Advanced practice organ procurement techniques: insertion of arterial catheters

Placement of arterial catheters by organ procurement coordinators is becoming more common. Classroom and clinical training in this technique and provision of appropriate quality assurance and supportive policies/procedures by organ procurement programs will ensure the coordinators' success. This discussion reviews technical aspects of insertion of catheters into the radial, femoral, and axillary arteries, potential complications, and alternative noninvasive methods of measuring blood pressure. (*Progress in Transplantation*. 2006;16:355-361)

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Notice to CE enrollees:
A closed-book, multiple-choice examination following this article tests your ability to accomplish the following objectives:

1. Review the technical aspects of insertion of arterial catheters
2. Complications of arterial catheters
3. List alternative noninvasive methods of measuring blood pressure

Organ procurement coordinators participating in an advanced practice program sponsored by their organ procurement organization (OPO) often place arterial catheters for direct measurement of arterial blood pressure or to facilitate blood sampling. Successful placement of arterial catheters by nonphysician clinicians is a well-documented standard practice.[1] Commonly used methods for insertion of femoral, radial, and axillary arterial catheters, alternative methods for assessing blood pressure, complications of catheter insertion, and sources of errors in measurement are discussed here. Data and information have been derived from a directed literature search of PubMed (1978-2006) and supplemented by publications from the author's files and personal experience.[2-7]

Coordinators must depend upon their OPOs to provide necessary credentials, classroom and clinical training, supervised experience, and an ongoing quality assurance program to ensure safe implementation of this advance practice technique. Donor injury resulting from insertion errors may be catastrophic and risks loss of potentially transplantable organs.

Does the Donor Need an Arterial Catheter?

Continuous monitoring of systolic, diastolic, and mean arterial blood pressure can almost be duplicated by frequent measurements from an automatic bedside oscillometric device, commonly a component of bedside monitors in the intensive care unit. Similarly, sampling of venous blood from peripheral or central venous catheters can suffice for all laboratory tests except arterial blood gas analysis. Frequent arterial sampling for blood gas analysis may also be unnecessary if the percentage saturation of hemoglobin by oxygen determined by a pulse oximeter, the Spo_2, is reliable. However, no similar noninvasive substitute is available for monitoring the arterial partial pressure for carbon dioxide ($Paco_2$) during adult donor care. Transcutaneous carbon dioxide monitoring is not used in adults, sublingual capnometry is better for evaluating tissue perfusion than ventilation[8] and end-tidal carbon dioxide partial pressure or percentage may not closely cor-

relate with the $Paco_2$ in critically ill patients (not assessed among donors).[9] Frequent assessment of $Paco_2$ and arterial pH, therefore, may be clinical indications for an arterial catheter if repeated percutaneous arterial punctures are not possible.

Noninvasive Devices for Monitoring Blood Pressure

Arterial blood pressure is most commonly assessed by using a blood pressure cuff around the patient's upper arm. Inflation of the cuff above systolic arterial pressure occludes the compressed artery. As this "counter" pressure in the cuff is reduced, flow resumes through the vessel and is detected as a sound (auscultatory), a surge felt over the artery (palpation), or oscillatory changes within the cuff (oscillometric).[10,11] These 3 methods of detection define the technology that has been developed into bedside devices.

The traditional "gold standard" method/device for assessing blood pressure is the mercury sphygmomanometer and the detection of the audible onset and cessation of the Korotkoff sounds indicating the systolic and diastolic arterial pressures.[11] Anaeroid units use air pressure rather than the weight (mass) of mercury to assess the arterial pressure, and although widely used, require frequent recalibration to remain accurate.[12] All commonly used noninvasive methods provide intermittent measurements requiring the time and presumed expert attention of a nurse, physician, or other operator.

Less labor-intensive automatic oscillometric devices are now incorporated into most commercially available bedside monitors and have largely replaced both mercury and anaeroid units for intermittent assessment of blood pressure. The capability to program the frequency of "cycling" to intervals as short as 1 minute allows this method to closely approximate the continuous monitoring provided by an arterial catheter.

