During the past 2 decades, radial access has been described for a broad range of coronary and peripheral interventional procedures and has been adopted throughout the world as an alternative to femoral access. There are several advantages of radial access over transfemoral and transbrachial techniques including: (1) the superficial nature of the radial artery facilitates palpation and compression; (2) the paucity of large nerves and veins surrounding the artery decreases risk of damage to surrounding structures; (3) a large collateral blood supply to the hand via the palmar arch, which, in appropriately chosen candidates, limits ischemia in the event of radial occlusion; and (4) there is a lower risk of severe access complications compared with the transfemoral and transbrachial approaches. Despite these well-recognized advantages, the radial approach still accounts for < 10% of all catheterization access worldwide and is even less prominent in the United States, where it accounts for < 5%.

Reasons for operator reluctance to use radial access are unclear and varied. Potential explanations may include a greater familiarity with femoral and brachial approaches, lack of 6-F-compatible equipment for higher-complexity interventions, and increased use of femoral vascular closure devices, particularly in patients with bleeding propensity. Operators may also be discouraged by the 1% to 5% failure rate of radial artery cannulation for interventional procedures, which is significantly higher than transfemoral or transbrachial approaches. The learning curve of the radial approach, smaller caliber of the radial artery, and existence of anatomical variations in the radial distribution may account for this increased failure rate.

Real-time ultrasound can overcome a number of factors leading to both failed radial cannulation and access complications. Ultrasound imaging can determine the patency and caliber of the artery before access is attempted (Figure 1). Anatomical variations of the radial artery can be defined, which may include tortuosity, hypoplasia, anomalous branching, and radioulnar loops (Figure 2). Anomalous anatomy may occur in up to 30% of cases and is associated with higher incidences of procedure failure and radial occlusion. Intravascular pathology such as calcified atheromas, scar tissue, and intimal thickening can be identified before instrumentation. Identification of surrounding veins and nerves can prevent inadvertent injuries to these structures. Finally, direct visualization of the orientation and spatial relationships among the artery, surrounding soft tissue, and puncture needle can assist in rapid and successful cannulation.

The use of ultrasound to assist central venous catheter placement has been widely accepted during the past decade and is considered to be the standard of care in some locations. Recent multicenter randomized trial data have shown...
shown that use of ultrasound guidance during femoral artery cannulation for catheterization access reduces the number of cannulation attempts, median time to access, and rate of vascular complications.\textsuperscript{12}

Early reports of ultrasound-assisted cannulation of the radial artery involved the use of auditory cues provided by a continuous-wave Doppler probe.\textsuperscript{13} Levin et al\textsuperscript{14} described the use of real-time B-mode ultrasound for radial access and compared this method with traditional palpation. Levin demonstrated that significantly fewer attempts were required for catheter insertion using ultrasound as compared with palpation, with a shorter overall time required for catheter insertion in the ultrasound group.\textsuperscript{14} A recent meta-analysis of available studies comparing ultrasound versus palpation in radial access showed a 71\% improvement in first attempt success when ultrasound was used.\textsuperscript{15}

Ultrasound-assisted radial cannulation may also decrease complication rates. Shiver et al demonstrated a 43\% reduction in radial hematoma with ultrasound usage compared to palpation.\textsuperscript{16}

At our center, staff and physicians are trained in the operation and setup of the portable ultrasound system, which is readily available for use. When performed with a systematic approach (see Step-by-Step Guide to Ultrasound-Guided Radial Access sidebar), the use of ultrasound guidance for radial cannulation facilitates efficient and successful radial cannulation.

**PATIENT PREPARATION**

Before the procedure, the patient should undergo careful examination of the pulses, including palpation of bilateral radial arteries, as well as femoral and distal pulses in the event that radial access is unsuccessful. Assessment of the patient’s anxiety level and appropriate premedication is important, because an overly tense patient can lead to arterial spasm and decreased radial artery caliber, making cannulation difficult.

A modified Allen test should be performed in the preprocedure area to ensure that dual blood supply to the hand is preserved by way of a patent radial and ulnar artery, as well as an intact palmar arch. If the ulnar artery is occluded or the palmar arch is interrupted, the patient is at risk for developing ischemia if instrumentation of the radial artery leads to damage and/or occlusion.

The Allen test is executed by having the patient clench his or her fist while the examiner compresses the radial and ulnar arteries. The patient is told to relax the hand while compression of the ulnar artery is released and compression of the radial artery is maintained. Initially, pallor is observed on the palm of the hand; if the color of the palm returns to normal within 10 seconds of release of the ulnar artery, this indicates that the blood supply to the hand is satisfactory via the ulnar artery and palmar arch.

