Central venous cannulation

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INTRODUCTION

Central venous cannulation is a relatively common procedure in many branches of medicine, particularly in anaesthesia and intensive care medicine. An estimated 200 000 central venous access procedures are carried out each year in the United Kingdom's National Health Service and over 5 million in the United States. Historically central venous access was gained by a surgical cut-down procedure, but central venous catheters (CVCs) are now predominantly inserted percutaneously, using a technique first described by Seldinger in 1953. There are many different types of catheter and a number of different sites suitable for central venous access. Site selection depends on numerous factors including the indication and duration of access, anatomy of the patient, local resources and operator skill and experience.

INDICATIONS

The main indications for CVC insertion are:

- Administration of drugs
  - Irritant drugs
  - Long-term treatment (chemotherapy, antibiotics)
  - Long stay patients (e.g. tetanus)
  - Parenteral nutrition
- Haemodynamic monitoring
  - Central venous pressure
  - Mixed/central venous oxygen saturations
- Difficult peripheral access
- Haemofiltration / haemodialysis
- Insertion of pacing wires or pulmonary artery catheters.

CATHETER SELECTION

There is a large range of catheters available and selection should be based on site, reason for insertion and length of use. In anaesthesia and intensive care medicine the main considerations are catheter length and the number of lumens. Three to five lumens are ideal for critically ill patients, allowing multiple drug infusions, but the lumens are usually narrow with a high resistance to flow and so less effective for rapid infusion of fluid during resuscitation. Larger, shorter catheters such as an 8.5F introducer sheath are better suited to this purpose.

Types of catheter

- Single/multiple lumens
- Peripherally inserted central catheters (PICC)
- Tunnelled (the catheter travels a few centimetres under the skin before entering the vessel, in order to decrease the incidence of line infections).
- Specialized
  - dialysis catheters
  - continuous central venous saturation monitoring.

Lumen size

Larger catheters allow greater fluid flow (e.g. for resuscitation and haemofiltration) but have a greater risk of significant haemorrhage or air embolism during insertion or inadvertent disconnection. They also have a significant dead space to consider during administration of potent drugs such as vasopressors - the narrow gauge lumens of multiple channel lines are better for this purpose. Larger catheters are more likely to cause thrombosis or late stenosis of the vessel.

Impregnated catheters

A number of manufacturers make catheters impregnated with antimicrobial agents, such as chlorhexidine and silver sulfadiazine, in an attempt to reduce catheter related infections. Many ICUs use these lines routinely despite the higher cost, the potential for development of drug resistance and the inconclusive evidence for reduced morbidity and mortality.

PRINCIPLES OF INSERTION

In well resourced settings, ultrasound guided insertion has become standard practice. As this is unavailable in most low-income countries, landmark techniques are emphasized here.

The basic preparation and equipment required for CVC insertion is the same regardless of site or technique. A

Summary

Central venous catheters are extensively used in ICUs in high-income countries, but they remain beyond the facilities available in many developing world ICUs. In developing countries, their main use is as access for delivery of irritant drugs such as catecholamine infusions and for intravenous access in patients requiring prolonged organ support due to illnesses such as tetanus. The different sites of insertion are described and the common techniques for insertion are outlined.

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suitable clinical area should be chosen where full aseptic technique can be observed. A trained assistant is useful and the patient should be monitored with continuous ECG, oxygen saturations and blood pressure measurement. The suggested essential equipment is listed in Table 1. There is evidence that the use of a dedicated 'lines trolley' increases compliance with best practice. Confirm that the CVC is still needed and select the most appropriate route (see below). Explain the procedure to the patient.

Strict asepsis at the time of insertion is a major factor in reducing line related infections - wear sterile gloves, a gown, mask and theatre hat. Drape the surrounding areas of the patient and bed as thoroughly as possible. Good positioning and identification of anatomical landmarks will minimise the risk of failure and complications. In conscious patients local anaesthetic should be used.

Table 1. *Suggested essential equipment for CVC insertion.*

It is well worth having all of your equipment laid out in a logical order before you proceed. Make sure that you are familiar with the set provided.

- Patient on a tilting bed, trolley or operating table
- Hat, mask and sterile gown and gloves
- Large sterile drapes and gauze swabs
- Antiseptic solution (chlorhexidine in alcohol)
- Local anaesthetic agent with needle and syringe
- Saline flush
- Appropriate central venous catheter set
- Three-way taps
- Scalpel blade
- Sutures

General technique (Seldinger)

The most common method of insertion is the 'catheter-over-guidewire' (Seldinger) technique (see Figure 1). The vein is punctured with a small gauge needle (18 or 20G) attached to an empty syringe and blood is aspirated easily. If the blood appears bright red, is at high pressure or pulsatile consider the possibility of an arterial puncture.

The guidewire commonly has a J-shaped tip to reduce risk of damage to the vessel wall and help negotiate tortuous vessels. It should advance and withdraw easily at all times.

After removing the needle, a dilator is then passed over the guidewire and a small incision made in the skin to allow the dilator to advance through the skin, subcutaneous tissues and a short distance into the vein (further passage along the vein may cause damage to the vessel or distal structures). Gentle skin traction and a twisting motion aids passage of the dilator and prevents kinking of the guidewire. Remove the dilator and insert the catheter over the guidewire. The guidewire is held whilst the catheter is advanced to the desired length. Care should be taken not to advance the guidewire with the catheter, as this may precipitate arrhythmias and intravascular loss of the guidewire has been reported.

