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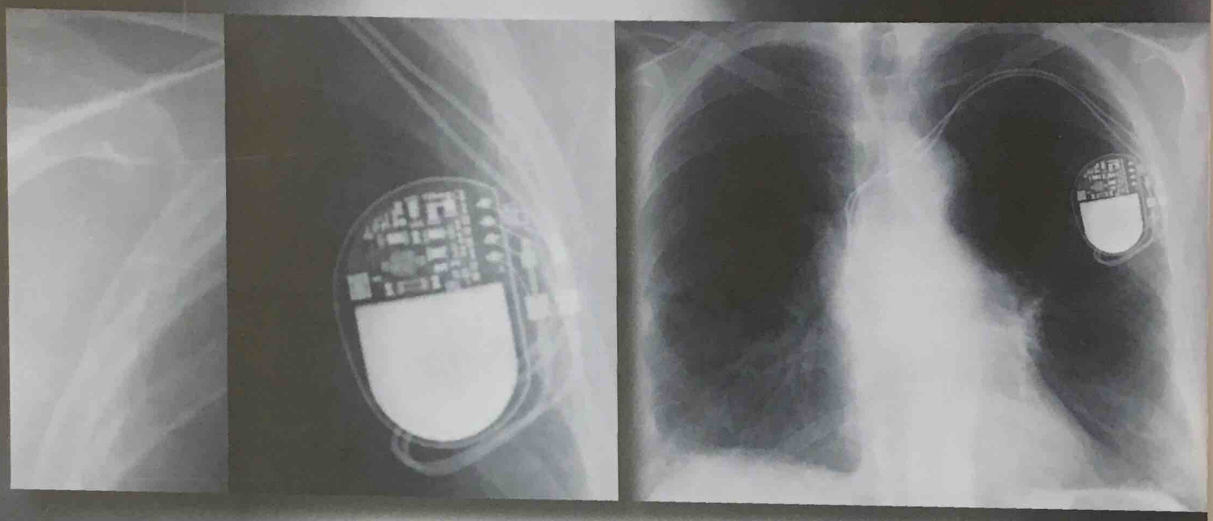

CORONARY CARE MANUAL

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46 Vascular access and ultrasound guidance techniques

Peter L. Thompson, Bradley M. Power and Mark J. Lennon

Vascular access in the coronary care unit can be literally a life-saving skill. All acute-care physicians in critical care and coronary care units need to be skilled in central cannulation. One of the first descriptions of central venous catheterization was that by Aubaniac in 1952[1] and the following year Seldinger described the use of a guide wire, a technique that has persisted to this day.[2] The most significant recent advance to that method has come recently with the advent of bedside portable ultrasound devices, available since the early 1990s, which has converted "blind" approaches to real-time imaging. Both techniques are described, with emphasis on the benefits of ultrasound guidance. It seems inevitable that this will become the standard of care.

This chapter focuses on central venous cannulation but also describes the techniques of cannulation of peripheral veins, as well as arterial cannulation. An appreciation of the mortality and morbidity attributable to the use of central venous catheters and the ability to reduce this with appropriate systems of management is important in improving safety.[3,4] Access to the left side of the heart is the province of the cardiac catheterization laboratory and will not be discussed.

PATIENT PREPARATION

The patient should be comfortable and every attempt should be made to allay their apprehension about the procedure. Written informed consent is required for all patients, but in emergency situations this may not be possible. A standardized consent form listing all the relevant complications may be useful. Identification and reversal of any coagulopathy is required for most cases; however, this needs to be balanced against the risks of discontinuing anticoagulant therapy in individual patients. Antiplatelet therapy should not be discontinued. In emergency situations waiting for coagulation studies or blood products may be inappropriate.

For most procedures the patient can be positioned supine and slightly head down to increase venous size and reduce the risk of air embolism.[5–7] On occasions, sedation may be required in a very apprehensive patient, and low-dose intravenous midazolam (titrated in 1–2 mg increments) may be necessary. Ideally, a second physician skilled in airway management should be present to administer sedation for unstable patients. All patients should be monitored with ECG and, if sedated, non-invasive blood pressure and oxygen saturation must be included. Unstable patients may not tolerate head-down posture for prolonged periods and staff should be cognizant of this.[8]

ASEPTIC TECHNIQUE

Meticulous technique is necessary to minimize the risk of bloodstream infection and phlebitis from intravascular devices (IVDs).[9–11] The rate of bloodstream infection has been calculated as 0.1 per 100 IVDs (0.1%) and 0.5 per 1000 IVD-days for peripheral intravenous catheters.[9,12] Far higher rates were seen with short-term central venous catheters (CVCs) (4.4% and 2.7 per 1000 catheter-days).[9,13,14] The use of infection control processes may reduce rates of bloodstream infection from 5 per 1000 IVD-days to 0.9 per 1000 IVD-days.[3] Such management processes pay assiduous attention to the provision of a maximum sterile barrier by the use of appropriate hand-washing techniques, sterile gloves, gowns, masks, and hair nets as well as large theatre-sized drapes for all procedures involving central venous access.[15] Skin preparation with 2% chlorhexidine has been shown to be more effective in preventing bloodstream infection than 10% povidone-iodine,[11,16] but lower concentrations of chlorhexidine may be less effective.[15,17] Catheter sites are usually covered with sterile gauze or semitransparent, semipermeable dressings, the latter making examination of the catheter site easier.[11,13] The value of education, standardization of technique, and quality assurance has been repeatedly demonstrated[3,4,18] and should be part of the management routine in the coronary care unit. Where antisepsis is breached during an emergency procedure, steps should be taken as soon as feasible to replace the IVD.

LOCAL ANESTHESIA

Local anesthesia with 1% lignocaine (lidocaine) may cause venous spasm or hematoma but is suggested for all but emergency or small gauge peripheral intravenous cannula insertion. Local anesthetics such as lignocaine may be cardiotoxic (hypotension and bradycardia) and neurotoxic (seizures) if safe dose limits are exceeded or if inadvertent intravascular injection

occurs. These complications are rare with 1% lignocaine as they usually require an injection of 100–150 mg (10–15 mL of 1% lignocaine) or more.

Initial skin puncture is achieved with a fine (25 gauge) needle raising a small wheal on the skin and injecting gradually deeper layers with multiple injections. Each injection should be preceded by aspiration to reduce the risk of inadvertent intravascular injection. Local infiltration can usually be achieved through the single entry site. If deeper infiltration is required, the 25-gauge needle can be removed and replaced with a longer 23-gauge needle using the same entry site, identified by a drop of blood on the skin or by leaving the finer needle in situ.

Lignocaine is usually effective in achieving local anesthesia within 5 minutes and lasts for approximately 1 hour.

PERIPHERAL VENOUS CANNULATION

Insertion of a cannula in a peripheral vein is usually a straightforward procedure.[19]

Shaving of the hairy areas of the skin improves visualization of the vein and allows application of an adhesive dressing after insertion of the cannula. In difficult situations, tapping of the vein, dependency of the limb, application of warm compresses, and local application of nitroglycerine cream or spray can all be attempted. With increasing use of anticoagulant and fibrinolytic agents in the coronary care unit, multiple venipuncture attempts should be avoided. If venous access has not been achieved after two or three attempts, more experienced assistance should be called for.

Venous access can be obtained by any peripheral vein. Veins in the dorsum of the hand are usually fragile and not suitable for long-term intravenous drip sites. Veins on the forearm are suitable but are often not available because of previous attempts at intravenous cannulation. The antecubital veins are commonly used for larger bore access and in emergencies but, because of flexion of the elbow, are often not suitable for routine use. Veins on the leg are available but cannulation of the saphenous vein may cause phlebitis, which would render the use of the vein unsuitable for subsequent coronary artery bypass surgery. Transillumination[19] and ultrasound can assist in the insertion of peripheral cannulas in difficult access patients.[10,20,21] Specialist teams (predominantly nursing) who insert and follow up cannulas for signs of infections may reduce bloodstream infection although the advantage of recommended routine cannula change at 48–72 hours is more difficult to confirm as beneficial.[11,12,22,23]

CENTRAL VENOUS CANNULATION

General considerations and site selection

There should always be a clear indication for the insertion of a central venous line and also for its continued use, as up to 20% of patients may experience complications that can be potentially serious and costly to manage.[8,24,25] Indications may include administration of vasopressor drugs or other medications that cannot be given safely by peripheral veins, or for monitoring of central venous or pulmonary artery pressures, or insertion of pacing wires. Patients at higher risk of complications are those with a low or high body mass index, with a history of previous surgery or radiotherapy to the area or previous failed catheterization. These patients may benefit from more experienced clinicians performing these procedures as they have significantly lower rates of complications.[8] Balancing the provision of procedural training with patient safety is a matter for individual units. Choosing a particular site may be influenced by the operator's experience and the particular indication for the central line.