If pulse oximetry is available, the Allen test can be conducted with the pulse oximeter placed on the index finger of the ipsilateral hand. A normal waveform should be observed before arterial compression. The test is conducted in the same manner, but instead of observing hand color when releasing the ulnar artery, the pulse oximetry tracing is examined. The tracing is initially blunted or flat when both the radial and ulnar arteries are occluded. The tracing should return to baseline within 10 seconds for the test to
be considered normal. The pulse oximetry method is preferred, because it is not as subjective as the traditional Allen test. Additionally, the patient can wear the finger oximeter during the procedure, which provides feedback regarding the integrity of the blood supply to the hand.

ULTRASOUND-GUIDED RADIAL ARTERY CANNULATION

Patient Positioning and Setup

One approach to ensure optimal positioning for right radial access is to abduct the right arm approximately 45º and immobilize the hand in an extended position on a splint or armboard. The operator stands at the patient’s right side during the procedure. When using the left wrist, the operator may also prefer to stand at the patient’s right side and drape the left hand across the lower chest in a “Napoleonic” pose.

The wrist area is prepared by sterilizing from the thumb to the brachial fossa. The groins should also be prepared in the event of an unsuccessful cannulation. The arm and hand are draped so that only the area from the styloid process of the radius to approximately 4 cm proximal is exposed. To ensure operator comfort, the height of the table is adjusted without having to bend or strain. The ultrasound unit is placed on the opposite side of the patient so the display screen can be easily viewed.

Ultrasound Setup and Imaging

A curvilinear, linear, or hockey stick transducer with the frequency set at 5 to 10 MHz is selected (Figure 3). Taking care to maintain sterility, a layer of ultrasonic coupling gel is applied to the head of the transducer and bottom of sterile plastic cover. The probe head and cable are draped in a sterile cover, and the cover is smoothed over the acoustic window of probe head to remove air bubbles and is fastened into place with an elastic band.

The optimal ultrasound depth setting for imaging of the radial artery is 1 to 2 cm. On most systems, there are depth markers on the screen that indicate the depth of the artery from the skin. In most cases, these markers are in 0.5- or 1-cm increments. Knowledge of the depth of the artery is critical to best judge the depth that the needle must pass to reach the vessel lumen. The gain of the system is adjusted to ensure optimal imaging and can be adjusted in 5% increments on most systems.

The transducer is initially held perpendicular to the vessel wall to obtain a transverse image. On most models, there will be a demarcation in the center of the probe corresponding to the center of the viewing screen. On some systems, there is an orientation marker on the left side of the probe,
which should correspond with the left side of the viewing screen.

The artery in the transverse view is a round, pulsatile, echolucent structure in the midst of static, echodense material and is accompanied in most cases by one or two small veins. Exerting gentle pressure with the ultrasound probe will compress the surrounding venous structures while rendering the arterial pulsations of the radial artery more prominent. Maximum and minimum diameters of the radial artery are measured in the transverse view, ideally at approximately 1 cm proximal to the styloid process of the radius.

After performing two-dimensional imaging of the artery in the transverse view, a longitudinal view of the artery is obtained by turning the transducer parallel to the course of the vessel. The artery is scanned in grayscale in the transverse and longitudinal plane from the styloid process of the radius to the brachial artery. The anatomy of the radial artery is defined in detail. To evaluate for stenosis or occlusion, if it is suspected, a pulsed Doppler examination of the radial artery is performed with the transducer oriented at an angle of insonation of 45º to 60º. A normal radial artery waveform is triphasic with a dicrotic wave in early diastole. Next, color Doppler imaging is performed to assess the presence of flow and to distinguish the artery from surrounding structures. As a general rule, blood flow toward the probe is red, whereas blood flow away from the probe is blue. If it is difficult to visualize the color flow when the transducer is completely vertical, the transducer can be tilted slightly toward or away from the direction of blood flow. Color-flow imaging is useful for discriminating flow deviations, flow narrowing within a vessel, and absence of flow indicative of occlusion.

Radial Artery Cannulation and Sheath Insertion

When the operator is prepared to cannulate the radial artery under ultrasound guidance, the radial artery is aligned in the center of the screen. It is often helpful if the operator anchors a portion of the hand holding the transducer to a fixed object to minimize movement of the probe during the puncture maneuver. The position of the transducer should be 0.25 to 0.5 cm proximal to the area where the artery will be cannulated. One to 3 mL of 2% lidocaine is applied to the subcutaneous tissue above the artery under ultrasound guidance, taking care to not infiltrate the artery. Injection of lidocaine into the artery wall may provoke spasm, making the artery more difficult to cannulate.