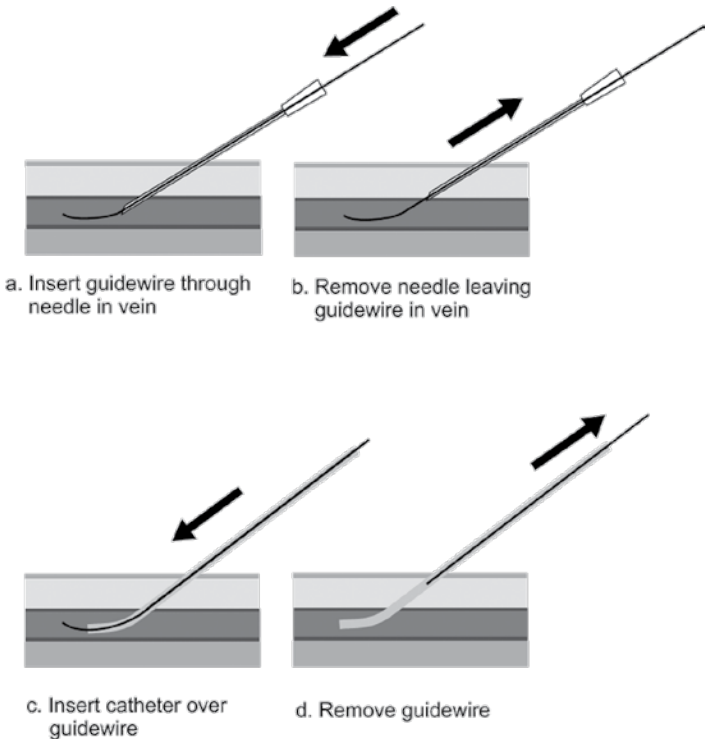


Figure 1. *The Seldinger technique.*

You can usually get some idea of the length required prior to insertion by laying the catheter on the patient's chest prior to insertion. Map out its course and note the distance between the tip at the medial right second intercostal space and the site of skin puncture. Remove the guidewire and aspirate and flush all the lumens with saline to check for free flow. Finally secure the catheter in place with sutures and a sterile non-occlusive dressing.

SITE SELECTION (Figure 2)

There are a number of approaches to the central venous system and these veins may be deep structures, running close to arteries, nerves and other structures (e.g. the pleura in the case of the subclavian vein). You must know the deep and surface anatomy of the area to undertake a landmark technique safely. 2-D ultrasound is increasingly used, where resources allow, and is well suited to the internal jugular, femoral and peripheral approaches. Ultrasound allows visualisation of the vessel, confirmation of placement of the wire within it and identification of anatomical variation.

The main entry sites are:

- Internal jugular vein
- Subclavian vein
- Femoral vein
- External jugular vein
- Veins of the arm or antecubital fossa (basilic or cephalic veins).

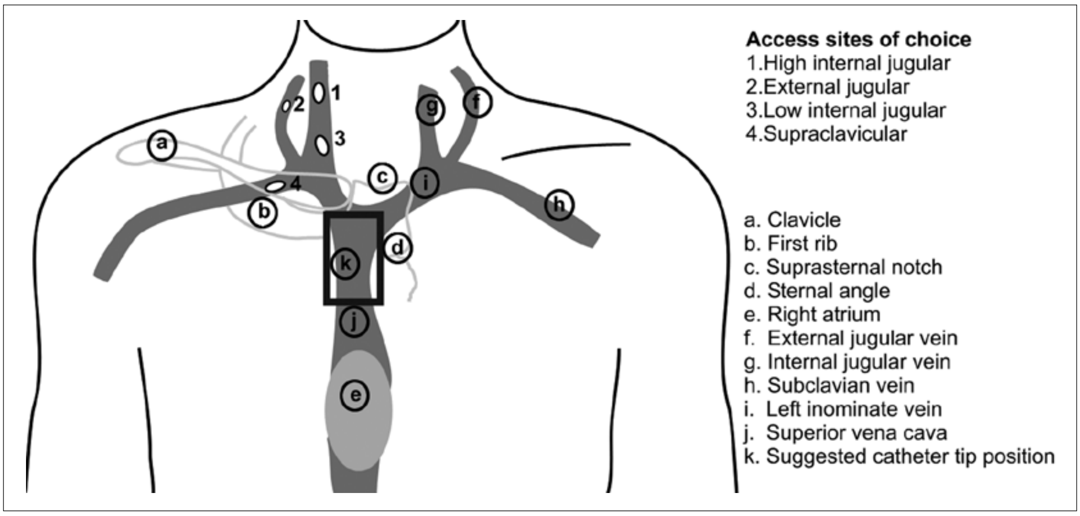


Figure 2. *Common sites for intrathoracic CVC placement.*

Factors determining choice

Duration of use

- Consider a tunnelled line for prolonged administration of antibiotics or where intravenous access has become difficult.
- Femoral lines are only appropriate for use for up to 48 hours due to the higher infection risk.

Suitability of site for planned CVC use

- e.g. for CVP measurement, catheter tip must be in thorax.