A Cochrane review[26] of evidence for central venous access sites for the prevention of venous thrombosis, stenosis, and infection identified only one high-quality study. One study[25] randomized patients to the femoral versus the subclavian approach and found that infectious, thrombotic, and mechanical complications were more frequent with femoral compared with subclavian venous access (relative risks were 4.57, 11.53, and 0.92 respectively). The risk of pneumothorax with the subclavian approach may be higher with hyperinflated lungs (and its significance more devastating in patients with pulmonary disease) and the jugular vein may be safer.[8] Further studies are required to compare subclavian and internal jugular access although both seem clinically acceptable.

Although femoral venous access is generally avoided, it is still occasionally of use. Pneumothorax may be devastating in a patient with severe hypoxemia. Bleeding complications from inadvertent subclavian arterial puncture, although infrequent, may be more difficult to control. This is particularly relevant with the widespread use of antithrombotic agents in coronary care units. Some patients will require large-bore intravenous devices such as for dialysis.[22,27] The various sites for access to the venous system are summarized in Table 46.1.

TECHNIQUES FOR CENTRAL VENOUS CANNULATION

Seldinger technique

The modified Seldinger technique is the standard technique used for the insertion of central venous catheters and pacing catheters via the subclavian, internal jugular, and femoral veins. It can also be used for arterial access in some circumstances such as the femoral artery for invasive blood pressure monitoring or for intraaortic balloon pump insertion.

- After infiltration of the area with local anesthetic, the vein or artery is located with a shallow beveled needle attached to a syringe.
- When a free flow of blood is obtained, the needle is advanced slightly, ensuring that a free flow of blood continues.

Table 46.1 Venous cannulation sites.

Site	Indications	Relative contraindications
Basilic or median cephalic vein	Administration of drugs and moderate volume of fluids Preferred route during CPR PICC line access	Local infection Lymphedema Thrombophlebitis
Femoral vein	Administration of large volumes during emergency resuscitation Short term central vein access Dialysis lines	Severe obesity Local infection
Internal jugular vein	Placement of a central catheters Administration of large volumes of fluid Administration of irritating medications or hypertonic solutions Vasopressor/inotrope infusions	Neck injury Local infection Coagulopathies (although may be preferable to use compared to subclavian) CPR Previous surgery or radiotherapy to the area
Subclavian vein	Placement of a central catheter or temporary pacemaker Administration of large volumes of fluid Administration of irritating medications or hypertonic solutions Vasopressor/inotrope infusions	Chest trauma or deformity Coagulopathies (more difficult to deal with bleeding complications) Positive-pressure ventilation Emphysematous patient Unilateral lung disease Previous surgery or radiotherapy to the area

CPR = cardiopulmonary resuscitation; TPN = total parenteral nutrition; PICC = peripherally inserted central catheter

- Ensure that the vessel is not arterial by disconnecting to observe for pulsatile flow or connect to a pressure transducer to observe the trace. The color of the blood alone is not always reliable.
- The floppy end or "J"-tipped end of the guide wire is advanced through the needle into the vessel lumen and advanced approximately 15 cm past the tip of the needle.
- The needle is removed while maintaining the guide wire in the vessel.
- A small nick in the skin 2–3 mm in length is made with a scalpel at the entry site of the wire.
- A firm dilator is then passed over the guide wire and advanced into the vessel. Care should be taken to prevent kinking of the tip of the dilator as it enters the skin as this can traumatize the vessel.
- The dilator is removed, leaving the wire in situ over which the catheter is then passed, taking care not to advance the wire at the same time.
- Finally, the guide wire is removed and the catheter secured to the skin with suture fixation.
- The length of catheter to be inserted may be approximated by mapping the catheter on the chest prior to insertion or by calculation from patient height.[8]

Special precautions with the Seldinger technique

- Prior to embarking on the Seldinger technique, ensure that the guide wire, dilator, and introducer are all compatible.
- Always use the soft end; never use the firm end of the guide wire.
- Be cognizant of length of guide wire inserted and never enter the heart. Observe the cardiac monitor for arrhythmia.
- Never advance the guide wire if resistance is met. It usually indicates migration of the needle tip out of the vessel.
- If resistance to the guide wire is experienced, remove the needle and guide wire together, reinsert the needle through another entry site, and ensure the free flow of blood before reinserting the guide wire.
- Never withdraw the guide wire over the needle or dilator as this can cause subsequent difficulty in removal of the guide wire or even guillotining and transection of the guide wire.
- Never force the dilator or introducer over the guide wire.
- To confirm vascular access, aspirate for free flow of blood. A chest x-ray is ultimately taken to confirm correct placement and absence of pulmonary complications.

ULTRASOUND-GUIDED TECHNIQUES

While techniques based on surface landmarks or appropriately named "blind" techniques are usually successful in experienced hands, occasionally serious complications may occur.[25,28,29] Some complications may be due to variations in anatomy. An ultrasound study of internal jugular anatomy in 200 patients found abnormal anatomy in 8.5%.[30] The internal jugular vein is not always lateral to the carotid artery and is often anterior to the artery at the base of the neck.[20] Ultrasound can improve the visualization of the relevant anatomy and reduce complications.[31,32] A prospective randomized study compared real-time ultrasound guided technique with standard landmark methods in 900 patients.[33] The physicians were well matched in terms of relative experience. The success rate for

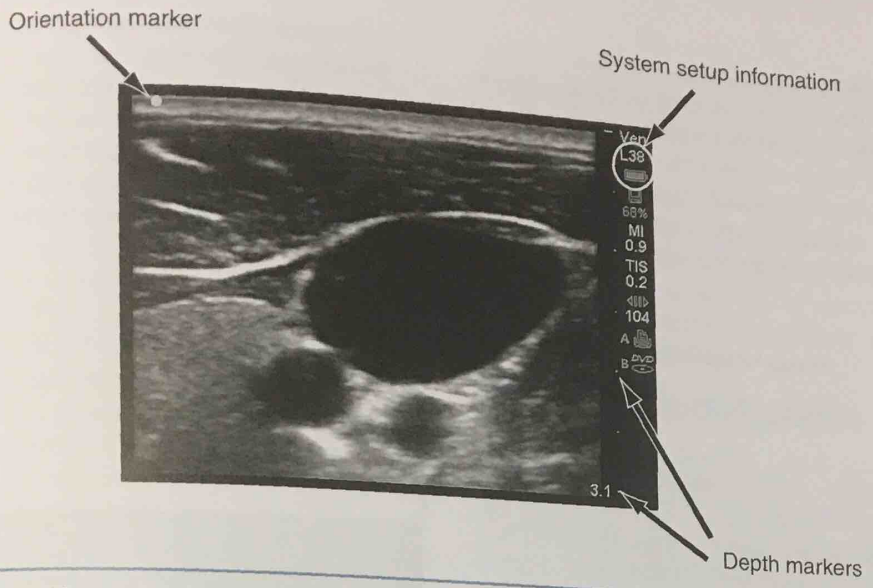

Figure 46.1 Ultrasound image Orientation. Image reproduced with the permission from SonoSite Australasia Pty Ltd.

insertion was 100% with ultrasound compared with 94% for standard technique, and the risk of complications with the standard technique were significantly higher: carotid puncture in 10.6% vs. 1.1%; hematoma 8.4% vs. 0.4%; pneumothorax 2.4% vs. 0%; and bloodstream infections 16% vs. 10.4%. In addition, the access time and frequency of attempts were lower in the ultrasound group. Given the growing weight of evidence now available in support of ultrasound guided techniques it is difficult to justify not using it.[32,34–37]

General principles of ultrasound guidance

Equipment

A high frequency linear array probe (10–15 MHz) will give the high resolution required for vascular access. These probes are very useful for superficial depth imaging but lose resolution beyond 4–6 cm. It is important to learn the basic "knobology" of the machine available. Important buttons are the depth, gain, and color flow Doppler settings. There will be an orientation marker on the side of the probe with a corresponding marker on the screen indicating to assist with medial and lateral orientation. This is demonstrated in Figure 46.1.

