## CENTRAL VENOUS ACCESS AND MONITORING

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Central venous access is the placement of a venous catheter in a vein that leads directly to the heart. The main reasons for inserting a central venous catheter are:

- measurement of central venous pressure (CVP)
- venous access when no peripheral veins are available
- administration of vasoactive/inotropic drugs which cannot be given peripherally
- administration of hypertonic solutions including total parenteral nutrition
- haemodialysis/plasmapheresis

### Which central vein to cannulate?

There are a number of central veins and for each of these there are a variety of techniques. It should be remembered that, with the exception of the external jugular, central veins are often deep and have to be located blindly. This is associated with risk to nearby structures, especially in the hands of the inexperienced operator. Veins commonly lie close to arteries and nerves, both of which can potentially be damaged by a misplaced needle. The subclavian vein also lies close to the dome of the pleura, damage to which can cause a pneumothorax. The choice of route will therefore depend on a number of factors as listed in table 1.

### Types of central venous catheters

Catheters are available which differ in length, internal diameter, number of channels (access ports), method of insertion (see below), material and means of fixation. Two useful lengths are 20cm catheters for subclavian and internal jugular lines, and 60cm catheters for femoral and basilic lines.

### Different methods of insertion

There are several basic methods of inserting the catheter after the vein has been found:

- **Catheter over the needle**. This is a longer version of a conventional intravenous cannula and may be quickly inserted with a minimum of additional equipment. The catheter is larger than the needle, which reduces the leakage of blood from the insertion site, but using a larger needle to find the vein makes the consequences of accidental arterial puncture more serious. In addition it is easy to over-insert the needle.
- **Catheter over guidewire (Seldinger technique**). This is the preferred method of insertion. A small diameter needle (18 or 20 gauge) is used to find the vein. A guidewire is passed down the needle into the vein and the needle removed. The guidewire commonly has a flexible J-shaped tip to reduce the risk of vessel perforation and to help negotiate valves in the vein e.g the external jugular vein (EJV). Once the wire is placed in the vein, the catheter is passed over it until positioned in the vein. The wire should

*Table 1. Factors which determine the choice of central vein*

| | |
|---|---|
| **Patient:** | How long will the catheter be required? ie. long term / intermediate / short term<br>Suitability of the vein for technique chosen e.g. for CVP measurement the tip of the catheter must be within the thorax. A femoral route therefore needs a long catheter |
| **Operator:** | Knowledge and practical experience of the technique –it is be 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 vein cannulation<br>Success rate of central placement<br>Complication rate.<br>Applicability to patients of different ages<br>Ease of learning<br>Puncture of a visible and/or palpable vein or 'blind' venepuncture based on knowledge of anatomy |
| **Equipment available:** | Availability of suitable apparatus<br>Cost<br>Suitability of material for long term cannulation |