Operator

- Knowledge and practical experience of the technique – it is better to have a few clinicians in each area who perform all the central venous cannulations and gain experience (a 'central venous access team').

Technique characteristics

- Success rate for cannulation and central placement
- Complication rate
- Ease of learning
- Puncture of visible/ palpable vein versus blind, landmark technique.
- Applicability to patients of different ages.

Equipment available

- Availability of suitable apparatus (including ultrasound)
- Cost.

SPECIFIC CVC SITES

Internal jugular vein

The internal jugular vein (IJV) is most frequently chosen site for CVC insertion. It is a potentially large vein with a lower risk of pneumothorax compared with the subclavian approach. Inadvertent arterial puncture can be controlled easily with manual compression. Many approaches have been described depending on the level of the neck at which the vein is punctured. A high approach reduces the risk of pneumothorax but increases the risk of arterial puncture. For lower approaches the converse is true. With experience this route has a low incidence of complications.

Anatomy (Figure 3)

The IJV arises from the jugular foramen at the base of the skull and is a continuation of the sigmoid sinus (within the skull). It descends in the neck in the carotid sheath, with the carotid artery and the vagus nerve. It lies initially posterior to internal carotid artery before becoming lateral then anterolateral to the artery. Behind the medial end of the clavicle it joins the subclavian vein to form the brachiocephalic vein. The vein has dilatations at both ends, the superior and inferior jugular venous bulbs. Cannulation can be difficult in the morbidly obese, as landmarks are often obscured and those patients with very short necks or limited range of movement can also be a challenge. The IJV is unilaterally absent in 2.5% of patients and is outside the predicted path in 5.5% of patients. The right IJV offers some advantages in that it tends to be larger and straighter than that on the left, it is more convenient for the right-handed practitioner and avoids the possibility of thoracic duct injury.

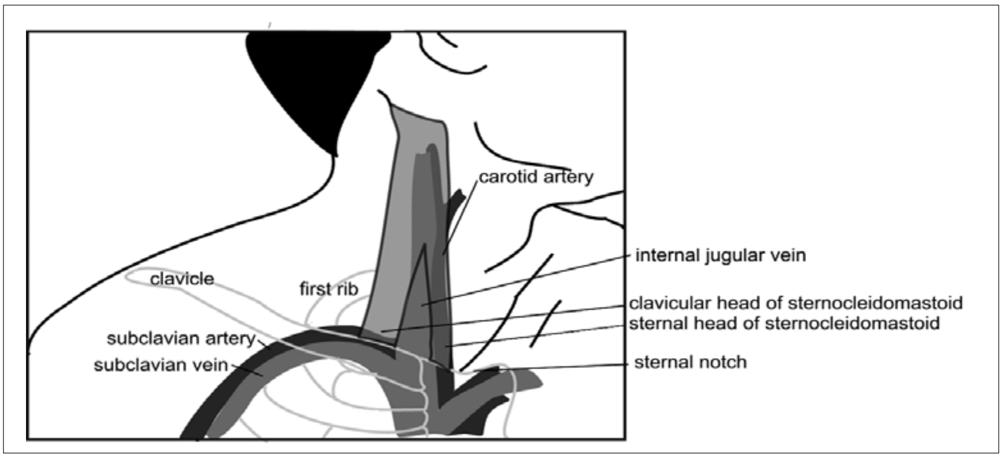
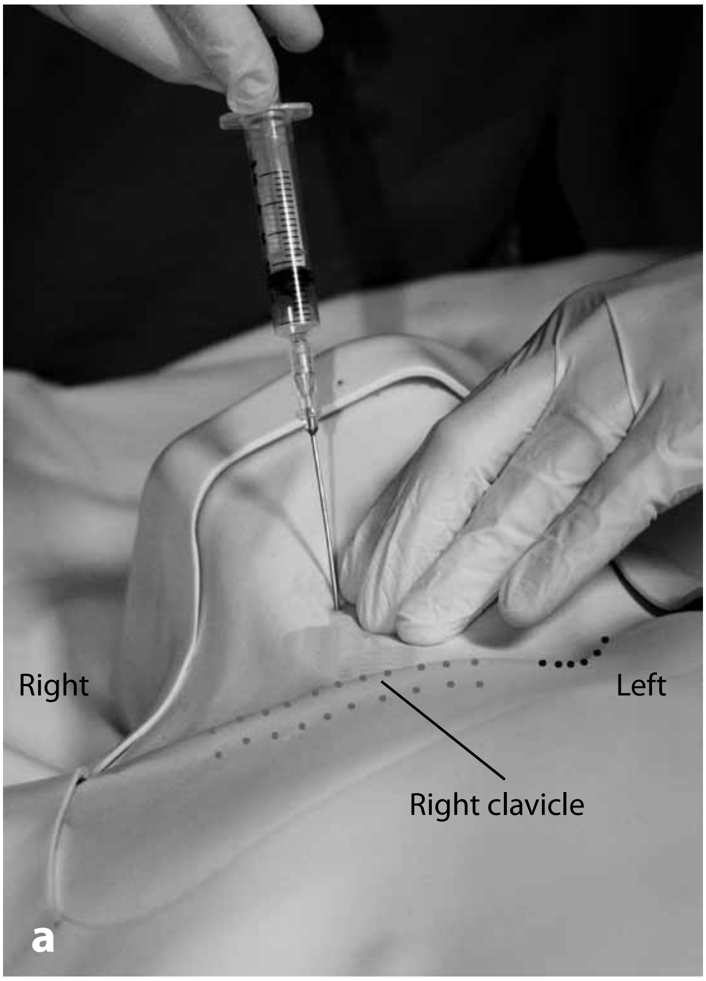


Figure 3. *The anatomy of the right internal jugular and subclavian veins*

Positioning

The patient is supine, arms by their sides, with a head down tilt to distend the veins and reduce the risk of air embolism. The head should be slightly turned away from the side of cannulation for better access (excessive turning should be avoided as it changes the relationship of the vein and artery and can collapse the vein). The patient's neck can be extended by removing the pillow and putting a small towel under the shoulders.