The machine should default to "vascular" settings once the probe is connected, but this may need to be set manually in some machines. A good quality sterile sheath, with elastic bands to enclose the probe and sterile gel, is required for real-time imaging.

Imaging

In standard two-dimensional imaging the blood will appear dark, and the vessel wall and adjacent tissue brighter. With experience, differentiating structures including thyroid tissue, muscle, and blood vessels will become easier. Blood vessels may be viewed in either longitudinal or transverse (short axis) orientation. See Figures 46.2 and 46.3. Differentiating a vein from an artery is described below.

Procedural tips

If inexperienced in "real-time" imaging and needle advancement, practice can be obtained on artificial preparations. Until proficiency is gained in this setting it is advisable to use the ultrasound to identify and mark the position of the vessel and return to the usual Seldinger approach. While real-time imaging is more difficult initially, once the basic skill of looking at the screen instead of the patient while advancing the needle is mastered, greater success will be achieved with this method than any other, particularly for difficult access. The ultrasound should be positioned to allow the operator to face the screen, usually on the opposite side from inserting the line.

Identify and mark the vessel

Before sterilizing the skin, the ultrasound can be used to mark out the location of the vessel. The image is adjusted so that the depth required is at a minimum and there is a clear transverse or longitudinal view of the vessel. The gain is then adjusted to optimize the grey-white interface. Differentiation between the vein and adjacent artery is made by identifying pulsatility and non-compressibility of the artery. If this is not clear on two-dimensional imaging, color flow Doppler may be applied and will demonstrate the type of flow more clearly. Note that the color indicates only the direction of flow in relation to the probe ("Blue Away, Red Towards" or BART) and not the type of vessel. With a marking pen, the skin overlying the middle of the vessel on either side of the probe is marked. Then the two marks are joined to outline the course of the vessel and the usual Seldinger technique is proceeded with.

"Real-time" imaging

- The patient is prepped and draped as usual and the ultrasound probe covered in a sterile sheath with gel or fluid placed inside the sheath where the transducer tip will be. The sheath is pulled tight over the probe and a plastic band wrapped around the neck of the probe to secure the sheath and prevent movement during scanning. Additional sterile gel is placed onto the skin.
- The probe is usually held in the non-dominant hand, keeping the dominant hand free for insertion of local anesthetic and then the needle.
- The vessel may be imaged in either transverse or longitudinal view. Initially the image is usually more

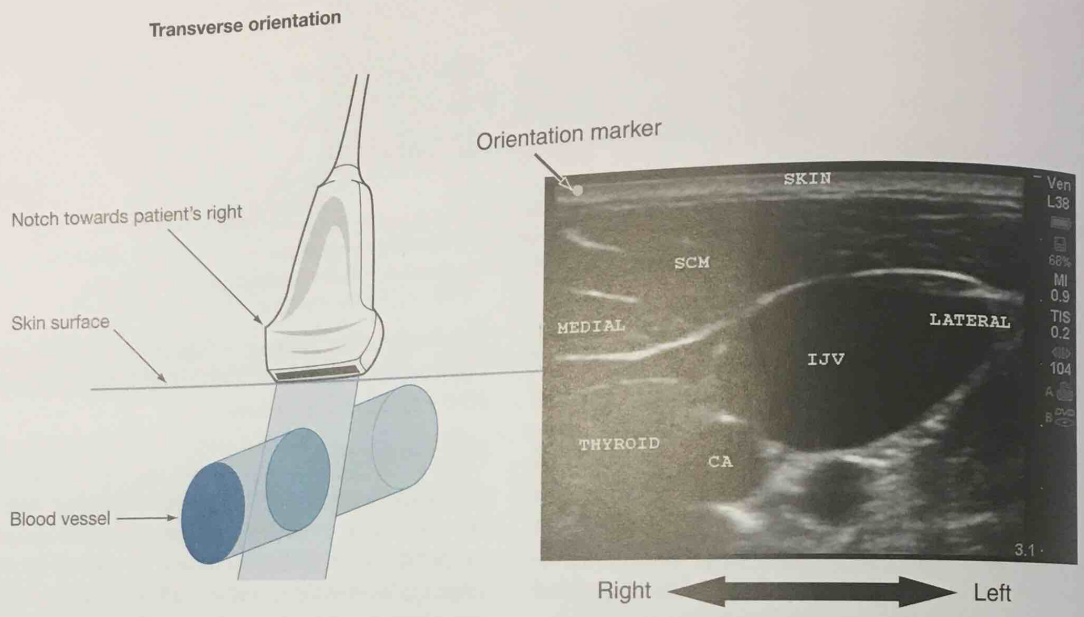

Figure 46.2 Transverse or short-axis view of blood vessels. SCM Sternocleiodomastoid muscle; IJV Internal jugular vein; CA Carotid artery. With permission from SonoSite Australasia Pty Ltd.

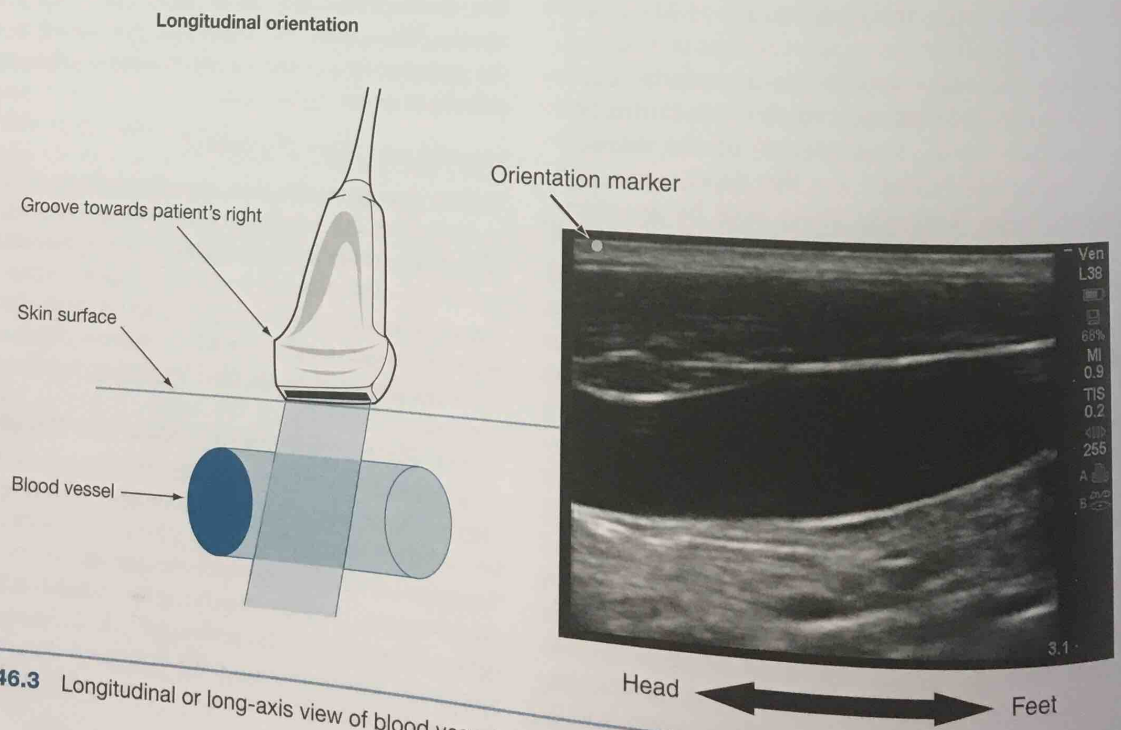

Figure 46.3 Longitudinal or long-axis view of blood vessels. With permission from SonoSite Australasia Pty Ltd.

stable in transverse view but the needle entry may be more difficult to track. In transverse view, the tip of the needle will be seen as it enters the ultrasound plane but it can be difficult initially to be sure of where the tip of the needle is. As the needle is advanced the tip may cross the ultrasound plane and the shaft; it then creates the "shadow" and, while the image does not change, the needle may be placed too deep.