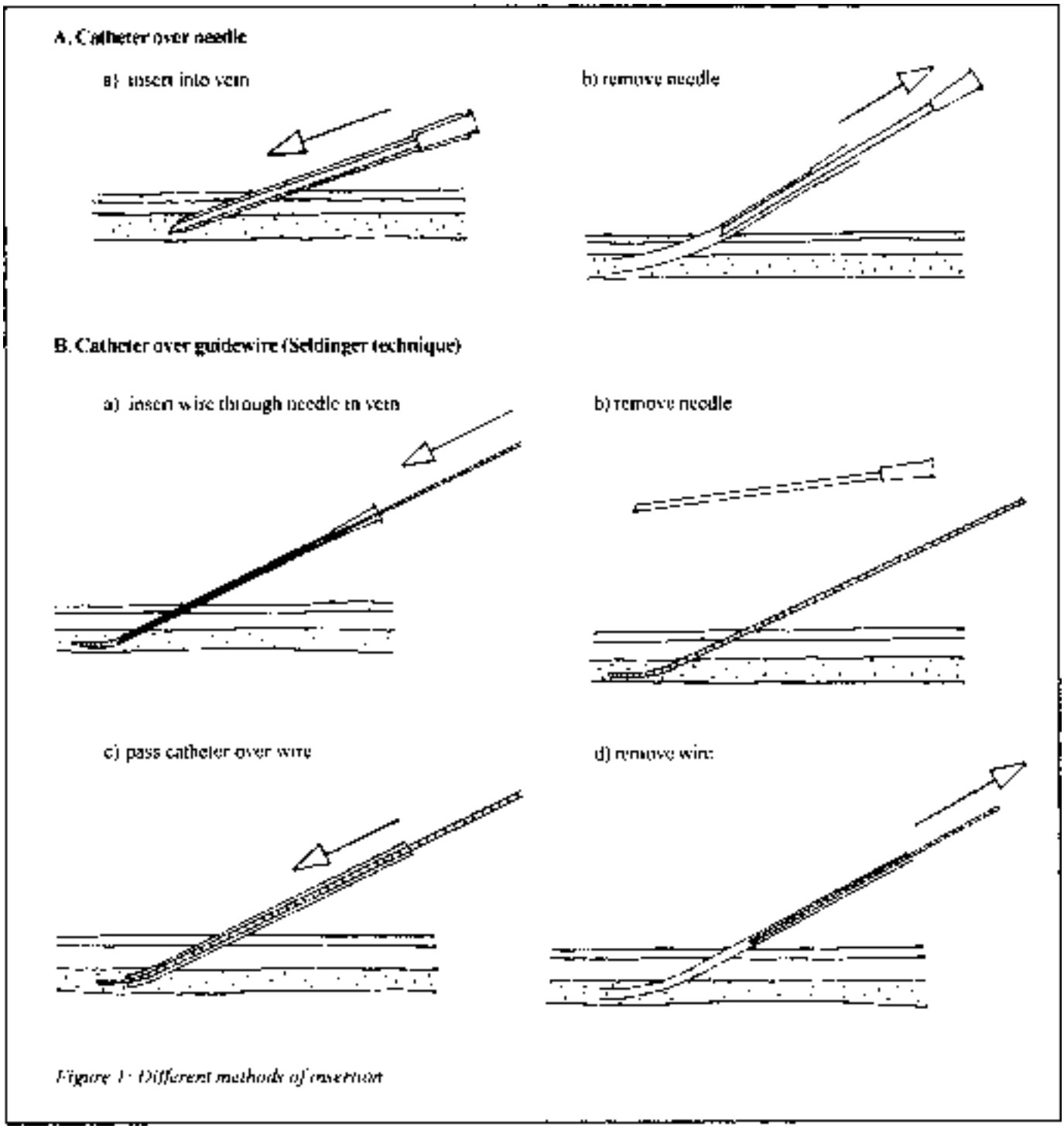


*Figure 1: Different methods of insertion*

not be over-inserted as it may kink, perforate the vessel wall or cause cardiac arrhythmias. This technique allows larger catheters to be placed in the vein after the passage of appropriate dilators along the wire and a small incision in the skin at the point of entry.

- **Catheter through the needle or catheter through cannula.** The catheter is passed through a cannula or needle placed in the vein. The technique is becoming less popular as the hole made in the vein by the needle is larger than the catheter that is passed leading to some degree of blood leakage around the site. If a problem is encountered during threading the catheter, withdrawal of it through the needle risks shearing part of the catheter off with catheter embolisation into the circulation. This technique is mainly reserved for the antecubital route.

**General preparation to obtain central venous access**

The basic preparation and equipment that is required for central venous cannulation is the same regardless of the route or technique chosen. Clinicians who insert central venous lines should be taught the technique by an experienced colleague. If this is not possible then the access routes associated with the fewest complications are the basilic vein or femoral vein.

**General technique for all routes**

- Confirm that central venous access is needed and select the most appropriate route. Explain the procedure to the patient
- Shave the needle insertion area if very hairy
- Using a strict aseptic technique, prepare and check all the equipment for use. Read instructions with the catheter.
- Sterilise the skin and drape the area
- Infiltrate the skin and deeper tissues with local anaesthetic. In cases where difficulty is anticipated use the small local anaesthetic needle to locate the vein before using the larger needle. This reduces the risk of trauma to other structures.
- Position the patient as for the specific route described – avoid long periods of head down, particularly in breathless patients
- Identify the anatomical landmarks for the chosen route and insert the needle at the recommended point. After the needle has penetrated the skin, aspirate gently whilst advancing the needle as directed until the vein is entered. If the vein is not found, slowly withdraw the needle whilst gently aspirating; often the vein has been collapsed and transfixed by the entry of the needle.
- If using a catheter over or through needle technique, thread the catheter into the vein, remove the needle, flush with saline and secure it in place (see checks below)
- If using a guidewire (Seldinger technique), pass this into the vein, flexible J-shape end first, then remove the needle. Small single lumen catheters may pass directly over the wire into the vein. In this case, thread the catheter over it until the end of the wire protrudes from the end of the catheter and whilst holding the wire still advance the catheter into the vein. TAKE CARE not to allow the wire to be pushed further into the vein whilst advancing the catheter
- It may be necessary to dilate up the hole in the vein when larger catheters are used. Make a small incision in the skin and fascia where the wire enters the patient. Thread the dilator over the wire into the vein with a twisting motion. Excessive force should not be needed. Remove the dilator taking care not to dislodge the guidewire. Thread the catheter over the wire as described above.
- Check that blood can be aspirated freely from all lumens of the catheter and flush with saline
- Secure the catheter in place with the suture and cover with a sterile dressing. Tape any redundant tubing carefully avoiding any kinking or loops which may snag and pull out the catheter.
- Connect catheter to a bag of intravenous fluid

*Table 2. Equipment required for central venous access.*

- Patient on a tilting bed, trolley or operating table
- Sterile pack and antiseptic solution
- Local anaesthetic – e.g. 5ml lignocaine 1% solution
- Appropriate CV catheter for age/route/purpose
- Syringes and needles
- Saline or heparinised saline to prime and flush the line after insertion
- Suture material – e.g. 2/0 silk on a straight needle
- Sterile dressing
- Shaving equipment for the area if very hairy (especially the femoral)
- Facility for chest X-ray if available
- Additional equipment required for CVP measurement includes: manometer tubing, a 3-way stopcock, sterile saline, a fluid administration set, a spirit level and a scale graduated in centimeters.

## Checks before using the line

- Ensure fluid runs in freely and that blood flows freely back. To observe the latter place the infusion bag below the level of the bed
- If available, take a chest X-ray (ideally erect) to check the position of the catheter tip and to exclude a pneumo, hydro or haemothorax. An early radiograph may not show up abnormalities and it may be best to wait 3-4 hours unless symptoms develop. The tip of the CVP line should lie in the superior vena cava just above its junction with the right atrium.
- Ensure that the patient will be nursed where their CV line can be supervised. Give appropriate written instructions regarding how, and what it is to be used for, and who to contact if there is a problem

## Practical problems common to most techniques of insertion

Table 3 lists some problems that can occur with any of the routes for central venous access.