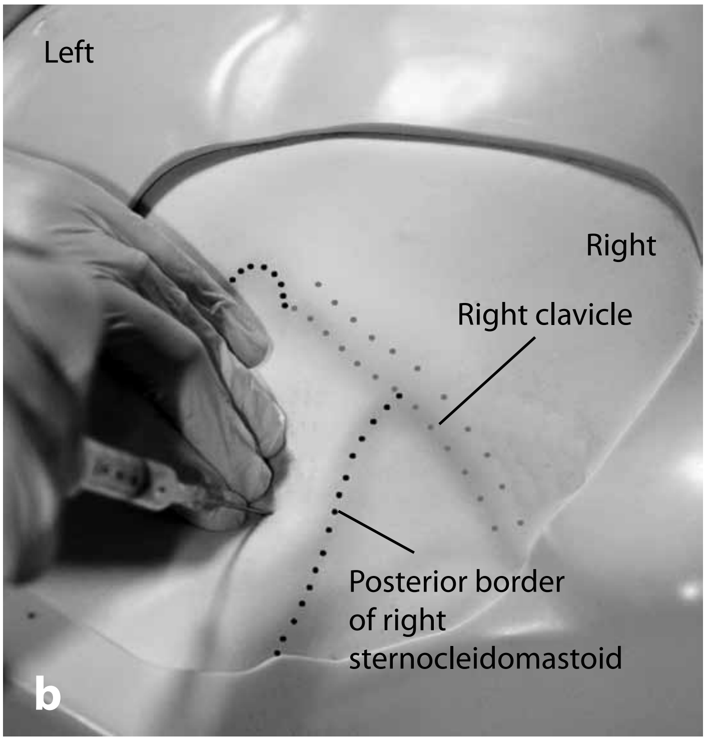


Figure 4. *Right IJV cannulation, (a) view from caudal aspect; (b) view from cranial aspect.*

Technique

Stand at the head of the patient and palpate the mastoid process and the sternal notch. The entry level is half way along a line joining these two landmarks. Palpate the carotid artery at this level and check your entry point is lateral to this. It is sometimes possible to ballot the vein which can aid accurate needle placement. Keeping your finger gently over this point (even small amounts of pressure can collapse the vein) insert the needle at 30-40° to the skin directed caudally towards the nipple on the same side (in females guess where it would be if it were a male) aspirating as you go. The vein is usually very superficial and only 0.5-2cm under the skin.

Practical problems

If the vein is not found recheck your landmarks, ensure the patient is adequately head down and consider rehydration if the patient is hypovolaemic. After a failed attempt to locate the vein, continue to aspirate as you slowly withdraw the needle; the vein may have collapsed on the way in and be transfixed as the needle has gone through the posterior wall. Resist the urge to advance the needle deeper into the tissues, as you are most likely to be in the wrong place rather than too superficial. If ultrasound is available use it to check that the anatomy is normal.

Subclavian vein

The subclavian vein (SCV) has a calibre of 1-2cm in adults and is thought to be held open by its surrounding tissues, even in severe circulatory collapse. It is often preferred for long-term central access as it is generally more comfortable for patients, can be easily tunnelled and has a lower risk of infection and other long-term complications. This route may also be preferred in trauma patients with suspected cervical spine injury.

This route is best avoided in patients requiring long-term renal replacement, as there is a significant risk of venous stenosis, causing problems for existing or future arteriovenous fistulae. The subclavian route is best avoided in patients with abnormal clotting or bleeding diatheses, as the vessels are inaccessible to direct pressure after inadvertent arterial puncture. Serious immediate complications are uncommon but occur more frequently than other routes. Pneumothorax is one of the most common major complications with an overall incidence of 1-2%. This figure increases to 10% if multiple attempts are made. Although possible in some patients, visualisation of the subclavian vein with ultrasound is difficult in most.

Anatomy

The SCV is a continuation of the axillary vein as it reaches the lateral border of the first rib (Figure 3). It ends at scalenus anterior where it joins the internal jugular vein, to form the brachiocephalic (inominate) vein, behind the medial end of the clavicle. Its only tributary is the external jugular vein and it lies anterior and parallel to the subclavian artery throughout its course. The cervical pleura lies behind the artery.

Initially the vein arches upwards and across the first rib and then inclines medially, downwards and slightly anteriorly across the insertion of scalenus anterior.