- In longitudinal view the needle will be more easily identified as it will be seen "in plane" and can be tracked more closely. This is more suitable for subclavian and femoral vessels.
- Once a satisfactory image is obtained, the image is stabilized in the center of the screen. The entry site, approximately 1–2 cm from the probe, can now be injected with local anesthetic.
- The needle is slowly advanced, care being taken to keep it in view at all times. In short axis or "out-of-plane" imaging the needle tip can be jiggled as it is advanced to appreciate the position of the advancing tip.
- The needle should be seen to indent the surface of the vessel.
- A common initial error is to advance the needle while it is not in view.
- Once the vessel is entered the ultrasound can be ceased and the wire passed into the vessel. Ultrasound can also confirm placement of the wire correctly prior to dilatation, as shown in Figure 46.4.
- Following dilatation the catheter can then be placed in the usual Seldinger manner.

Figure 46.4 "Real-time" longitudinal view of vessel with guide wire in place. With permission from SonoSite Australasia Pty Ltd.

PERIPHERALLY INSERTED CENTRAL CATHETERS

Peripherally inserted central catheters (PICCs), first described in 1975,[38] are long, flexible catheters inserted via the upper limb veins with the tip lying in the superior vena cava adjacent to the right atrium. The main advantages of PICC lines are to avoid some of the insertion risks of centrally inserted lines, to provide longer-term access particularly for outpatient use, and to reduce infection risk. Sepsis rates are not necessarily lower in acute hospital patients.[39] PICC lines have a higher rate of thrombosis compared to central venous lines but the clinical significance of this is uncertain.[39–41] PICC lines are also more suitable for central access in coagulopathic patients and generally correction of coagulopathy is not required. Insertion proximal to the antecubital fossa offers advantages over distal insertion in terms of less kinking and oozing from dressing sites, and improved cosmesis for outpatients. Ultrasound is recommended for access to proximal veins, with the basilic vein most suitable due to its relatively straight course and reduced risk of median nerve injury or brachial artery puncture.

Indications for PICC line placement

- Alternative to central venous catheter insertion
- Long-term intravenous requirement

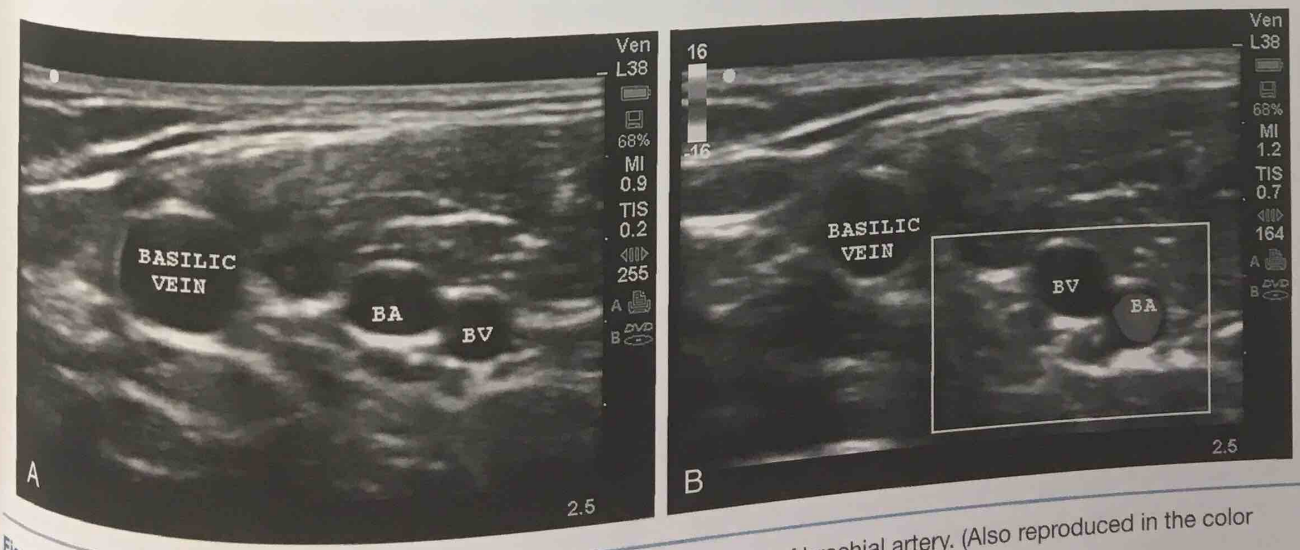

Figure 46.5 Ultrasound image of (A) basilic vein; (B) color flow Doppler of brachial artery. (Also reproduced in the color section.) BA Brachial artery; BV Brachial vein. With permission from SonoSite Australasia Pty Ltd.

- Administration of vasopressors, chemotherapy, or other drugs that can cause tissue necrosis with extravasation
- Poor peripheral access

Insertion of PICC lines

- Obtain informed consent.
- Use full aseptic technique and ECG monitoring.
- Apply tourniquet to proximal arm.
- Use real-time ultrasound if available.
- After infiltration with local anesthesia, enter the vein with a 20-gauge cannula or needle and, using the Seldinger technique, insert the soft-tipped end of the wire into the vein.
- Release the tourniquet and advance the wire while the patient's head is turned toward the limb to prevent entry into the jugular vein.
- Remove the cannula or introducer needle and pass the dilator and sheath over the wire.
- Then remove the wire and dilator, leaving in place the sheath through which the catheter is passed. Some kits have a second wire, which can be inserted in to the catheter to stabilize it as it is advanced.
- Advance the catheter, taking care to ask the patient to turn toward the side of insertion to prevent entry to the jugular vein. If using fluoroscopy, the tip should be positioned in the distal superior vena cava, adjacent to the right atrium. If fluoroscopy is not available, ultrasound may identify if the line has entered the jugular vein.
- Catheter insertion length should be adjusted relative to patient size. Note the internal and external lengths of catheter.
- The sheath can then be split and removed by pulling it apart, leaving the catheter in place.
- Securely anchor the line to the skin using the adhesive devices usually provided with the kit. Suturing is rarely required. Apply a sterile dressing.
- Unless performed under fluoroscopy, a chest x-ray is required to confirm position. If the line tip is seen to be in the jugular vein at this point, it can either be withdrawn 8–10 cm so that it lies at the base of the neck, or a new line can be inserted.

Complications of PICC lines

- Insertion risks:
  - hematoma formation
  - median nerve injury
  - brachial artery puncture
  - arrhythmias
  - catheter or wire emboli [42]
- Thrombosis[39–41]
- Phlebitis[39]
- Catheter-related bloodstream infection[9,39]
- 2–5 per 1000 catheter-days for inpatients; 0.4 per 1000 catheter-days for outpatients
- Air embolus

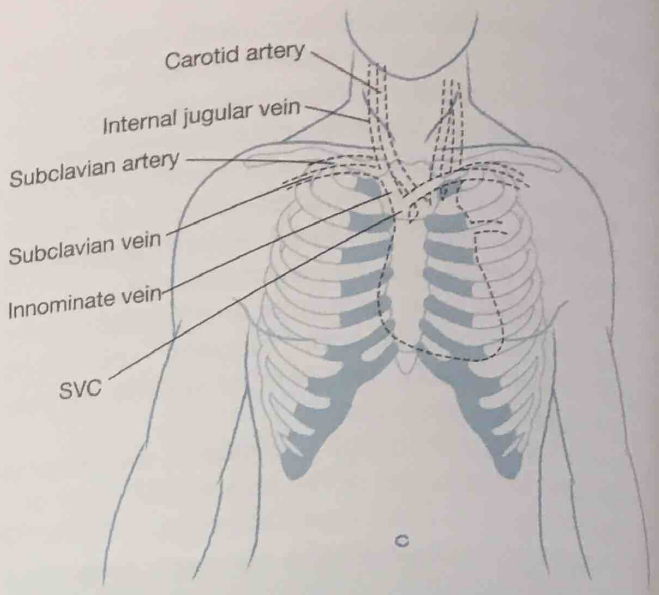

Figure 46.6 Anatomy of the subclavian vein in relation to the clavicle, first rib and subclavian artery. Reproduced with permission from Daily EK, Tilkian AG. Venous access. In: Cardiovascular procedures. Diagnostic techniques and therapeutic procedures. St Louis: CV Mosby, 1986.

