are removed, leaving the outer 4–5F sheath in place. An 0.035 inch wire is then advanced into the vessel, and this wire is used to complete the standard catheterization. By starting with a 21-gauge needle, the risk to the vessel or adjacent non-target structures is minimized.

Larger systems such as the 6F Neff set (Cook Inc., Bloomington, IN) and Accustik® (Boston Scientific, Watertown, MA) also allow the operator to progress from a 22–21 gauge needlestick to placement of these 6F sheaths. These are longer than the micropuncture sets and are adaptable to transhepatic hepatic vein, portal vein and biliary duct punctures. They are also widely used as access for abscess drainages and percutaneous nephrostomy. They may also be used for translumbar puncture of the aorta and vena cava. These 6F sheaths will accept 4F diagnostic catheters with various shapes, so that selection of branches may be performed without removing the sheath.

Catheters and Guidewires

Standard Diagnostic Catheters

A wide selection of diagnostic catheters is now available from many manufacturers. It is the responsibility of the angiographer/interventionalist to be familiar with the variety of shapes, sizes, lengths, coatings, and handling characteristics of available products. A particular catheter may be ideal for one situation and unsuitable for another. For example, a hydrophilic catheter may track better in a tortuous vessel, but may be too slippery in the operator's hands in another situation requiring application of high torque. While polyethylene-and-nylon-composite catheters work well as conduits for stainless steel embolization coils, these coils may become impacted in polyurethane catheters due to the high coefficient of friction of this material.

Radio-opacity of catheters is important, so that they can be visualized fluoroscopically. Manufacturers have increased radio-opacity of the catheter tips and distal curved portions, so that manipulations during fluoroscopy are more easily observed.

The diameters of diagnostic catheters have decreased as newer materials and manufacturing techniques have evolved. Standard diagnostic catheters are now in the 4–5F range. The small size of these catheters is associated with a lower rate of complications at the puncture site and makes ambulatory procedures more feasible.

Microcatheters

Small flexible catheters, which can be passed through the lumen of a standard 5F catheter, have gained wide acceptance as a means of performing catheterization of small, more distal vessels (Fig. 1). Thus, chemoembolization of tumors in the liver or remote sites is now routine. These microcatheters can be used to deliver chemotherapeutic agents and can also deliver particles and coils to bleeding sites (8). Since these catheters are in the 2–3F range, they often have a gold or platinum bead on the catheter tip or on their guidewires to facilitate fluoroscopic observation.

Guidewires

Guidewires come in a variety of lengths, diameters, stiffnesses, and coatings. Most standard guidewires have a Teflon coating. It is important to remember that the distal tip of a wire may be straight or have a variety of distal J-like curves. Some wires have a shapeable distal tip. The other variable is the amount and length of softness ("floppiness") of the distal portion of a guidewire.

The standard diameters of guidewires are 0.035 and 0.038 inches. Microcatheters use

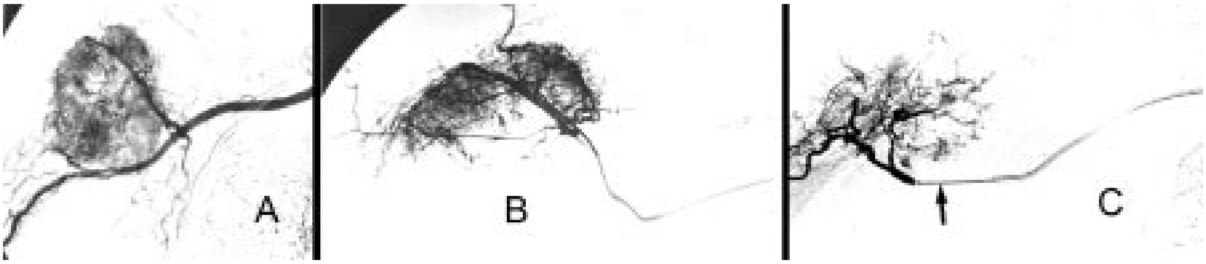

Fig. 1. Renal cell carcinoma metastatic to the humerus. Use of microcathether for preoperative embolization. **A.** Subclavian artery injection via 5F H1H catheter inserted via the right common femoral artery. The tumor is hypervascular. **B.** Large feeding branch entered with 5F catheter. Vessel was embolized with 350 micron polyvinyl foam particles. **C.** Small, more distal branch entered with microcatheter (arrow) placed through the 5F guiding catheter.

wires in the 0.010 – 0.018 inch range, depending on the choice of microcatheter. One of the major advances in angiography and guidewire design is the hydrophilic-coated guidewire. The best example of this is the Glidewire® (Terumo, Tokyo, Japan), which is available in a variety of lengths, diameters, and degrees of stiffness. This wire, which may have a straight or angled tip, has greatly increased our ability to traverse stenoses and manipulate through tortuous vessels, bile ducts and obstructed kidneys (9 – 11).

Sheaths and Guidecatheters

A majority of vascular procedures are performed through vascular access sheaths. The standard is 10 cm long, with a sidearm which allows continuous flush of saline to prevent clot formation between the sheath and the catheter. The catheters and guidewires are advanced through the sheath via a hemostatic valve. A major advantage of a vascular sheath is that repeated trauma to the puncture site is eliminated, because all necessary exchanges of catheters and wires can be made via the sheath.

Sheaths are now available in a variety of lengths, diameters, and shapes. They are constructed in such a way as to avoid kinking, even when passing through tortuous vessels. Some sheaths can be shaped before inserting them into vessels (Fig. 2).