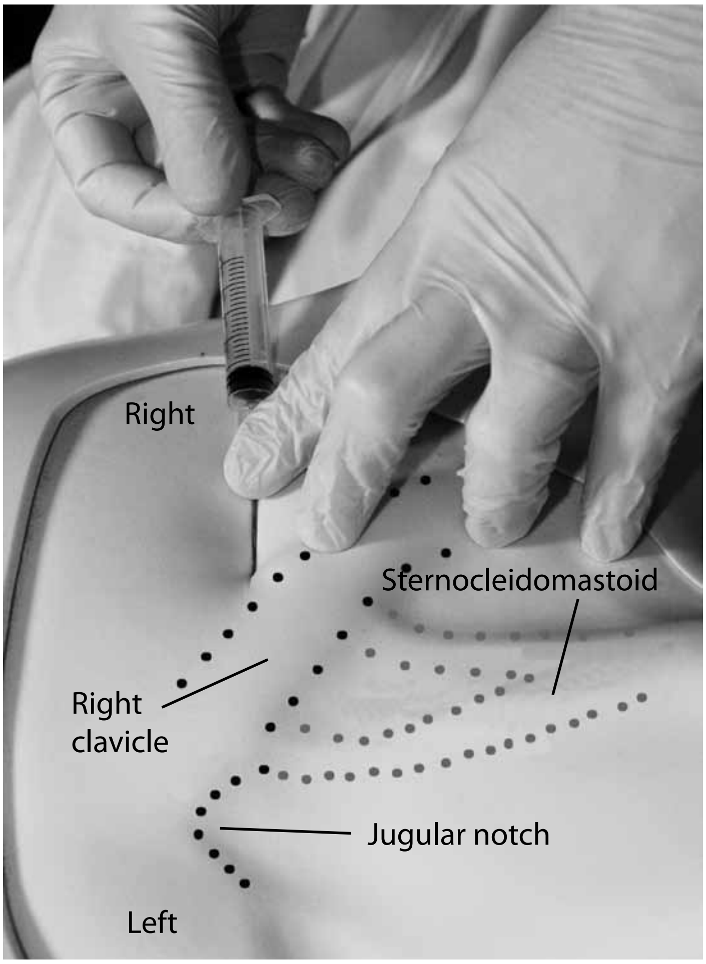


Figure 5. *Right SCV cannulation (mannequin).*

Positioning

The patient should be positioned as for the internal jugular approach with the head down to fill the veins and reduce the risk of air embolism.

Technique

The right SVC is usually preferred as this approach avoids damage to the thoracic duct. However in the presence of unilateral lung pathology, cannulation should be performed on the same side so that a pneumothorax will not affect the healthy lung. The infraclavicular approach is most commonly used, where the needle is inserted into the skin slightly below the lower border of the clavicle, at the junction of the middle and medial thirds of the clavicle. The needle is kept in the horizontal plane advancing medially, posterior to the clavicle aiming for the sternal notch. The needle should not pass beyond the sternal head of the clavicle.

Practical problems

If you are unable to get beneath the clavicle consider starting more laterally and bending your needle upward slightly. Some axial traction on the arms by your assistant and a pillow or rolled up towel between the shoulder blades may also improve success. If you still cannot find the vein, direct the needle a little more cephalad - place your finger fully into the sternal notch and aim for the middle of it. Do not persist after repeated attempts as the complication rate increases dramatically. Try an alternative route on the same side unless Xray is available to confirm there is no pneumothorax.

External jugular vein

As the external jugular vein (EJV) lies superficially in the neck it is often visible or palpable, which negates many of the complications of the deep vein approaches. It is a useful when expertise is lacking, for emergency fluid administration and in cardiac arrests where no carotid pulse is palpable. A long catheter will not reliably thread into the SCV (due to the presence of valves and other anatomical abnormalities), so it is usual to use a short peripheral cannula.

Anatomy

The EJV drains blood from the superficial facial structures and scalp and passes down in the neck from the angle of the mandible, crosses the sternocleidomastoid muscle obliquely and terminates behind the middle of the clavicle where it joins the SCV. The vein is variable in size and contains valves which may prevent the passage of the guidewire and catheter. There is a wide range in EJV size and prominence due to natural variation and disease states.

Positioning

As for IJV.

Technique

Standing at the head of the patient identify the EJV as it crosses the sternocleidomastoid. Insert the needle into the vein where it is most easily seen or palpated.

Figure 6. *Cannulation of the external jugular vein.*

Practical problems

If the vein is not visible or palpable, press on the skin above the middle of the clavicle and reduce drainage into the SCV, thereby distending the vein (Figure 6). Alternatively ask the patient to do a valsalva manoeuvre, tilt the patient more head down or hold in inspiration if ventilated. If there is difficulty threading the guidewire or catheter, try twisting whilst advancing or flushing saline through the catheter as you insert it. Slowly moving the head from one side to the other may also help. Caution should be used when manipulating the wire with the needle attached as there is a risk of the needle shearing of the end of the wire (a plastic cannula is safer)

Femoral vein

The femoral vein (FV) may be cannulated with low risk of serious short-term complications and, for this reason, is preferred by less experienced operators. This route is also useful in urgent situations when the patient is coagulopathic and is perhaps the safest central vein in children requiring resuscitation, where central access is needed for vasopressor therapy. The large diameter of the FV allows large fluid volumes to be removed and infused and is commonly used in the ICU for placement of short-term haemofiltration catheters.