## Complications

The main complications that can arise from central venous cannulation are listed in table 4. The incidence of each complication varies for each route described.

## The Subclavian Vein

The subclavian vein (SCV) has a wide calibre (1-2cm diameter in adults) and is thought to be held open by surrounding tissue. In severely shocked patients, however, it may be safer to perform a venous cutdown (eg. onto the long saphenous vein) or use the EJV which may be accessible. In conscious patients the subclavian route is often preferred (since head movement does not affect it) and also in trauma patients with suspected cervical spine injury. Subclavian cannulae are easier to secure which reduces subsequent movement and dislodgment. Whilst a high success rate for placement can be achieved, serious complications occur more commonly than with the other routes. Subclavian puncture should be avoided in patients with abnormal clotting since it is difficult to apply pressure to the subclavian artery following accidental puncture.

*Table 3. Problems during CV cannulation*

| | |
|---|---|
| **Arterial puncture** | Usually obvious but may be missed in a patient who is hypoxic or hypotensive. If unsure, connect a length of manometer tubing to the needle / catheter and look for blood flow which goes higher than 30cm vertically or is strongly pulsatile. Withdraw the needle and apply firm direct pressure to the site for at least 10 minutes or longer if there is continuing bleeding. If there is minimal swelling then retry or change to a different route. |
| **Suspected pneumothorax** | If air is easily aspirated into the syringe (note that this may also occur if the needle is not firmly attached to the syringe) or the patient starts to become breathless. Abandon the procedure at that site. Obtain a chest radiograph and insert an intercostal drain if confirmed. If central access is absolutely necessary then try another route ON THE SAME SIDE or either femoral vein. DO NOT attempt either the subclavian or jugular on the other side in case bilateral pneumothoraces are produced. |
| **Arrhythmias during the procedure** | Usually from the catheter or wire being inserted too far (into the right ventricle).<br>The average length of catheter needed for an adult internal jugular or subclavian approach is 15cm. Withdraw the wire or catheter if further than this. |
| **Air embolus** | This can occur, especially in the hypovolaemic patient, if the needle or cannula is left in the vein whilst open to the air. It is easily prevented by ensuring that the patient is positioned head down (for jugular and subclavian routes) and that the guidewire or catheter is passed down the needle promptly. |
| **The wire will not thread down the needle** | Check that the needle is still in the vein. Flush it with saline. Try angling the needle so the end of it lies more along the plane of the vessel. Carefully rotate the needle in case the end lies against the vessel wall. Reattach the syringe and aspirate to check that you are still in the vein. If the wire has gone through the needle but will not pass down the vein it should be very gently pulled back. If any resistance is felt then the needle should be pulled out with the wire still inside, and the procedure repeated. This reduces the risk of the end of the wire being cut off by the needle tip. |
| **Persistent bleeding at the of entry** | Apply firm direct pressure with a sterile dressing. Bleeding should usually stop unless there is a coagulation abnormality. Persistent severe bleeding may require surgical exploration if there is an arterial or venous tear |

**Anatomy.** The SCV lies in the lower part of the supraclavicular triangle (figure 2.) and drains blood from the arm. It is bounded medially by the posterior border of the sternocleidomastoid muscle, caudally by the middle third of the clavicle, and laterally by the anterior border of the trapezius muscle. The SCV is the continuation of the axillary vein and begins at the lower border of the first rib. Initially the vein arches upwards across the first rib and then inclines medially, downwards and slightly forwards across the insertion of the scalenus anterior muscle into the first rib to enter the thorax where it joins with the IJV behind the sternoclavicular joint.

Anteriorly, the vein is covered throughout its entire course by the clavicle. It lies anterior to, and below the subclavian artery as it crosses the first rib. Behind the artery lies the cervical pleura which rises above the sternal end of the clavicle.

**Preparation and positioning.** The patient should be supine, both arms by the sides, with the table tilted head down to distend the central veins and prevent air embolism. Turn the head away from the side to be cannulated unless there is cervical spine injury. Normally the right SCV is cannulated since the thoracic duct is on the left and may occasionally be damaged during SCV cannulation.

**Technique.** Stand beside the patient on the side to be cannulated. Identify the midclavicular point and the sternal notch. The needle should be inserted into the skin 1cm below and lateral to the midclavicular point. Keeping the needle horizontal, advance posterior to the clavicle aiming for the sternal notch. If the needle hits the clavicle withdraw and redirect slightly deeper to pass beneath it. Do not pass the needle further than the sternal head of the clavicle.

**Complications.** Any of the complications described above can occur but pneumothorax (2-5%) or rarely haemothorax or chylothorax (fatty white fluid in the pleural cavity due to leakage of lymph from thoracic duct) are more common with this route than the others. Occasionally the catheter may pass up into either jugular or the opposite SCV rather than into the chest. This will not give reliable CVP readings and infusion of some drugs (hypertonic solutions/vasoconstrictors) may be contra-indicated.