The precision of measurements provided by any device or system describes the reproducibility of repetitive measurements of an unchanging parameter. For example, if a blood pressure monitor repeatedly measured a fixed pressure within a laboratory experiment and always recorded the same value, that device would be highly precise. Measurement accuracy, however, refers to how correctly the device records the parameter's "true" value and assumes knowledge of that true value acquired by some other means. In the preceding example, the blood pressure monitor may be highly precise but inaccurate if it does not correctly measure the "actual" pressure created for the experiment. Finally, over time and repetitive testing, the precision and/or accuracy of many electronic devices will begin to vary, a characteristic known as "drift." Precision, accuracy, or drift of automatic blood pressure devices or transducer systems are not routinely assessed during bedside clinical care, but are important variables considered during equipment purchase and should be recognized as potential concerns by clinicians involved with donor care.

Table 1 Factors affecting noninvasive measurements of blood pressure[13]

Width of cuff relative to circumferential size of the donor's arm
Limb used, namely, upper arm, lower arm, lower leg, thigh
Hypothermia
Obesity
Edema at the insertion site

Variables that affect the accuracy of measurements by automatic bedside oscillometric units are listed in Table 1. The most common cause of such potential errors is use of an arm cuff that is of the wrong width or length for the donor's arm circumference. A cuff that is too narrow will yield a falsely high measurement, and conversely, a larger cuff around a small arm will produce an inaccurate low reading.[10,11,13-15] Charts of appropriate cuff dimensions are available.[11]

Most commonly, the mean arterial pressure (MAP) is used during monitoring of general organ perfusion. A goal for the MAP is usually at least 60 mm Hg. Each OPO should specify optimal levels, methods of measurement, and titration methods for both hypertension and hypotension.[16] The MAP is calculated or measured by automatic blood pressure devices or may be calculated from the following formula[17]:

$$\text{MAP (mm Hg)} = \text{diastolic pressure} + 1/3\ (\text{systolic} - \text{diastolic pressures}) + 5$$

Relative Contraindications to Insertion of an Arterial Catheter

Few absolute contraindications to placement of an arterial catheter in some location are recognized. Severe coagulopathy may raise general concerns and direct catheter placement toward a more superficial location, such as the radial artery, because inadvertent bleeding may be more easily controlled there. Replacement of coagulation factors may be indicated, but may not increase the safety of catheter insertion.[18] Specific sites should be avoided if local infection/inflammation, burn injury, or any other condition is present that might disrupt the skin's barrier to infection.[3]

Techniques for Insertion of Arterial Catheters

Selection of an Arterial Site

In general, even for the relatively short duration of donor care, the principle of the "smallest catheter in the largest artery" applies. Site choice may also be influenced by the operative sequence of organ removal

wherein an upper extremity arterial access is required or preferred. In addition, donor blood pressure at the time a catheter is placed, atherosclerotic peripheral vascular disease, previous vascular surgery, the concurrent administration of vasoconstrictor medications, donor hypothermia or coagulopathy, the technical experience of the coordinator, and other possible variables might influence the location chosen. A more "central" site for monitoring provides a more accurate value than the smaller and more distal radial artery, especially for systolic blood pressure estimates or if sepsis is present or active rewarming is being attempted.[19,20] The OPO should incorporate site preferences into program guidelines/protocols, but the many variables just noted require that the procurement coordinator be granted considerable latitude in the final selection.

Site Preparation and Positioning of the Donor

Optimal positioning of the insertion site will greatly contribute to successful placement of the catheter. If the femoral artery is selected, the donor should be fully supine with the bed flat (the reverse Trendelenberg position may be used if head elevation is needed to offset risks of pulmonary aspiration). Too much hip flexion may make passage of the wire or catheter more difficult.

During radial artery catheterization, the patient's hand is supinated (palm upward). Often slight dorsiflexion of the wrist (by placing a small towel under the head of the radius; Figure 1) will move the radial artery to a more superficial location (closer to the skin) and facilitate arterial puncture or cannulation.