Femoral catheters are better suited to ventilated, sedated patients as excessive movement can cause kinking of the catheter and mechanical complications. The CVP measurement from a femoral catheter can be affected by intra-abdominal pressure, although in ventilated patients values correlate well with those from intra-thoracic catheters. Arterial puncture or femoral nerve damage are both possible if insertion is too lateral. The risk of infection in the medium and long-term is higher with femoral catheters compared with most other routes because of the greater degree of bacterial colonisation found in the groin compared to other sites. There is also an increased risk of thromboembolic complications compared with internal jugular and subclavian approaches. For these reasons femoral catheters should be removed within 48-72 hours of insertion.

Anatomy

The FV starts at the saphenous opening in the thigh and runs alongside the femoral artery to the inguinal ligament where it becomes the external iliac vein. In the femoral triangle the FV lies medial to the artery in the femoral sheath.

Positioning

The patient should be supine with a pillow under the buttocks to elevate the groin. The thigh should be abducted and externally rotated.

Technique

Palpate the femoral artery 2cm below the inguinal ligament and insert the needle 1cm medial to the pulsation and aim cephalad and slightly medially at an angle of 20-30° to the skin. In adults the vein is usually 2-4cm below the skin. In children the FV is more superficial so the angle should be 10-15°. Cannulation can be difficult because of the lack of landmarks especially in obese patients.

Practical problems

It can be difficult to feel the arterial pulsation especially in obese patients. Get an assistant to retract the abdomen if this is a problem and recheck the landmarks. As with the internal jugular approach 2-D ultrasound, if available can be very useful to assess anatomy and guide the needle. As with other routes, ensure no digital pressure is collapsing the vein.

The antecubital veins

The superficial, palpable veins of the antecubital fossa provide a very safe route for central access. Risk of infection is lower than other routes and lines can be used for longer periods (e.g. TPN, prolonged antibiotic courses or chemotherapy). A long catheter is required (around 60cm) to thread the tip into the central veins and for this reason flow rates are low, with large dead space making them less useful for resuscitation and inotropes. Tip position is important as migration can occur with movement of the arm (up to 7cm in cadaveric studies but around 2cm in vivo).

Anatomy

Two main veins are available but the more medial basilic vein has a smoother, more direct route to the SCV. The more lateral cephalic vein turns sharply to pass through the clavipectoral fascia and also has valves at its termination. These factors frequently cause difficulty in advancing the catheter.

The basilic vein ascends along the medial side of the forearm before moving anterior to the medial epicondyle, where it is joined by the median cubital