*Table 4. Potential complications.*

| Early | Late |
|---|---|
| Arterial puncture | Venous thrombosis |
| Bleeding | Cardiac perforation and tamponade |
| Cardiac arrhythmias | Infection |
| Injury to the thoracic duct | Hydrothorax |
| Injury to surrounding nerves | |
| Air embolism | |
| Catheter embolus | |
| Pneumothorax | |

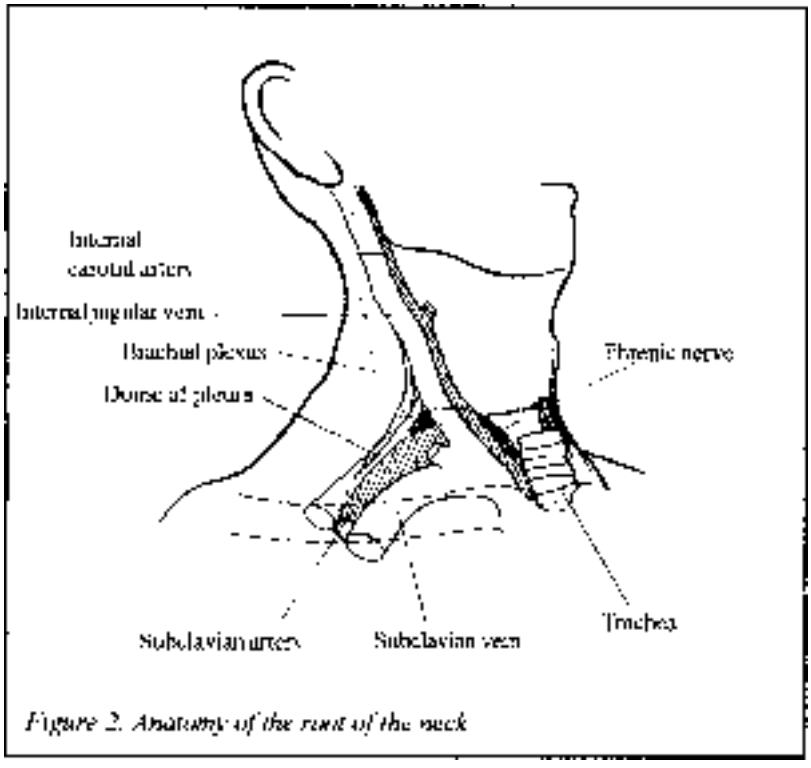


*Figure 2. Anatomy of the root of the neck*

**Practical problems specific to the subclavian route**

- **Keep hitting the clavicle**: Check that you are starting from the correct position. Redirect the needle slightly more posterior whilst being careful not to enter the chest. Try bending the needle slightly to encourage it to pass beneath the clavicle. Try placing a pillow under the shoulders or getting someone to pull gently down on the arms.
- **Cannot find the vei**n: direct the needle a little more cephalad
- **Fail after repeated attempts**: DO NOT PERSIST since the likelihood of complications increase. Try an alternative route ON THE SAME SIDE unless chest radiography is available to exclude any possible pneumothorax.

- **The catheter tip is not in the chest:** Usually detected on chest X-ray, or if the fluid level in the CVP manometer does not rise and fall with breathing. A simple test that may increase the suspicion of jugular placement is to rapidly inject 10ml of fluid into the catheter whilst listening with a stethoscope over the neck. An audible 'whoosh' or thrill under the fingers suggests the catheter has entered the jugular vein. If this is positive, in the presence of a CVP reading which does not change with respiration, then the position of the cannula must be questioned.

**The Internal Jugular Vein**

The internal jugular vein (IJV) is a potentially large vein commonly used for central venous access which drains blood from the brain and deep facial structures. Cannulation is associated with a lower incidence of complications than the subclavian approach. Unlike the subclavian route, failure on one side does not prevent the operator from trying the other side although this should be discouraged if arterial puncture had occurred. Many approaches have been described depending upon the level in the neck where the vein is entered. High approaches reduce the risk of pneumothorax but increase the risk of arterial puncture the opposite being true of a low approach. A middle level approach is described below.

**Anatomy.** The sigmoid venous sinus passes through the mastoid portion of the temporal bone, emerging from the jugular foramen at the base of the skull as the IJV. It passes vertically down through the neck within the carotid sheath. The vein initially lies posterior to the internal carotid artery, before becoming lateral and then anterolateral to the artery. It is able to expand laterally to accommodate increased blood volume. It joins the SCV behind the sternal end of the clavicle to enter the chest as the innominate vein (figure 2).

**Preparation and positioning.** The patient should be supine, both arms by the sides, with the table tilted head down to distend the central veins and prevent air embolism. Slightly turn the head away from the side to be cannulated for better access (turning it too far increases the risk of arterial puncture).

**Technique.** Stand at the head of the patient. Locate the cricoid cartilage and palpate the carotid artery lateral to it at this level. Keeping a finger gently over the artery, insert the needle at an angle of 30-40$^{o}$ to the skin and advance it downward towards the nipple on the same side (in a woman guess where the nipple would be if she were a man). Always direct the needle away from the artery under your finger. The vein is usually within 2-3cm of the skin. If the vein is not found, redirect the needle more laterally.

**Complications.** With experience this route has a low incidence of complications. Arterial puncture is easily managed by direct pressure. Pneumothorax is rare providing the needle is not inserted too deeply.

**Practical problems**

- **Cannot feel the artery**. Check the patient! Try the carotid on the other side. It is safer to consider a different approach rather than 'blindly' try to find the jugular.
- **Arterial puncture**. Remove needle and apply firm pressure over the puncture site for 10 minutes.
- **Cannot find the vein**. Recheck your position. Ensure that you are not pressing firmly on the artery as this can compress the vein next to it. Try tipping the patient further head down if possible. If the patient is hypovolaemic, and central venous access is not immediately required to correct it, give intravenous fluids and wait until the veins are fuller. Try inserting the needle a little closer to the artery but beware of puncture.