After the skin is anesthetized, the radial artery is realigned in the center of the ultrasound viewing screen. With a 21-gauge micropuncture needle (although any needle that is 19–21 gauge and 2–5 cm in length can be used) positioned at approximately 45º from the skin surface, the subcutaneous tissue is penetrated while observing the approach on ultrasound (Figures 3 and 4). The operator observes for the linear, dense echogenic needle entering the subcutaneous tissue. The tip of the needle is often difficult to see, so indirect evidence of the artery being compressed can give an idea of the needle tip position. “Tenting” of the front wall of the radial artery may be detected as the needle exerts pressure on the tissue immediately above the artery (Figure 4B). Gentle pressure is exerted on the needle. A tactile “pop” of the needle may be experienced as the needle passes through the front wall of the artery. The needle tip can be observed in the lumen of the vessel on ultrasound (Figure 4C). The operator observes for blood return, which indicates that the needle is within the vessel. Blood return may not be pulsatile with a micropuncture needle.

If there is no blood return from the needle, possible causes include subintimal positioning, an occluded radial artery, or the needle is not within the lumen of the artery. Study the ultrasound screen. The shadow of the echodense body of the needle may be detected adjacent to the vessel lumen. At times, the needle can be difficult to visualize, and visual cues should be acquired from the movement of the tissues surrounding the artery. If the needle cannot be visualized at

**Figure 4. Ultrasound images showing access of the radial artery. Panels on the top row are baseline images; the outlines of the needle and the artery lumen have been demarcated in red in panels on the bottom row. At baseline, the radial artery is pulsatile, round, echolucent, and noncompressible (A). “Tenting” of radial artery as the needle approaches (B). Needle entry into the radial artery (C).**
IS ULTRASOUND NECESSARY FOR ALL TRA PROCEDURES?

By Ramon Quesada, MD, FACP, FACC, FSCAI

In this article, it is suggested that the use of ultrasound to guide transradial access (TRA) may be a way to encourage wider use of this approach. There is definitely a learning curve to the adoption of TRA; the authors suggest a failure rate of approximately 5%. When I first started using the technique 14 years ago, my failure rate was higher at 9% in my first set of patients (approximately 100). I quickly learned to overcome anatomical variations and tortuosity through the use of proper techniques according to the clinical scenario. In retrospect, the use of ultrasound may have helped me avoid certain problems; I have used it for femoral access to prevent vascular complications. However, there are no critical structures at the radial access puncture site, as is the case with femoral access. Use of this access site is relatively simple, and ultrasound should be used selectively rather than as a standard procedure.

Today, I can perform all interventions, regardless of complexity, via TRA; I use ultrasound access guidance to size the vessel when I am considering the use of larger sheaths. Ultrasound guidance, like a good proctor, can get the operator over the “speed bumps,” but it will never replace proper catheter techniques.

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all, it should be retracted to the skin surface and the cannulation process restarted. It is very helpful to have another operator with ultrasound experience observe the image with you as you perform the procedure and provide feedback regarding your orientation and approach.

When convinced that the needle tip is within the true lumen of the artery, the angle of the needle to the skin surface is decreased slightly, and a 0.018-inch micropuncture wire (wire generally 30–50 cm in length with a floppy tip and more rigid shaft) is threaded within the lumen of the needle. This can be performed under ultrasound guidance, where the wire appears as a bright, echodense structure within the lumen of the vessel. The wire is advanced if no resistance is felt. If there is resistance, fluoroscopic guidance is used to ensure that the tip of the wire is free. Over the micropuncture wire, either a sheath with a dilator tapered to just slightly larger than the 0.018-inch wire or a 4-F micropuncture introducer is advanced with a gentle torquing motion. Several hydrophilic-coated sheaths with tapered dilators are available. These allow direct introduction of the sheath over the micropuncture wire. If a 4-F introducer is used, the inner cannula is removed, leaving the outer cannula within the lumen of the radial artery; brisk pulsatile flow should be observed. A 0.035-inch standard J or soft floppy straight-tipped wire can then be advanced and the outer cannula removed to facilitate placing the sheath desired for the catheterization procedure.

The size of the sheath used should be based on the minimum inner diameter needed to accommodate the equipment used for the procedure. The incidence of radial artery occlusion is higher when the ratio of radial artery inner diameter to sheath outer diameter is < 1. The ratio of radial artery to sheath diameter can vary greatly between male and female patients. Data acquired from the pre-procedure ultrasound are useful for selecting the appropriate sheath size.

When the sheath is introduced, it is immediately aspirated and flushed. A cocktail of heparin, verapamil, and nitroglycerin should be expeditiously administered through the sidearm of the sheath to prevent vasospasm and occlusion. Diluting the mixture with blood before injection can prevent patient discomfort during injection. The radial catheterization procedure can be performed in a routine fashion.

CONCLUSION

Use of real-time ultrasound to guide cannulation of the radial artery can facilitate successful sheath placement during catheterization procedures. Radial access with ultrasound guidance should be accomplished in a systematic, stepwise approach. Operators should familiarize themselves with the ultrasound systems available in their centers and stay practiced in their use. The routine use of ultrasound for radial puncture can lead to increased cannulation on the first attempt with a lower risk of complications.

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