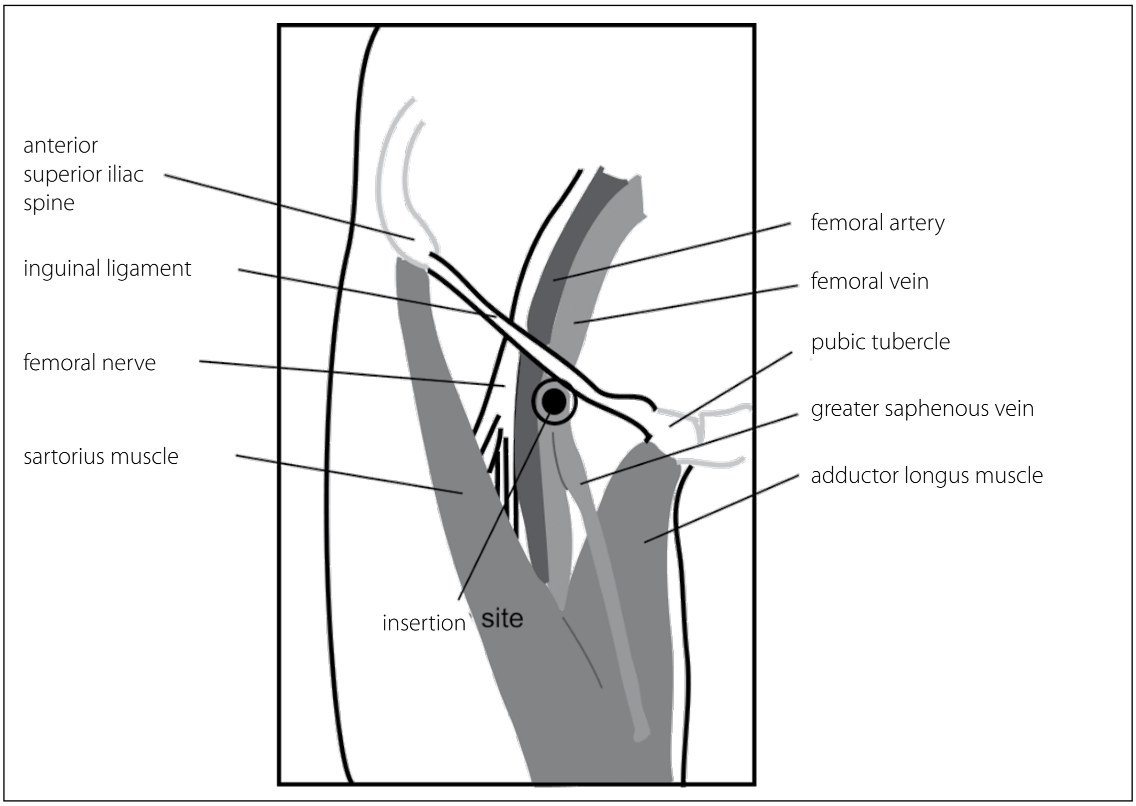


Figure 7. *Anatomy of the right femoral vein.*

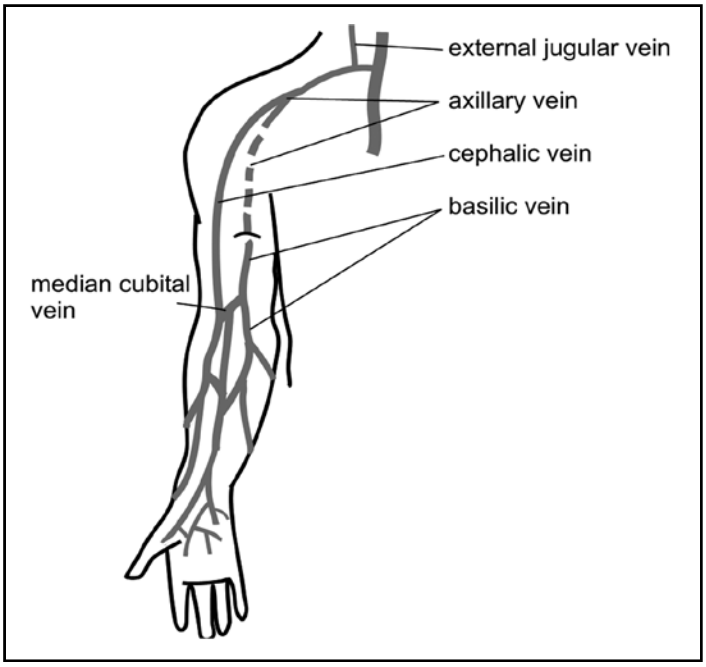


Figure 8. *Anatomy of the peripheral veins of the right arm.*

vein. It then runs along the medial edge of the biceps muscle to the middle of the upper arm, where it pierces the deep fascia and runs alongside the brachial artery, becoming the axillary vein.

The cephalic vein ascends on the front of the lateral side of the forearm to the front of the antecubital fossa, where it communicates with the basilic vein via the median cubital vein. It ascends along the lateral edge of the biceps muscle until it reaches pectoralis major, where it pierces the clavipectoral fascia to pass beneath the clavicle, where it usually terminates in the axillary vein (occasionally it may join the EJV).

Positioning

Apply a torniquet to the upper arm and select the best vein. The medial side of the arm is best for the reasons mentioned above. Lie the patient supine with the arm abducted at 45° to the patient and the head turned towards the ipsilateral arm (this may help prevent the catheter passing into the IJV).

Technique

Estimate the length of catheter required to reach the SCV. Insert the cannula supplied in the set and remove the needle. Thread the catheter through the cannula and advance it 2-4 cm before releasing the torniquet. Continue to advance the catheter until the desired length is inserted. The cannula is often designed to tear apart to remove it from the catheter. Other sets contain a guidewire and dilator for a Seldinger technique which is useful for smaller vessels.

Practical problems

In critically ill patients numerous attempts at venepuncture and cannulation have usually occurred, leaving vessels thrombosed and unusable. Looking more proximally may reveal untouched veins, especially on the inner aspect of the upper arm. 2-D ultrasound can be very useful for locating and checking patency of veins as well as guiding the needle. A more proximal approach can improve patient comfort as the line does not cross the joint and will be less prone to kinking and other mechanical complications. If difficulty in threading the catheter is encountered first check the tourniquet has been released and check you are definitely in the vein. Flushing with saline as the catheter is advanced may facilitate passage through valves. Further abduction of the arm may also help.

CHECKS BEFORE USING THE CATHETER

It is important to ensure that the catheter is within the vein prior to use. This is best done by transducing the pressure waveform or comparing synchronous arterial and venous blood gases. Dark blood at low pressure is not always a reliable sign especially in a hypoxaemic, poorly perfused patient. The position of catheters that enter the chest (i.e. jugular or subclavian approach) should be confirmed on chest Xray (Figure 9). The tip of the catheter should lie in the SVC, just above its junction with the right atrium. On chest Xray it should be above or overlying the right main bronchus. Check there is no pneumothorax.