If a catheter is to be placed in the axillary artery, the donor's arm is flexed at the elbow to about 90° and the upper arm is extended outward from the shoulder until perpendicular to the body. The donor need not be flat for this procedure, but securing the arm in that position with tape or a restraint is usually helpful even though the donor is unlikely to reflexively move.

At any location, the arterial pulse must be palpable before attempted cannulation. Repositioning the limb may be necessary to optimize pulse strength. Shaving around femoral or axillary sites may facilitate subsequent cleansing of the area, but whether or not that practice reduces infection is a matter of controversy.

A wide area around the anticipated puncture site is cleansed in accord with the hospital's infection control guidelines before the final aseptic field is established. The coordinator should wear a mask, hat, and nonsterile gloves for the initial cleaning process. Thereafter, the coordinator should don attire (eg, sterile gown, gloves) per OPO or hospital policies and create a wide aseptic field with sterile drapes. Supplies are then aseptically "handed-off" to the coordinator by the nurse or other assistant. Great care is taken to avoid contamination of the aseptic area.

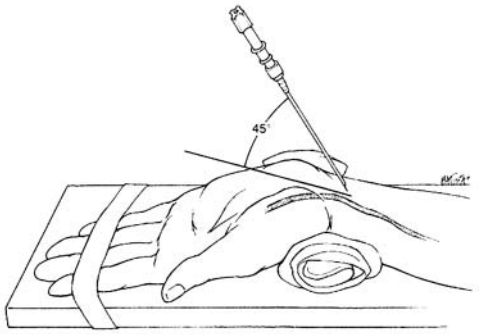

Figure 1 Wrist positioning for radial artery cannulation.

Reproduced from Chen et al,[7] with permission.

General Insertion Guidelines and Complications

The arterial catheter insertion kit supplied by the hospital should be used. Most commercial kits contain equipment for either the needle-wire-catheter (Seldinger) method, appropriate for any site, or a catheter-over-needle assembly used only for radial artery cannulation. The technique selected (and hence the equipment used) is largely a matter of personal preference and operator experience. However, the traditional Seldinger method was associated with a lower failure rate in most or selected patients.[21-23] Topical anesthesia is not necessary for the donor. The general procedure for insertion using either method is reviewed in Table 2.

Complications of this procedure are similar at any site. Arterial injury, bleeding, hematoma formation, and occlusion of the artery are the most severe. An overall incidence of "major adverse effects" in 15% of intensive care unit patients is reported.[24] Significant bleeding into the thigh or axilla may not immediately be apparent, and close inspection of the site for an expanding hematoma should routinely follow insertion at those sites.

The traditional technique of identifying the location of the artery by palpation can be supplemented by use of an ultrasound Doppler device.[25] This method may also be helpful when the arterial pulse is difficult to locate because of poor blood pressure, obesity, regional soft-tissue edema, and so on.

Site-Specific Considerations During Insertion

Femoral Artery

Figure 2 illustrates the anatomy of the area around the femoral artery insertion site. Note the relatively lateral position of the femoral artery and its relation to the more horizontal inguinal ligament. Arterial puncture/cannulation should always be below the inguinal ligament. If the femoral vein is inadvertently entered, the needle should be removed and manual compression applied for a few minutes. Subsequent attempts should be lateral to the venous puncture site.