**The External Jugular Vein**

Since the external jugular vein (EJV) lies superficially in the neck and is often visible or palpable, complications associated with 'blind' venepuncture of deep veins are avoided. The EJV is preferred when expertise is lacking, for emergency intravenous fluid administration and in cardiac arrests, when the carotid pulsation cannot be felt. However, because of the way the EJV joins the SCV there is a 10-20% chance that a cannula will not pass into the SVC. In this situation it will not be suitable for CVP measurements but can still provide central access for other purposes as described at the beginning.

**Anatomy.** The EJV is formed from the junction of the posterior division of the posterior facial vein and the posterior auricular vein, draining blood from the superficial facial structures and scalp. It 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 has valves above the clavicle and just before its junction with the SCV which may obstruct the passage of CV catheters. If a guidewire with a J shaped tip is used the wire can often pass through these valves by rotating it at the lower end of the EJV. Natural variations and disease states are responsible for the wide range in the degree on prominence of the EJV.

**Preparation and positioning.** The patient should be supine, both arms by the sides, with the table tilted head down to distend the central veins and prevent air embolism. Turn the head away from the side to be cannulated for better access.

**Technique.** Stand at the head of the patient and identify the EJV as it crosses the sternocleidomastoid muscle. If it is not palpable or visible (see problems) then choose an alternative vein for catheterisation. Insert the needle in line with the vein where it is most easily seen or palpated. Thread the guidewire and then the catheter.

**Complications**

If the vein is easily seen or palpated this route carries a very low risk.

**Practical problems**

- **Cannot see the vein**: Ask the patient to take a big breath in and strain as if trying to go to the toilet (Valsalva manoeuvre). If mechanically ventilated briefly hold the lungs in inspiration. Press on the skin above the midpoint of the clavicle where the vein enters the chest. If none of these make the EJV visible then use a different vein.
- **Catheter will not pass into chest**: Press on the skin where the vein enters the chest. Try rotating the catheter or flushing it with saline as you insert it. If using a guidewire, rotate the wire when it reaches the bottom of the vein. Try slowly turning the head in either direction. It may be useful to insert a normal plastic cannula into the vein first, then thread the guidewire down this. By doing this, the wire can be pushed, pulled and rotated without the risk of it being cut which could occur if the wire is manipulated through a needle.

**The Femoral Vein**

This may be the safest and most accessible central vein in children requiring resuscitation where peripheral access has failed. It is also a preferred route for inexperienced operators, due to the minimal risk of serious complications. The femoral vein (FV) should not be used for more than a few days due to the risk of contamination and infection from the groin area. With pelvic or intra-abdominal injury an alternative central vein is preferred. Remember that the femoral route is not a good choice for CVP monitoring since the value will be altered by the intra-abdominal pressure unless a long catheter is used to pass above the level of the diaphragm.

**Anatomy.** The FV starts at the saphenous opening in the thigh and accompanies the femoral artery ending at the inguinal ligament, where it becomes the external iliac vein. In the femoral triangle the FV lies medial to the artery. Here it occupies the middle compartment of the femoral sheath, lying between the artery and the femoral canal. The femoral nerve lies lateral to the artery. The vein is separated from the skin by superficial and deep fasciae.

**Preparation and positioning.** Abduct and externally rotate the thigh slightly.

**Performance of the technique.** Identify the pulsation of the femoral artery 1-2 cm below the inguinal ligament. Insert the needle about 1cm medial to the pulsation and aim it towards the head and medially at an angle of 20-30$^{o}$ to the skin. In adults, the vein is normally found 2-4cm from the skin. In small children reduce the elevation on the needle to 10-15$^{o}$ since the vein is more superficial.

**Complications.** Arterial puncture is possible if the needle is directed too lateral. Femoral nerve damage may follow incorrect lateral insertion of the needle. Infection is the commonest problem with femoral catheters and they are not recommended for long-term use.

**Practical problems**

- **Cannot feel the artery**: Try the other side. Check the blood pressure. Treat any hypotension and retry. If there is no other venous access then it may be acceptable to try to locate the FV with a small needle starting medially to avoid the femoral nerve. Once found, change to the normal needle and continue the procedure. If the artery is accidentally punctured, apply direct pressure with your fingers and insert the normal needle medial to the puncture site.
- **Cannot locate the vein**: Recheck the anatomical landmarks. It is possible for the femoral vein to be compressed by the fingers on the artery. Release pressure but leave the fingers resting on the skin over the artery and retry. Cautiously redirect the needle closer to the artery and in a more lateral direction.

### The Antecubital Veins

A palpable vein in the antecubital fossa provides the safest route for central venous access. A long 60cm catheter is required. There are a number of veins in the antecubital fossa – use one on the medial side.

**Anatomy.** Venous blood from the arm drains through two intercommunicating main veins, the basilic and the cephalic as illustrated in figure 3.

**Basilic vein.** Ascends from the hand along the medial surface of the forearm draining blood from that area and medial side of the hand. Near the elbow the vein changes to a position in front of the medial epicondyle where it is joined by the median cubital vein. It then runs along the medial margin of the biceps muscle to the middle of the upper arm where it pierces the deep fascia to run alongside the brachial artery becoming the axillary vein.

**Cephalic vein.** Ascends on the front of the lateral side of the forearm to the front of the elbow, where it communicates with the basilic vein through the median cubital vein. It then ascends along the lateral surface of the biceps muscle to the lower border of pectoralis major muscle, where it turns sharply to pierce the clavipectoral fascia and pass beneath the clavicle. It then usually terminates in the axillary vein although it can join the EJV. There are valves at the termination of the cephalic vein. The sharp angle and the valves frequently obstruct the passage of a catheter along the cephalic system.