- Catheter occlusion[39]
- Cardiac tamponade (rare)

CENTRAL VENOUS ACCESS

Subclavian vein—infraclavicular approach[43]

Of the sites used for central venous cannulation, the subclavian vein is the most widely used because of relative ease of access, low rate of complications, and convenience for the patient.[25] The recent introduction of "health care bundles" sees it as the preferred site for most patients.[4,13]

Anatomy

The anatomy of the subclavian vein in relation to the subclavian artery is summarized in Figure 46.6.

The subclavian vein drains the axillary vein and joins the internal jugular behind the sternoclavicular joint to form the innominate vein. It crosses the first rib and runs medial and inferior to the subclavian artery from which it is separated by the anterior scalenus muscle. The vein sits atop the apical pleura.

Surface markings

The vein is located at the junction of the medial and middle thirds of the clavicle immediately below the clavicular head of the sternomastoid.

Landmarks technique

The patient is supine and mild head down position is preferable with a small pillow.[6,8] The skin is entered below the clavicle, 2 cm medial to the junction of the middle and medial third of the clavicle and just lateral to the clavicular head of the sternomastoid. This allows a flat traverse under the clavicle toward

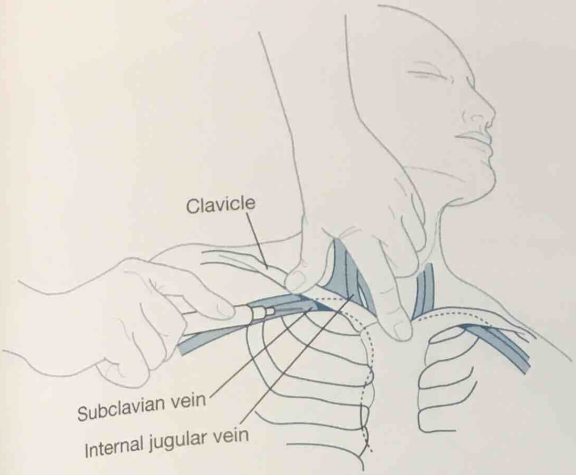

Figure 46.7 Cannulation of the right subclavian vein. The technique for the left subclavian vein is identical; the left subclavian is preferable in the patient who may need a permanent pacemaker. Reproduced with permission from Daily EK, Tilkian AG. Venous access. In: Cardiovascular procedures. Diagnostic techniques and therapeutic procedures. St Louis: CV Mosby Co., 1986.

the point where the vein will be punctured. The Seldinger technique is then used to enter the vein and insert a central venous catheter, pulmonary artery catheter, or pacing catheter. The technique for right subclavian infraclavicular cannulation is demonstrated in Figure 46.7.

Ultrasound guided technique for subclavian vein access

The subclavian vein is best imaged by placing the probe in longitudinal axis along the deltopectoral groove (Fig 46.8).

Using this approach, due to the width of the probe, the entry point to the vein is actually the axillary vein, slightly more lateral than with landmark techniques (Fig 46.9).[44]

The adjacent subclavian artery can be identified by tilting the probe superior to point about 10–20° toward the head. Do not rotate or move the probe while doing this maneuver. It should become clear which is the artery and which is the vein by identifying pulsatility and non-compressibility of the artery. The vein may partially collapse on inspiration, depending on the filling pressures of the patient. Using this method, local anesthetic can be placed with minimal discomfort to the patient, as the clavicle is not encountered. The pleura may also be imaged, lowering the risk of pneumothorax. Of key importance when advancing the needle is the need to keep it fully in view using an "in-plane" or long-axis view. The needle should be seen to indent the surface of the vein quite clearly, at which point the needle can then be advanced into the vein. If blood is not aspirated it is important to withdraw the needle to a shallower depth and confirm needle visualization prior to repeat advancement.

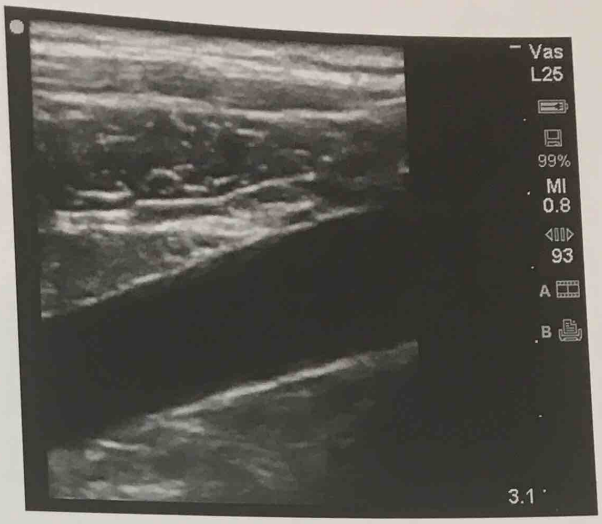

Figure 46.8 Longitudinal view of subclavian vein. With permission from SonoSite Australasia Pty Ltd.

Complications of the subclavian infraclavicular approach[8,43]

Air embolism[7]

Air can be aspirated into the venous system by a patient taking a deep breath in an upright position during cannulation. This can be prevented by asking the patient to maintain normal respirations with the patient in the supine position and with the head slightly down.

Pneumothorax and hemothorax[8]

Multiple attempts at cannulation should be avoided and preferably the vein should be identified with a narrow bore needle. Subclavian cannulation is best avoided in patients with hyper-expanded chests or emphysema.

Subclavian artery cannulation

This can be avoided by ensuring that the cannula is passed medially and not lateral with the landmark technique or by direct real-time visualization under ultrasound. The vein is best located with a small bore needle. If subclavian artery perforation occurs, pressure over the clavicle or the first rib is usually sufficient to prevent major bleeding; however, the patient should be carefully monitored for ongoing bleeding and correction of any coagulopathy is usually required.

Cannulation of the jugular vein

The cannula or guide wire may be inserted into the subclavian vein and redirected to the ipsilateral jugular vein. This can be detected by image intensifier control and can be corrected by having the patient bring their head or ear down to the shoulder on the site of insertion.

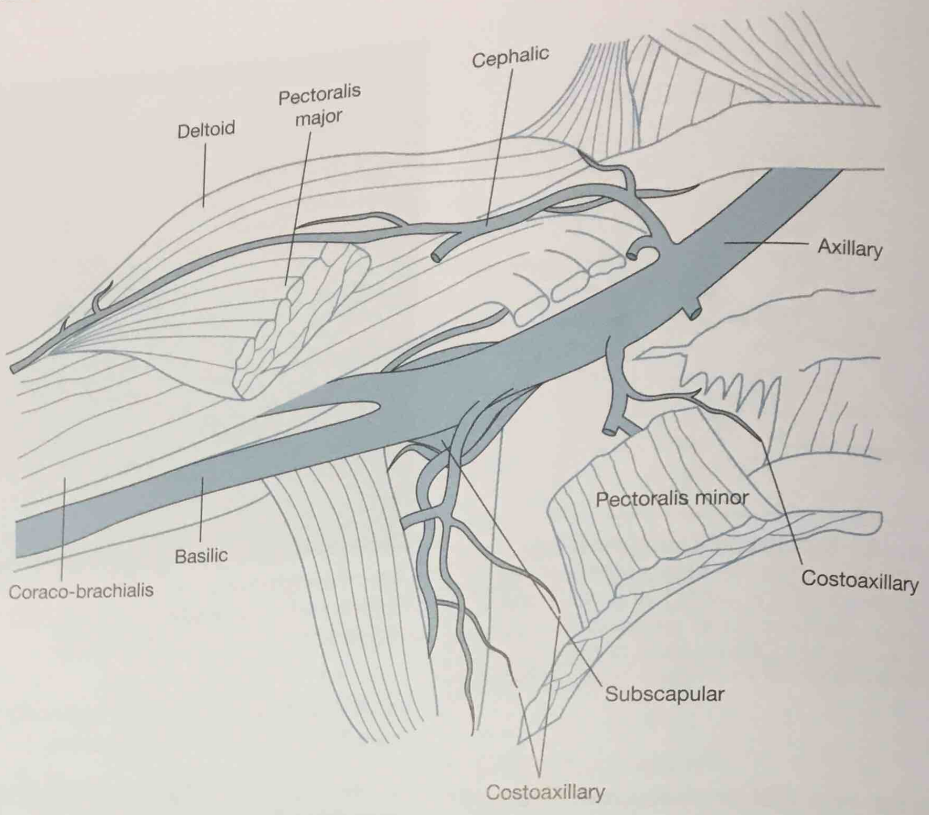

Figure 46.9 Anatomy of the axillary vein. With permission from SonoSite Australasia Pty Ltd.