Table 2 Insertion techniques for arterial catheters

After the donor is positioned, the catheter insertion site is cleansed, appropriate apparel has been donned, the sterile field has been prepared, and the appropriate equipment acquired, the following procedure is recommended:

1. Repalpate the location of the arterial pulse.
2. Maintain a finger(s) of the nondominant hand over the pulse as a point of reference, to stabilize the artery and to prevent side-to-side movement.
3. A syringe may or may not be attached to the needle or catheter-over-needle assembly selected. Aspirating with the syringe during insertion is helpful in verifying arterial entry in smaller arteries or if the pulse is weak.
4. Either needle is positioned with the bevel outward, as shown in Figure 1. The skin is entered at about a 45º angle from horizontal. If the angle at which the artery is entered is too acute (closer to 90º), passing the wire or catheter may be more difficult.
5. If a syringe is used, gentle aspiration is applied with the fingers of the dominant hand as the needle is advanced. If a syringe is not used, the needle is advanced until arterial blood emerges from the proximal end of the needle.
6. After successful arterial puncture, the needle is held firmly with the nondominant hand to ensure that it is not inadvertently withdrawn from the artery or advanced through the artery.
7. The syringe, if used, is removed.
8. If the Seldinger technique is being used, the wire is advanced through the needle. Usually the "J" end of the wire is introduced as the soft "J" tip is intended to facilitate entry through the needle tip into the artery and to move around any plaques in the vessel as the wire is advanced. "Twirling" the wire with your fingertips may facilitate passage. The straight end of the wire should be attempted if any resistance is encountered when using the "J" tip.
9. The wire should be inserted for a distance equal to the length of the catheter that will follow plus the estimated depth of the skin and soft tissue above the artery.
10. If resistance is encountered and "twirling" the wire is ineffective, do not force the wire forward as the artery may be damaged. Withdraw the wire and ensure that blood return through the needle continues. Realignment of the needle bevel within the artery may be attempted by *very gentle and slight* elevation of the proximal hub of the needle. This increases the insertion angle (closer to 90º). Similarly, *minuscule* movement of the needle hub from side to side may realign the needle in the artery. Do not withdraw the needle during these maneuvers, which are best done with the nondominant hand. Reinsertion of the wire is then attempted. It is possible, particularly in older donors where intra-arterial atherosclerotic plaques are more common, that passage of the wire may not be possible and a different insertion site must be selected.
11. Once the wire is in place, remove the needle. Bleeding from the puncture site around the wire may occur.
12. Unlike during placement of central venous catheters, plastic dilators are not commonly used during cannulation of arteries because the dilators may injure the artery. A skin incision/short stab wound along the track of the wire, however, may facilitate subsequent passage of the final catheter.
13. The catheter is next placed over the wire and advanced close to the skin incision. The wire is then slowly withdrawn and passed retrograde through the catheter until the wire tip protrudes from the proximal catheter hub. *Never* advance the catheter through the skin until the wire is secured beyond the catheter hub as the wire might be forced into the artery and carried into the circulation. Some operators attach a hemostat to the wire for this purpose. "Twirling" the catheter with the fingertips during insertion may also assist catheter passage along the wire through the soft tissue. Resistance may be encountered and may require minimal enlargement of the subcutaneous incision.
14. The catheter is fully inserted to its hub and the wire is then withdrawn. Arterial blood should spontaneously flow from the catheter. If not, reattach the syringe and ensure that blood can be easily aspirated.
15. Attach the connecting tubing to the transducer prepared by the bedside nurse and ensure that an arterial waveform appears on the monitor display.
16. If the short catheter-over-needle assembly is used (radial artery only), the wrist is positioned and prepared as previously discussed (Figure 1). A syringe may or may not be used. When the artery has been entered, the intention is to smoothly advance the Silastic catheter over the needle into the artery. No wire is used with this technique. Catheter advancement is usually accomplished with the nondominant hand while the dominant hand holds the needle in place. Gentle "twirling" of the catheter as it is advanced may be possible and is helpful in overcoming soft-tissue resistance. If significant resistance is encountered, a small soft-tissue incision may be needed or slight upward movement of the needle hub (without withdrawal or advancement) may be helpful. Once the catheter is fully advanced to its hub, the needle is withdrawn. Arterial blood should flow from the catheter. If not, gently aspirate from the catheter. Attach the transducer tubing and observe for an arterial waveform.
17. Suture the catheter in place around the hub and apply a sterile dressing as recommended by the guidelines of the organ procurement organization or hospital.