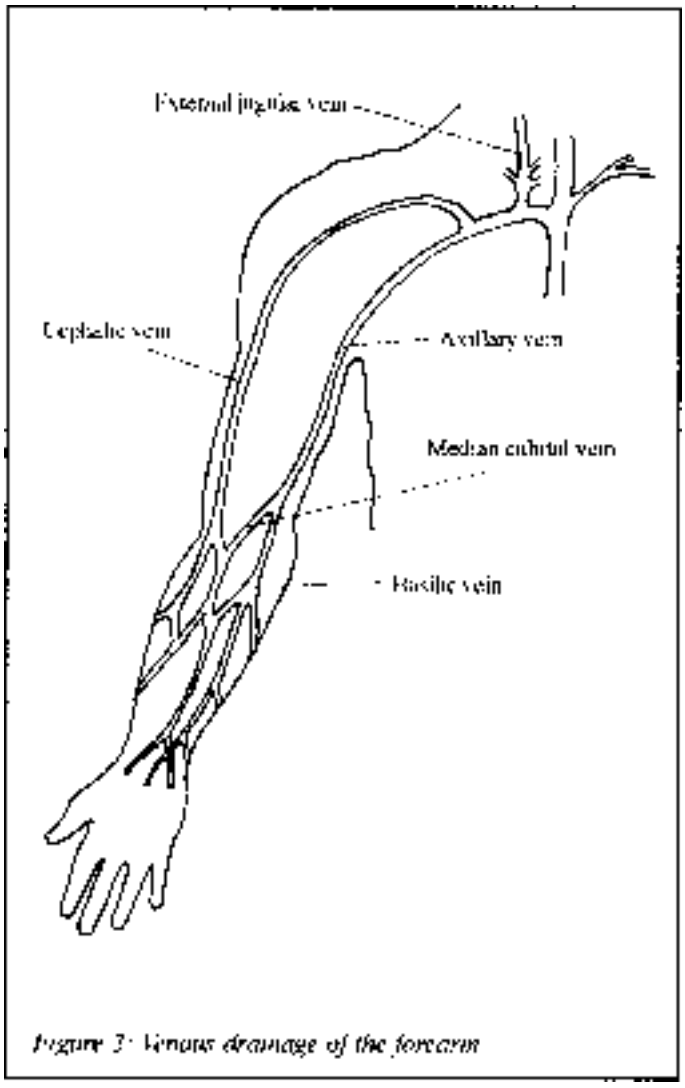


*Figure 3: Venous drainage of the forearm*

**Median cubital vein.** The median cubital vein is a large vein that arises from the cephalic vein just below the bend in the elbow and runs obliquely upwards to join the basilic vein just above the bend in the elbow. It receives veins from the front of the forearm which themselves may be suitable for catheterisation. It is separated from the brachial artery by a thickened portion of the deep fascia (bicipital aponeurosis).

**Preparation and positioning.** Apply a tourniquet to the upper arm to distend the veins and select the best one. The order of preference for veins are:

- A vein on the medial side of the antecubital fossa – the basilic or median cubital vein. Even when not visible, these veins are often easily palpable when engorged
- A vein on the postero-medial aspect of the forearm – a tributary of the basilic vein. Rotation of the arm may be required.
- The cephalic vein

Lie the patient supine with the arm supported at 45° to the body and the head turned towards you (helps prevent the catheter passing into the IJV on that side).

**Technique.** Stand on the same side of the patient. Estimate the length of catheter needed to reach the SVC. Puncture the chosen vein with the needle and cannula and remove the needle. Insert the catheter through the cannula and advance it a short distance (2-4cm in adults, 1-2cm in children) then release the tourniquet. Steadily advance the catheter along the vein until it is estimated to be in the correct position.

**Complications.** Local bleeding since the catheter is smaller diameter than the needle used to puncture the vein. Apply direct pressure with a sterile swab.

**Practical problems**

- **Cannot thread the catheter along the vein**. Do not use force to pass it. If using a catheter-through-needle technique and you are sure that the catheter

is in the vein, remove the needle from the vein and slide it to the end of the catheter. This will allow you to advance and withdraw the catheter without risk of cutting it on the needle. Try flushing the catheter with saline whilst advancing. Try the arm in different positions. Rotate the catheter whilst inserting.

**Care of the Central venous Catheter**

- Use an aseptic technique when inserting the catheter and any subsequent injections or changing fluid lines
- Keep the entry site covered with a dry sterile dressing
- Ensure the line is well secured to prevent movement (this can increase risks of infection and clot formation)
- Change the catheter if there are signs of infection at the site.
- Remember to remove the catheter as soon as it is no longer needed. The longer the catheter is left in, the greater the risks of sepsis and thrombosis
- Some people suggest changing a catheter every 7 days to reduce the risks of catheter related sepsis and thrombosis. However, providing that the catheter is kept clean (sterile injections and connections) and there are no signs of systemic sepsis, routine replacement may not be necessary. Repeated cannulation to change lines on a routine basis, rather than based on clinical need, can increase the risks to the patient.

**What is Central Venous Pressure ?**

Blood from systemic veins flows into the right atrium; the pressure in the right atrium is the central venous pressure (CVP). CVP is determined by the function of the right heart and the pressure of venous blood in the vena cava. Under normal circumstances an increased venous return results in an augmented cardiac output, without significant changes in venous pressure. However with poor right ventricular function, or an obstructed pulmonary circulation, the right atrial pressure rises. Loss of blood volume or widespread vasodilation will result in reduced venous return and a fall in right atrial pressure and CVP.