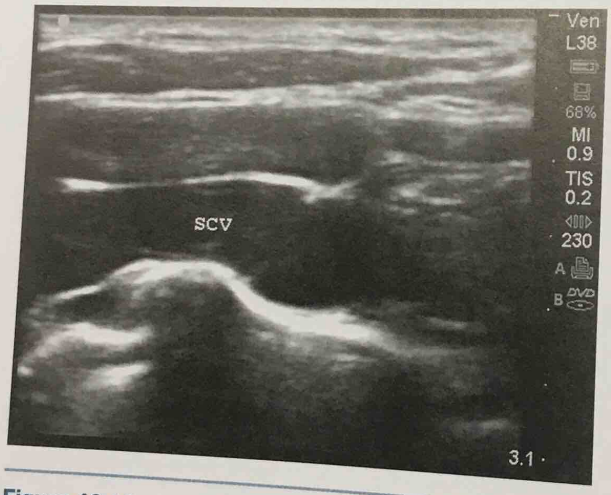

Figure 46.10 Ultrasound appearance of supraclavicular view of the subclavian vein. With permission from SonoSite Australasia Pty Ltd.

Subclavian vein—supraclavicular approach

The supraclavicular approach to the subclavian vein has been reported as being safer with less chance of pneumothorax and, in skilled hands, carries a greater rate of success, but the positioning of a cannula or pacing wire following insertion is less convenient and more uncomfortable for the patient than the infraclavicular approach because of the contour of the neck, clavicle, and supraclavicular fossa.

Internal jugular vein[24,45]

The internal jugular vein approach to venous cannulation has the advantage over the widely used infraclavicular approach to the subclavian vein in that there is less risk of pneumothorax or arterial puncture and there is more direct access to the superior vena cava.[24] Cannulation of the internal jugular vein can be life-saving during acute resuscitation when venous access is impossible via other routes. However, it is not an ideal site for elective cannulation for insertion of pulmonary artery catheters and temporary pacing catheters, which may be in place for several days, because of difficulties in securing the catheter to the soft tissues of the neck, particularly in bearded males.

Patient preparation

The patient is prepared by lying in the supine position with extension of the neck, assisted by a small pillow under the neck, and the procedure is preferably performed in a slight head-down position.

Entry sites

The right internal jugular is most commonly used because of ease of entry and ready access to the superior vena cava. While a variety of entry sites have been described, including high entries lateral or medial to the sternoclavicular muscle in the neck, the most commonly used entry site is the low central entry between the sternal and clavicular heads of

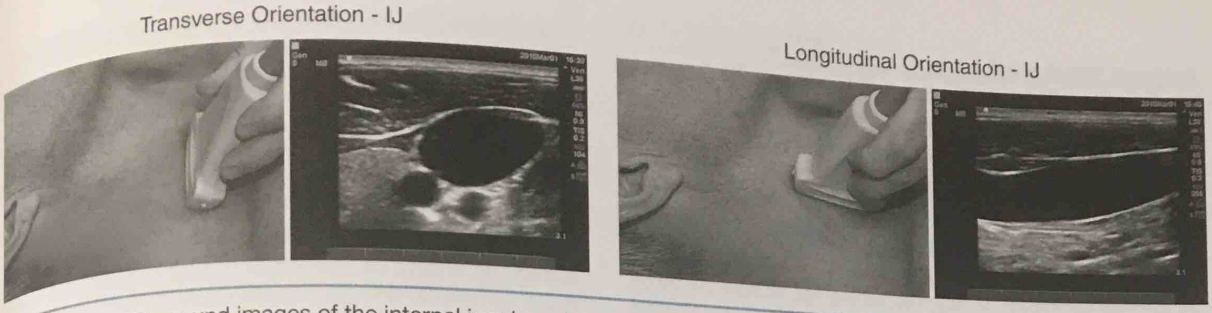

Figure 46.11 Ultrasound images of the internal jugular vein. With permission from SonoSite Australasia Pty Ltd.

the sternomastoid muscle. The latter approach will be described here.

Technique

Following preparation of the patient, the surface landmarks are identified, preferably with a skin-marker pen. The sternoclavicular heads are identified by asking the patient to turn their head laterally against resistance or lifting the head slightly off the pillow.

Routine preparation for the Seldinger technique is followed, including a check on compatibility of the guide wire, dilator, introducer, and cannula.

The skin is entered in the center of the triangle between the sternal and clavicular heads of the sternomastoid 3–4 cm above the medial aspect of the clavicle.

Local skin infiltration with 1% lignocaine is followed by locating the internal jugular with a fine needle. Leaving the needle in position, the Seldinger needle is used to enter the internal jugular vein at a 30° angle to the skin with the tip of the needle directed toward the ipsilateral nipple. When the vein is entered and a free flow of blood is obtained, the syringe is removed and the guide wire passed.

If the vein is not entered immediately the needle is passed more medially, but without angling the needle toward the midline. In a cooperative patient the Valsalva maneuver may help distend the vein or, in a less cooperative patient, an assistant applying abdominal compression may be helpful.

The dilator is then passed over the wire assisted by making a small nick in the skin in the usual Seldinger fashion, with expiration and head-down position being favored to prevent air embolism. Following dilatation, the catheter or sheath (for a pacing or pulmonary artery catheter) can then be passed.

The catheter should be securely sutured to the skin, preferably with nylon suture material at two fixation points. A sterile dressing is then applied.

Ultrasound-guided internal jugular vein access

Due to variations in internal jugular anatomy, it can be very useful to use ultrasound to verify the anatomy (in about 8% of patients it is not in the position predicted by landmarks or is thrombosed).[30] At the base of the neck the vein is often found to be anterior to the carotid artery. A transverse view, or "out-of-plane," approach to the vein is usually more practical than "in-plane" longitudinal approach. Ultrasound can be used to identify and mark the vessel prior to proceeding or used with "real-time" imaging with the probe in a sterile sheath. It is useful to scan the vein proximally and distally to find the best entry point. It is also quite easy to completely compress the vessel so light application of the probe is advisable.

Complications of internal jugular vein cannulation[45]

Air embolism

This can be avoided by performing the procedure in the head-down position and ensuring that all manipulations are performed during expiration or with the Valsalva maneuver or manual abdominal compression.

Carotid artery puncture[45]

Usually, needle puncture of the carotid artery is not a significant misadventure and local pressure for 5–10 minutes will prevent significant bleeding. In the elderly patient with known carotid atherosclerosis, manual compression may cause problems with central blood flow, and should be done with care; indeed a past history of transient cerebral ischemia should be a contraindication to the jugular approach unless there are no alternative venous cannulation sites. If the carotid artery has been dilated and a catheter inserted, immediate referral to a vascular surgeon is advisable.[46] While removal and direct pressure is the simplest pathway, should ongoing bleeding become a problem the airway may easily become compromised and the complication will become far more serious. Radiologists may also be helpful to assist with hemostasis during catheter removal using various percutaneous vascular sealing devices now available.[47] This complication is less likely to occur in the normotensive patient but in the shocked or hypotensive patient, inadvertent carotid artery cannulation may occur. Pulsatile blood flow may be so compromised as to be unrecognizable and in this case urgent blood gas analysis may help to distinguish arterial from venous blood. The use of ultrasound has been shown to reduce the risk of this complication.[33]

External jugular vein

Despite its obvious superficial location, the external jugular is not ideally suitable for venous cannulation because it is excessively mobile under the skin, making it difficult to enter on occasions and difficult to allow passage of a cannula into the great veins at the base of the neck. If there is expertise in subclavian, internal jugular, or femoral vein cannulation, the external jugular is best avoided.