Axillary Artery

Figure 3 shows the anatomy of the area around the axillary artery insertion site. Unfortunately, no specific landmark can be used to guide the initial puncture, and no constant relation exists between the axillary vein and artery, should the axillary vein be inadvertently

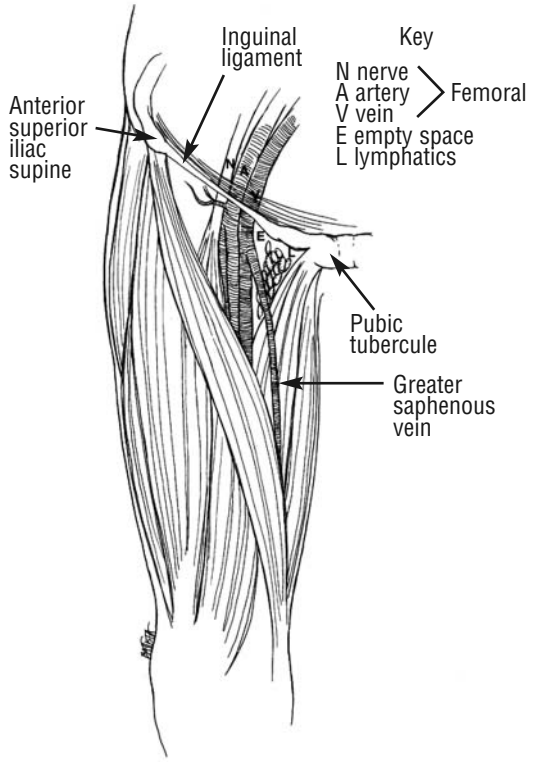

Figure 2 Anatomical illustration of proximal thigh to localize the femoral artery.

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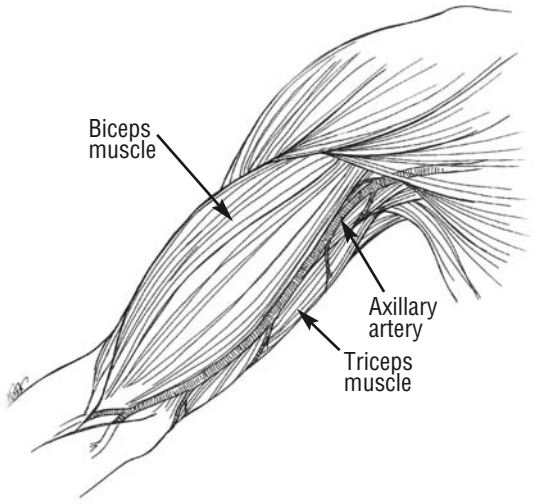

Figure 3 Anatomical illustration of the right upper arm and axillary artery.

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Figure 4 Illustration of technique for axillary artery puncture.

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entered. Palpation across the area to locate the arterial pulse is, therefore, the usual method of identification. The artery, vein, and brachial nerve run in close proximity, and venipuncture or reflex arm movement if the nerve is irritated is common. Figure 4 shows the technique of localizing the pulse with fingers from the nondominant hand while arterial puncture proceeds. Axillary artery cannulation, in general, is more difficult than femoral cannulation, but when the femoral site is unavailable or an upper extremity arterial catheter is necessary, but the radial pulse is weak or cannot be cannulated, the axillary artery is an appropriate alternative.[26]

Radial Artery

Figure 1 identifies recommended hand positioning and insertion of the catheter-over-needle assembly without a syringe. Assessing collateral circulation to the hand from the ulnar artery by using the Allen test is usually recommended when this site is chosen.[14] The importance of such testing is not clear during the relatively short duration of donor care and recognizing the subsequent plans for termination of treatment. The coordinator should remain alert, however, for any signs of diminished arterial blood flow to the hand such as blue discoloration, cool/cold skin temperature to the touch, diminished capillary refill time, and so on. If noted, subsequent removal of the radial catheter should be considered.