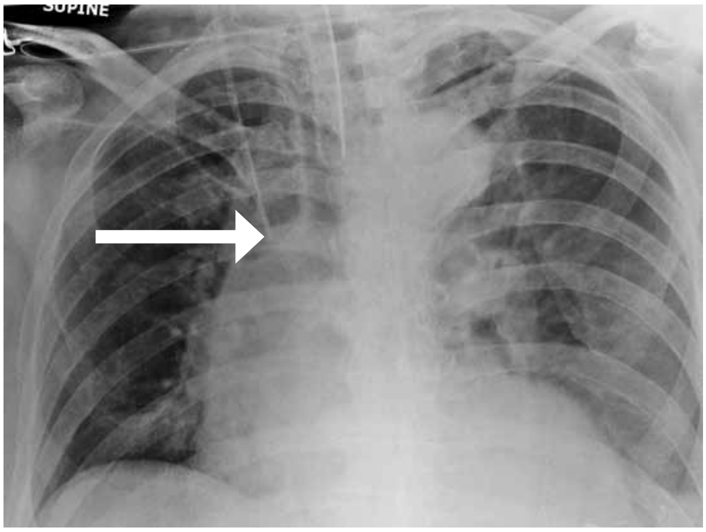


Figure 9. *Chest Xray showing optimal CVC tip position (arrow).*

COMPLICATIONS

Complications occur in up to 10% of CVCs and can be divided into mechanical, infectious and thromboembolic aetiologies, the most common of which are listed below. The complication rate is dependant on a number of factors including site, patient factors (concurrent illness and variations in anatomy) and operator skill and experience. Interventions recommended to prevent complications are also listed below. There are no absolute contraindications to central venous cannulation, as it can be a lifesaving procedure, but serious complications, including death, may occur during insertion or ongoing use of a CVC. Operator training and experience are important factors in reducing complication rates and experienced help should be sought after repeated attempts. The frequency of mechanical complications is six times greater than after a single attempt. Caution should be used to try and avoid complications in high risk patients and may influence site of access. There is a higher risk of pneumothorax with the subclavian approach and as the vessels are not amenable to direct compression. This site is least appropriate in patients with severe respiratory disease or bleeding diatheses. Penetrating abdominal trauma or known inferior vena caval disruption would make the femoral approach less desirable.

Mechanical complications
Arterial puncture
Haematoma
Pneumothorax
Haemothorax
Haemorrhage
Arrhythmias during procedure
Cardiac tamponade
Respiratory obstruction
Thoracic duct injury
Brachial plexus injury
Infectious complications
Local infection
Bacteraemia, sepsis
Thromboembolic complications
Thrombosis of vessel
Thrombus formation
Venous air embolism
Catheter/guidewire embolism
Interventions to prevent complications
Use antimicrobial–impregnated catheters
Insert in the subclavian vein
Strict asepsis at insertion
Avoid antibiotic ointment
Remove catheter when promptly when no longer required
Recognize risk factors for difficult catheterization and seek experienced assistance
Avoid femoral route
Use ultrasound during internal jugular insertion

ULTRASOUND GUIDANCE

In 2002 the National Institute for Clinical Excellence (NICE) in the United Kingdom recommended the use of ultrasound for the elective placement of CVCs into the IJV. Since this time the use of ultrasound use has increased dramatically. More clinicians are becoming experienced in its use and there is now increasing evidence showing a reduction in number of passes, failure rates, arterial puncture and time to placement and infectious complications using this technique.

Ultrasound guidance is particularly suited to the IJV, FV as well as peripheral veins. It is not possible to visualise the subclavian vein easily with ultrasound, due to the shadow cast by the clavicle, however the axillary vein can be visualised more laterally on the chest. The ultrasound image provides information about the patency and location of the vessel and can be used to guide the needle in real time (Figure 10).

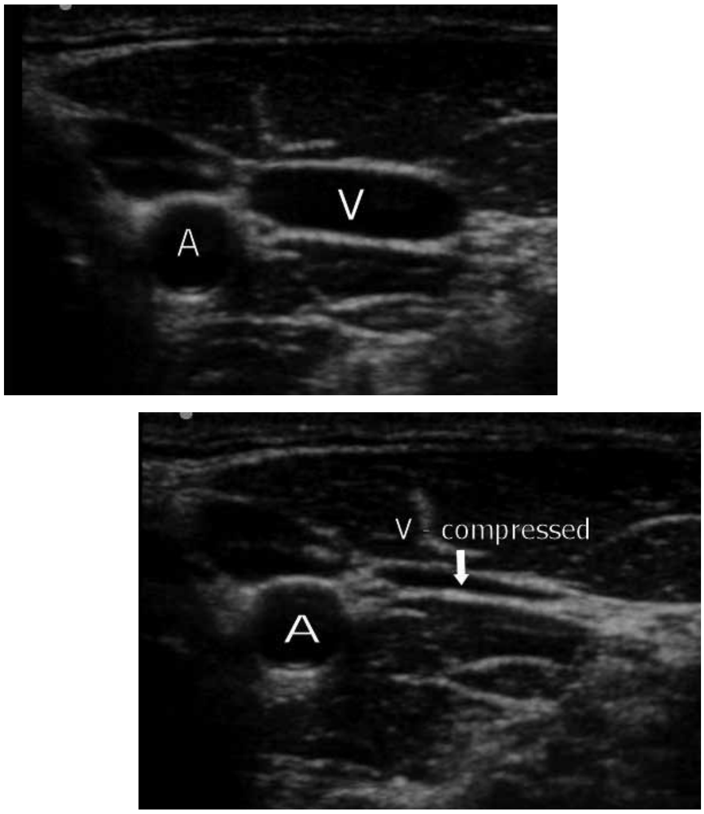


Figure 10. *Ultrasound images of internal jugular vein. Application of pressure using the probe identifies the vein as the compressible structure.*

SUMMARY

Central venous access is a commonly performed procedure that can be lifesaving, but is associated with significant complication rates. Operator experience, familiarity with the range of sites available, along with sound knowledge of anatomy and use of ultrasound can help to minimise some of the mechanical complications. Strict asepsis at the time of insertion, use of impregnated catheters, proper maintenance and timely removal can minimise infective complications.

FURTHER READING

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