The CVP is often used to make estimates of circulatory function, in particular cardiac function and blood volume. Unfortunately the CVP does not measure either of these directly, but taken in the context of the other physical signs useful information can be gained. The supply of blood to the systemic circulation is controlled by the left ventricle. In a normal patient the CVP closely resembles the left atrial pressure and is usually used to predict it. However in patients with cardiac disease the right and left ventricles may function differently – this can only be detected clinically by measuring the pulmonary capillary wedge pressure (see later).

**When should CVP be measured?**

- Patients with hypotension who are not responding to basic clinical management.
- Continuing hypovolaemia secondary to major fluid shifts or loss.
- Patients requiring infusions of inotropes.

**How to measure the CVP**

The CVP is measured using a manometer filled with intravenous fluid attached to the central venous catheter. It needs to be 'zeroed' at the level of the right atrium, approximately the mid-axillary line in the 4th interspace supine. Measurements should be taken in the same position each time using a spirit level and the zero point on the skin surface marked with a cross. Check that the catheter is not blocked or kinked and that intravenous fluid runs freely in, and blood freely out. Open the 3-way tap so that the fluid bag fills the manometer tubing (check there is no obstruction to fluid flow and that the cotton wool in the top of the manometer is not blocked or wet). Turn the tap to connect the patient to the manometer. The fluid level will drop to the level of the CVP which is usually recorded in centimeters of water ($cmH_2O$). It will be slightly pulsatile and will continue to rise and fall slightly with breathing - record the average reading. An alternative to the manometer and 3-way tap is a butterfly needle inserted into the rubber injection port of ordinary intravenous tubing (figure. 4). In Intensive Care Units or theatres, electronic transducers may be connected which give a continuous readout of CVP along with a display of the waveform. Useful information can be gained by studying the electronic waveform. The CVP reading from an electronic monitor is sometimes given in mmHg (same as blood pressure). The values can easily be converted knowing that $10cmH_20$ is equivalent to 7.5mmHg (which is also 1kPa)

**Interpretation of the CVP**

As previously stated, the CVP does not measure blood volume directly and is influenced by right heart function, venous return, right heart compliance, intrathoracic

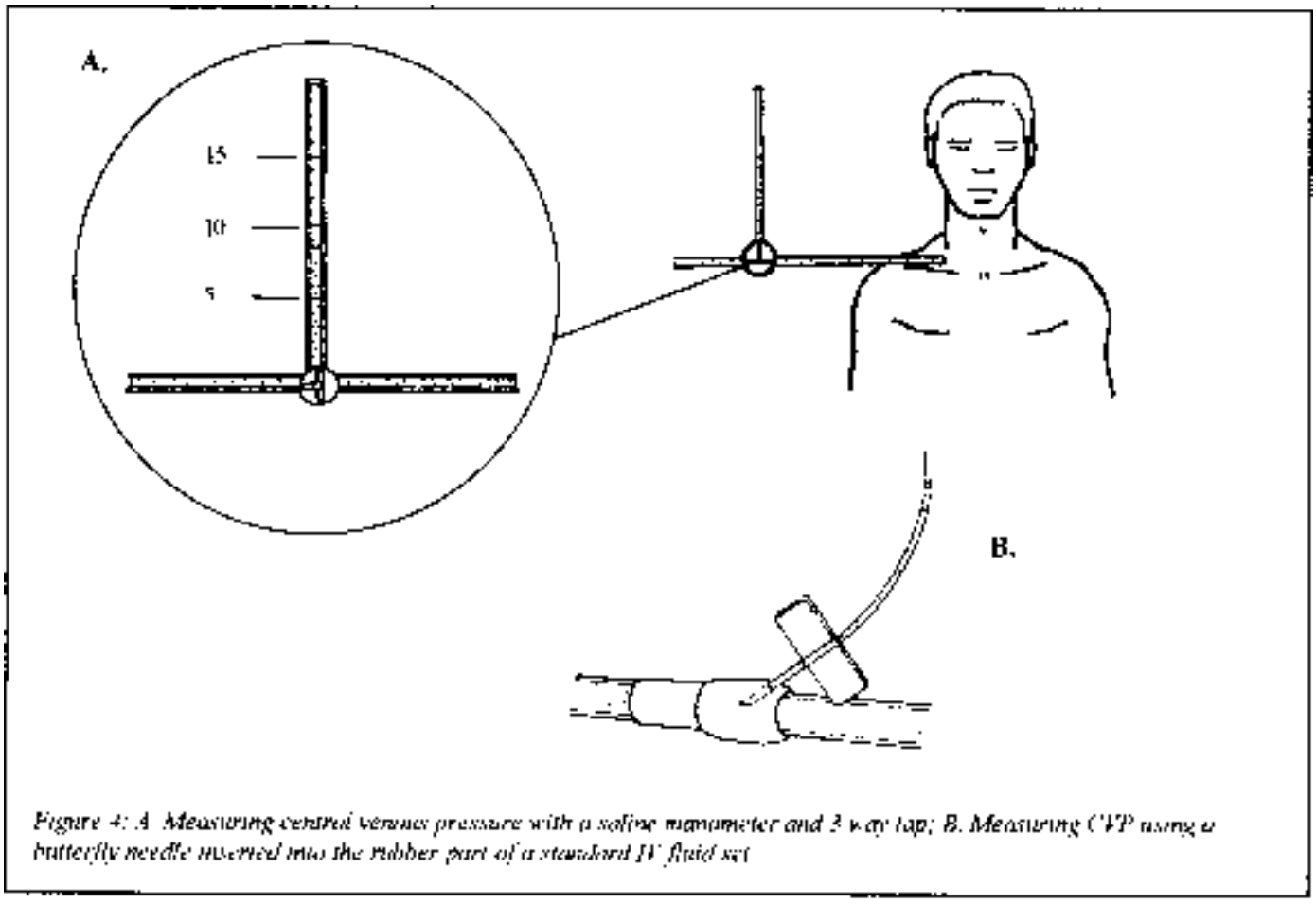


*Figure 4: A. Measuring central venous pressure with a saline manometer and 3 way tap; B. Measuring CVP using a butterfly needle inserted into the rubber part of a standard IV fluid set*