Other Sites

Other possible sites in the adult include the dorsalis pedis and brachial arteries. The dorsalis pedis artery, over the anterior midfoot, is often a good site for obtaining samples for arterial blood gas analysis but may not reflect the central arterial blood pressure. The dorsalis pedis artery may also be more mobile than other sites, making puncture more difficult. The brachial artery is not used in critical care patients because there would be no collateral circulation to the distal arm and hand if the brachial artery became occluded. This, of course, is of less concern during donor care. The brachial artery provides upper extremity access and is usually easily palpable in the medial

antecubital space. Optional utilization of either of these arteries should be decided by each OPO.

Summary

Arterial catheterization is commonly considered desirable for continuous blood pressure monitoring and blood sampling. Although alternative methods to accomplish both of those goals are available, the organ procurement coordinator should consider placement of arterial catheters essential to his or her advanced practice skills. Likewise, the OPO should consider appropriate training, in-hospital resources, and quality assurance programs essential to its responsibilities to support advanced practice clinicians.

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CE Test

Test ID 4000-J46: Advanced Practice Organ Procurement Techniques: Insertion of Arterial Catheters

Learning objectives: 1. Review the technical aspects of insertion of arterial catheters 2. Complications of arterial catheters 3. List alternative noninvasive methods of measuring blood pressure

1. Which one of the following is a clinical indication for an arterial catheter in a donor?
a. Frequent blood sampling
b. Decreasing PaO_2
c. Frequent assessment of $PaCO_2$ and arterial pH
d. Increasing blood pressure

2. What is the difference between measurement precision and measurement accuracy?
a. Precision is the amount of variance the equipment experiences
b. Accuracy is how correctly the device records the true value
c. Precision is how often the device records the value
d. Accuracy is the equipment's knowledge of false values

3. Which of the following mean arterial pressures is acceptable in a donor?
a. 30 mm Hg
b. 40 mm Hg
c. 50 mm Hg
d. 60 mm Hg

4. What is the most common contraindication to insertion of an arterial catheter?
a. Sepsis
b. Extremity trauma
c. Coagulopathy
d. Peripheral vascular disease

5. What intervention may ease placement of a femoral arterial catheter when resistance is noted?
a. Elevate head of bed
b. Place donor in a lateral position
c. Check for hip flexion
d. Hold leg straight by applying traction on foot

6. A femoral arterial puncture/cannulation should be below what anatomic area?
a. Inguinal ligament
b. Anterior superior iliac
c. Pubic tubercule
d. Greater saphanous vein

7. When is the axillary artery preferred for cannulation?
a. The femoral site is unavailable
b. The axillary site is always preferred
c. The brachial artery is not accessible
d. The axillary site should never be used

8. What does the Allen test determine?
a. Patency of the radial artery
b. Blood flow to the hand
c. Collateral blood flow
d. Degree of stenosis of radial artery

9. What is the disadvantage of using anaeroid units?
a. Is not an accurate method
b. Is cost prohibitive
c. Requires frequent recalibration
d. Is difficult to use

10. Which of the following statements is correct?
a. All arm cuffs are accurate regardless of size.
b. Arm cuff length is more important than cuff width.
c. A cuff that is too large creates a falsely high blood pressure reading.
d. A cuff that is too narrow creates a falsely high blood pressure reading.

11. What is the correct formula for determining mean arterial pressure?
a. Diastolic pressure + 1/3 (systolic-diastolic pressures) + 5
b. Systolic pressure + 5 (systolic-diastolic pressures) / 1/3
c. Diastolic pressure + 1/3 (systolic-diastolic pressures) 1/3
d. Systolic pressure + 1/3 (diastolic-systolic pressures) + 5

12. What is the disadvantage of using the dorsalis pedis artery for blood pressure measurement?
a. May hinder circulation to the distal arm and hand
b. Is hard to cannulate
c. Does not reflect central arterial blood pressure
d. Should not be used in people with peripheral vascular disease

Test answers: Mark only one box for your answer to each question. You may photocopy this form.

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