Femoral vein[48]

Although femoral vein cannulation is widely used in the cardiac catheterization laboratory for right heart catheterization, temporary pacing cover, and electrophysiology study, it should not be used as a longer term venous access site for the coronary care unit if prolonged cannulation such as pulmonary artery catheter or temporary pacemaker is contemplated because of the risk of deep vein thrombosis, pulmonary embolism, and infection.[25] Nevertheless, femoral vein cannulation can be a very useful route for venous access, especially if emphysematous disease (or severe coagulopathy) is likely to make subclavian cannulation hazardous, or during resuscitation when cardiopulmonary resuscitation and endotracheal intubation cause overcrowding at the upper half of the body and prevent clean access to the internal jugular.

The femoral vein lies medial to the artery and nerve in the femoral triangle (nerve-artery-vein, NAV). The location of the vein can be identified by palpating along the length of the femoral artery. When the pulsations of the artery are recognized the vein should lie immediately medial to the pulsations. The artery can be moved laterally with the tips of three fingers and the skin entry site located approximately 1 cm medial to the pulsations. It is important to enter the vein below the inguinal ligament so that, in the event of inadvertent femoral artery puncture or oozing from the femoral vein, bleeding can be controlled with local pressure rather than dealing with intrapelvic hematoma.

Following the location of the vein and the free flow of venous blood, the vein is entered with the usual Seldinger technique and the cannula is passed to the iliac vein, inferior vena cava, and right heart under fluoroscopic control.

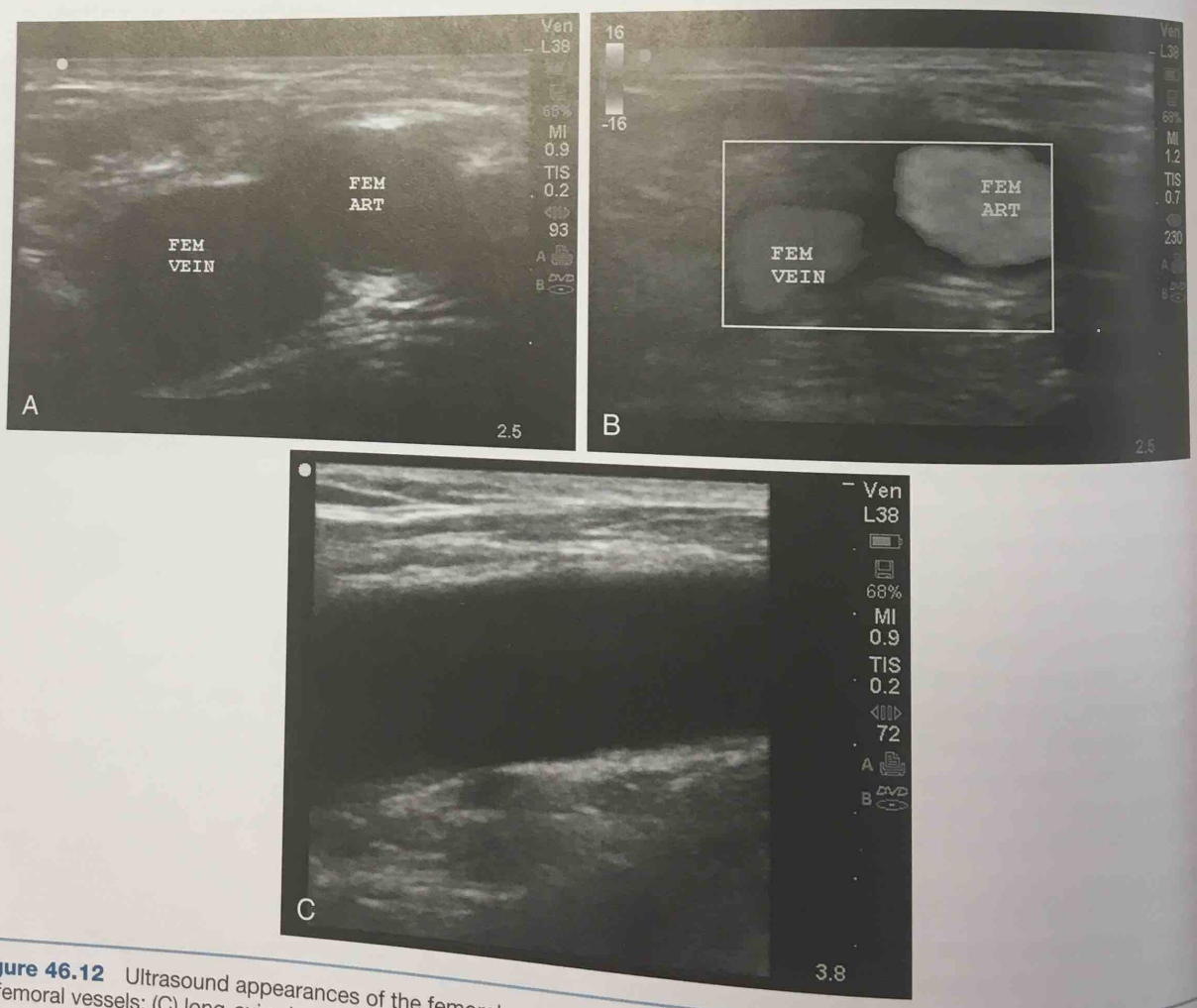

Figure 46.12 Ultrasound appearances of the femoral vessels: (A) Short-axis view of femoral vessels; (B) Colour flow Doppler of femoral vessels; (C) long-axis view of femoral vein. With permission from SonoSite Australasia Pty Ltd.

Ultrasound-guided femoral vein cannulation

Ultrasound is very useful in femoral vein or arterial access, particularly in obese patients. Typical "textbook" anatomy will frequently not be evident and the vein may overlie or sit deep to the artery. Both transverse and longitudinal views are suitable; however, the transverse view may offer the best image in practice as the probe may be more stable.

Complications of femoral vein approaches[48]

Inadvertent puncture of the femoral artery can be dealt with by withdrawal of the needle and application of local pressure for 5 minutes (longer in the presence of anticoagulant or thrombolytic therapy). If the artery is dilated and a catheter or sheath passed into it, this can be managed as for the elective removal of arterial sheaths using pressure devices or percutaneous hemostatic devices.

Inadvertent needle puncture of the femoral nerve is recognized by the patient complaining immediately of searing pain down the medial aspect of the thigh. Immediate withdrawal of the needle usually prevents any femoral nerve damage.

General complications and prevention

The complication rates associated with the antecubital, internal jugular, subclavian, femoral, and external jugular vein sites are summarized in Table 46.2.[24,49]

ARTERIAL ACCESS

Arterial access[50] in the coronary care unit is necessary for arterial puncture for blood gas analysis, for hemodynamic monitoring via the radial or femoral artery, or for percutaneous insertion of an intraaortic balloon pump via the femoral artery.

Arterial puncture

Arterial puncture for blood-gas analysis is performed with a heparin-loaded syringe using a small-bore needle. While a 26-gauge needle will reduce the risk of arterial damage or subsequent hematoma formation, it may not be of sufficient caliber to allow satisfactory aspiration of a blood sample, so a 23-gauge needle is usually used.

The radial artery is the preferred site. The patient's hand is extended and the vessel palpated. In the most commonly used technique the vessel is transfixed by inserting the needle at a 45° angle and gradually withdrawn, allowing blood to well up into the barrel of the syringe under its own pressure. When a satisfactory sample has been withdrawn the needle is removed and bleeding from the arterial puncture site controlled by local pressure for about 2 minutes (longer in the anticoagulated or thrombolysed patient).

Arterial blood sampling from the brachial artery or femoral arteries is usually done using the direct cannulation technique rather than transfixion of the

Table 46.2 Indications and contraindications for venous access sites.