Guidecatheters are preshaped catheters designed to be placed through standard vascular sheaths, so that they can provide access to target vessels for interventions. They tend to be cumbersome and require upsizing of the initial entry sheath. They have been progressively replaced by the previously described shaped vascular sheaths.

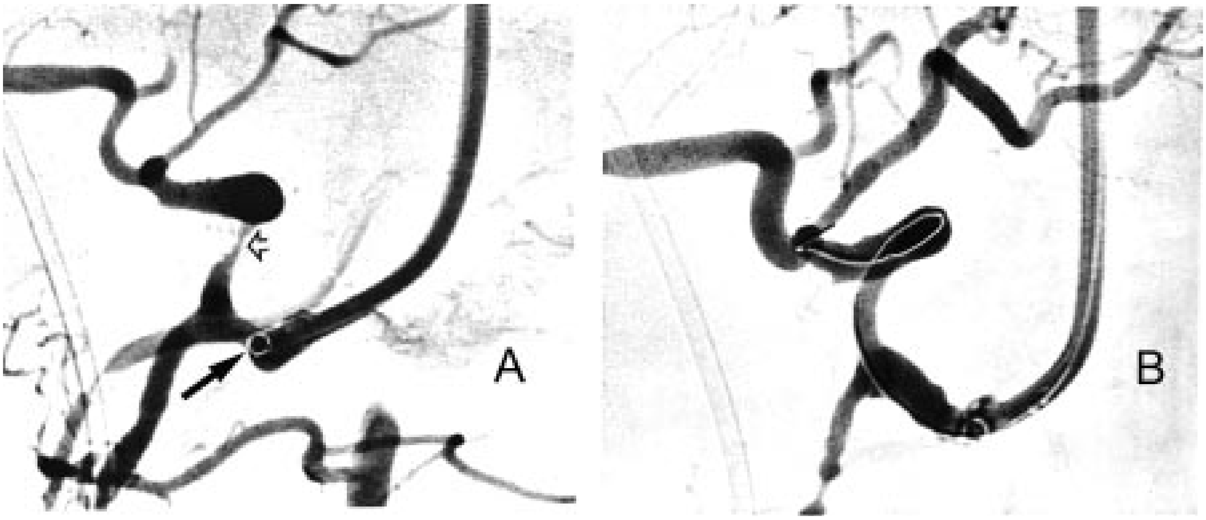

Fig. 2. Use of shaped guidesheath and 0.018 inch guidewire during transbrachial approach to a hepatic artery stenosis following orthotopic liver transplant. **A.** The 6F guidesheath has been advanced into the common hepatic artery. The inner tapered dilator has been removed, leaving an open end (arrow) which allows passage of wires, balloons, and stents, if necessary. Note the stenosis (open arrow). **B.** An 0.018 inch wire is seen across the stenotic area, which has been balloon dilated. The vessels distal to the angioplasty site have dilated in response to the increased blood flow.

Conclusion

The diverse technology available for vascular and nonvascular interventions requires that the interventional radiologist, endovascular surgeon, neurointerventionalist, and interventional cardiologist be knowledgeable about products which change or are improved on a regular basis.

References

1. Tobis J, Johnston WD, Montelli S, et al. Digital coronary roadmapping as an aid for performing coronary angioplasty. Am J Cardiol 1985; 56(4):237 – 241.
2. Boland GW, Murphy B, Arellano R, et al. Dose reduction in gastrointestinal and genitourinary fluoroscopy: use of grid-controlled pulsed fluoroscopy. AJR Am J Roentgenol 2000; 175(5):1453 – 1457.
3. Waugh R, McCallum HM, McCarty M, et al. Pediatric pelvic imaging: optimization of dose and technique using digital grid-controlled pulsed fluoroscopy. Pediatr Radiol 2001; 31(5):368 – 373.
4. Fletcher DW, Miller DL, Balter S, Taylor MA. Comparison of four techniques to estimate radiation dose to skin during angiographic and interventional radiology procedures. J Vasc Interv Radiol 2002; 13:391 – 397.
5. Koenig TR, Mettler FA, Wagner LK. Skin injuries from fluoroscopically guided procedures: part 2, review of 73 cases and recommendations for minimizing dose delivered to patient. AJR Am J Roentgenol 2001; 177(1):13 – 20.
6. Andrews RT, Brown PH. Uterine arterial embolization: factors influencing patient radiation exposure. Radiology 2000; 21(3):713 – 722.
7. Lookstein RA. Impact of CT angiography on endovascular therapy. Mt Sinai J Med 2003; 70:367 – 374.
8. Doerfler A, Goericke S, Wanke I, et al. Flow-directed microcatheters for cerebral embolizations using Ethibloc — an in vitro study. Neuroradiology 2001; 43(12):1112 – 1117.
9. McFarlane JP, Cowan C, Holt SJ, Cowan MJ. Outpatient ureteric procedures: a new method for retrograde ureteropyelography and ureteric stent placement. BJU Int 2001; 87(3):172 – 176.
10. Park HS, Choo IW, Do YS, Choo SW. Migrated Hickman catheters: a simple repositioning method using a stiff hydrophilic guidewire. Cardiovasc Intervent Radiol 2000; 23(1):70 – 72.
11. Koizumi J, Mouri M, Watanabe M, Hiramatsu K. Transbrachial selective pulmonary angiography using a new 4 Fr curved pigtail catheter and hydrophilic-coated guidewire. Cardiovasc Intervent Radiol 1998; 21(4):347 – 349.