Complication	Overall complication rate (%)	Specific complications and rate (%)	Prevention
Infections	Femoral 4.4 Subclavian 1.5	0.9–7.0 catheter-related blood stream infections per 1000 catheter days	Use infection control processes: • maximum sterile barrier • > 2% chlorhexidine skin preparation • antimicrobial catheters • standardized catheter care protocols.
Mechanical	Internal jugular < 10 Subclavian < 5 Femoral < 15	Carotid artery puncture 6.3–9.4 Subclavian artery puncture 3.1–4.9 Femoral artery puncture 9–15 Pneumothorax 1.5–3.1 Hemothorax 0.4–0.6 Myocardial perforation of pacing catheter 1–10 Hydrothorax < 1 Hemothorax < 1 Air embolism < 1 Catheter embolism < 1 Nerve damage rare Horner's syndrome rare Sternoclavicular osteomyelitis rare	Recognize risk factors • obesity, underweight (BMI > 30 or < 20) • previous surgery/radiotherapy to area • previous failed attempts. Avoid multiple (> 3) attempts. Experience reduces risk (> 50 procedures). Use ultrasound guidance. Do not schedule routine changes. Subclavian approach has lower incidence of complications but potentially more serious in selected patients.
Thrombotic	2–21	Femoral up to 21 Subclavian 1.9	Subclavian catheterization has a lower risk of thrombosis compared to either internal jugular or femoral

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posterior wall. The brachial artery is located with the elbow extended and the site of maximal arterial pulsation identified. The femoral artery is entered approximately 2 cm below the inguinal ligament.

Arterial cannulation for pressure monitoring[50]

The radial artery is the most widely used although there is increasing use of the femoral artery. If the radial artery is to be used, the adequacy of arterial blood supply to the hand must be assessed. If there is not adequate arterial collateral supply by the ulnar artery, radial artery spasm, thrombosis, or compression can cause serious ischemia of the hand. To ensure adequate collateral supply, a modified Allen test is performed.[50] The patient's arm is elevated above the heart, and both radial and arterial pulses are occluded by thumb pressure for approximately 5 seconds. With the arterial compression maintained the hand is lowered and pressure from the ulnar site of the wrist is released. The hand should flush pink within 15 seconds of lowering. If it does not do so this indicates that ulnar arterial blood supply is compromised and that problems with radial artery cannulation could have serious consequences. If the results of the manual Allen test are inconclusive, the use of a Doppler flow probe over the ulnar artery may help to clarify the extent of arterial collateral blood supply. An even simpler technique is to monitor pulsatile flow with an oximetry probe on a finger and observe for disappearance of the trace.

Having confirmed adequate ulnar collateral supply, the radial artery is cannulated under local anesthesia using a modified Seldinger technique. The artery is entered with a 20-gauge needle and a soft flexible guide wire is passed proximally. The cannulating needle is removed and replaced with a Teflon catheter followed by removal of the guide wire and connection to the arterial monitoring system (see Ch 24).

A similar technique is used for entry to the femoral artery or brachial artery. If the radial artery site is not suitable, femoral artery cannulation is preferred because this avoids the problems of elbow flexion with brachial artery cannulation.

PERCUTANEOUS FEMORAL ARTERY CANNULATION FOR INTRAAORTIC BALLOON

Balloon catheters were initially inserted by a cut-down technique on the femoral artery and while this is still often used by surgeons during cardiac surgery, percutaneous insertion has become the main method of insertion and is the preferred method in coronary care unit (see Ch 50).

Preparation

The patient's legs and vascular supply are examined as are any angiographic studies, which may suggest a favored site of insertion. Previous vascular surgery is noted. An assistant (scrubbed) may help maneuver the long guide wire used during balloon insertion and can assist with control of blood loss from the femoral insertion site.

Procedures

Sheathed catheter insertion

- Standard preparation of the femoral artery for cannulation is made and local anesthesia is introduced.
- Femoral artery puncture is made and a guide wire inserted by Seldinger technique.
- If fluoroscopy is available (recommended) and is to be used for insertion, the guide wire is advanced until it comes to lie at the level of the left subclavian artery.
- Serial dilators are then passed over the guide wire.
- A sheath (approximately 10 French) containing a dilator is then advanced over the guide wire until approximately 2–3 cm of sheath protrudes from the skin. Undue force should not be applied to avoid femoral or iliac artery rupture.
- A hemostasis valve applied to the sheath prior to insertion helps minimize blood loss. The dilator is left in place until the balloon catheter is ready for insertion.
- Gentle suction is applied to the balloon inflation lumen and is maintained throughout balloon insertion.
- The dilator is removed and the balloon catheter is advanced over the guide wire until the tip lies approximately 1–2 cm proximal to the left subclavian artery.
- The guide wire is removed and a heparinized pressure monitoring line is connected to this lumen.
- The balloon inflation lumen is connected to the balloon console.
- The sheath is withdrawn until approximately 8–12 cm of sheath remains in the femoral artery. Care is taken not to retract the balloon catheter. A sheath-locking device is used to lock the catheter in situ. The sheath is sutured in place.
- Where fluoroscopy is not available, the balloon catheter may be advanced directly through the sheath without the use of a guide wire. The length of balloon catheter should be measured prior to use. The length is measured from the manubriosternal joint to the umbilicus and from the umbilicus to the femoral insertion site.
- Postinsertion, re-examine the limb for presence of ischemia. Consider sheath removal if ischemic. Review position of balloon catheter on the chest x-ray and repeat this procedure daily.

Sheathless catheter insertion

- This technique is similar to the above except that, after dilation of the artery, the balloon catheter is inserted directly over the guide wire.

- Fluoroscopy is again recommended to assist balloon placement. A guide wire must always be used for this technique of insertion.

Balloon removal

- Check patient sedation and analgesia.
- Check coagulation status and platelet count. Heparin is ceased at least 4 hours.
- Catheters implanted by surgical cut-down are best removed by surgical exploration and closure of the arteriotomy site.
- Ballooning is ceased and gentle suction may be applied to the inflation lumen.
- The catheter is withdrawn until it just engages in the balloon sheath. Further attempts at retraction into the sheath may "concertina" the sheath increasing its diameter and causing increased vessel damage on withdrawal.
- The catheter and sheath are then withdrawn as a unit.
- The distal femoral artery is compressed to prevent clot passing down the leg. The proximal portion is then allowed to bleed for 1–2 seconds. The proximal artery is then compressed and back-bleeding from the distal artery is then briefly allowed.
- Pressure is then applied to the artery for a period of 30–60 minutes before checking for bleeding on release. Mechanical clamps are available for this compression. Pedal pulses are checked regularly and foot perfusion examined during this period.
- Where there is prolonged bleeding not attributable to coagulopathy, surgical exploration may be required.

INSERTION OF LONG-TERM CENTRAL VEIN CANNULA

An indwelling cannula in the subclavian vein may be required where there is a requirement for long-term intravenous drug administration, such as with infective endocarditis. These catheters are generally well accepted by patients, and allow out-patient treatment with a low incidence of major complications.

Specialized sets are commercially available and provide all the equipment necessary for insertion of these long-term catheters (e.g. Groshong catheters:™ Groshong is a trademark of CR Bard Inc).

Procedure

A standard infraclavicular subclavian vein puncture is performed under strict asepsis and local anesthesia. A tearaway sheath is placed in the subclavian vein using the Seldinger technique. The dilator and J-wire are removed, and through the sheath a flexible silicon catheter is placed in the low superior vena cava (SVC). The tearaway sheath is then removed, as is the catheter's inner support wire.

After administration of more local anesthetic, a 5–10 cm subcutaneous track is created (superficial to the pectoral muscles) with the metal spear provided. The catheter is attached to the end of this spear and then drawn through the track with constant, gentle traction. A small nylon tethering sleeve around the catheter should remain subcutaneous. Once the distal end of the catheter has been passed through the skin, the catheter should be cut just proximal to the spear attachment. A flushing port can then be attached, but blood should be aspirated before the catheter is flushed with heparinized saline.

Care should be taken to ensure the catheter does not kink, particularly at the site of the superior incision. The latter may need to be closed with a 3/0 silk suture. Maintenance of the catheter should follow manufacturer guidelines and strict infection control guidelines.

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