pressure and patient positioning. It should always be interpreted alongside other measures of cardiac function and fluid state (pulse, BP, urine output etc.). The absolute value is not as important as serial measurements and the change in response to therapy. A normal value in a spontaneous breathing patient is 5-10cm water $cmH_2O$, rising 3-5$cmH_2O$ during mechanical ventilation. The CVP measurement may still be in the normal range even with hypovolaemia due to venoconstriction. A guide to interpretation is shown in table 5.

**Short case examples of CVP interpretation**

1. A 20 year old woman had a large post-partum bleed. Despite initial resuscitation her BP remained low and did not respond to large volumes of intravenous fluids. A CVP line was inserted. Her observations after insertion were: pulse 130/min, BP 90/70, and a CVP +1 $cmH_2O$. The CVP confirmed continuing hypovolaemia. After further IV fluid her pulse rate began to come down and her BP and CVP started to improve.
2. A 32 year old man was involved in a road accident sustaining chest and leg injuries. After initial resuscitation he was found to have a pneumothorax on the right which was drained with an underwater seal drain. Initially his respiratory function improved but despite fluid loading he remained hypotensive and a CVP line was inserted to guide fluid replacement for his leg injuries. After insertion he had a pulse of 120/min and BP90/60 and a CVP reading of +15cm $H_2O$. His neck veins were distended suggesting a high venous pressure. He was reassessed clinically and was found to have developed a tension pneumothorax on the left side which was drained with improvement in his condition.
3. A 19 year old man was admitted with an infected wound on his leg. His observations are: pulse 135/min, BP 80/30, CVP 7, hyperdynamic circulation. His pulse and BP does not respond to 2 fluid challenges so inotropes are started to support his circulation. His hypotension is due to septicaemia.

*Table 5. Guide to interpretation of the CVP in the hypotensive patient*

| CVP reading | Other features that may be present | Diagnosis to consider | Treatment |
|---|---|---|---|
| **Low** | Rapid pulse<br>Blood pressure normal or low<br>Low urine output<br>Poor capillary refill | Hypovolaemia | Give fluid challenges* until CVP rises and does not fall back again. If CVP rises and stays up but urine output or blood pressure does not improve consider inotropes |
| **Low or normal or high** | Rapid pulse<br>Signs of infection<br>Pyrexia<br>Vasodilation/constriction | Sepsis | Ensure adequate circulating volume (as above) and consider inotropes or vasoconstrictors |
| **Normal** | Rapid pulse<br>Low urine output<br>Poor capillary refill | Hypovolaemia | Treat as above.<br>Venoconstriction may cause CVP to be normal.<br>Give fluid challenges* and observe effect as above. |
| **High** | Unilateral breath sounds<br>Assymetrical chest movement<br>Resonant chest with tracheal deviation<br>Rapid pulse | Tension pneumothorax | Thoracocentesis then intercostal drain |
| **High** | Breathlessness<br>Third heart sound<br>Pink frothy sputum<br>Oedema<br>Tender liver | Heart failure | Oxygen, diuretics, sit up, consider inotropes |
| **Very High** | Rapid pulse<br>Muffled heart sounds | Pericardial tamponade | Pericardiocentesis and drainage |

**Fluid challenge. In hypotension associated with a CVP in the normal range give repeated boluses of intravenous fluid (250 – 500mls). Observe the effect on CVP, blood pressure, pulse, urine output and capillary refill. Repeat the challenges until the CVP shows a sustained rise and/or the other cardiovascular parameters return towards normal. With severe blood loss, blood transfusion will be required after colloid or crystalloid have been used in initial resuscitation. Saline or Ringers lactate should be used for diarrhoea/bowel obstruction/vomiting/burns etc.*

## When may the CVP reading be unreliable?

The use of CVP readings to estimate cardiac function and blood volume rely on the fact that there is no right ventricular disease and normal pulmonary vascular resistance. Table 6 lists some situations when CVP readings may be unreliable.

## Catheter removal

Remove any dressing and suture material. Ask the patient to take a breath and fully exhale. Remove the catheter with a steady pull while the patient is breath holding and apply firm pressure to the puncture site for at least 5 minutes to stop the bleeding. Excessive force should not be needed to remove the catheter. If it does not come out, try rotating it whilst pulling gently. If this still fails, cover it with a sterile dressing and ask an experienced person for advice.

## Pulmonary artery flotation catheters (PAFC) catheters

A PAFC or Swan-Ganz catheter is a central venous catheter with a small inflatable balloon at the end. An introducing catheter is sited in a central vein and the catheter is then 'floated' along the central vein with the balloon inflated, through the right atrium and ventricle until it lies in a branch of the pulmonary artery. The position of the PAFC can be predicted as it moves through the circulation by the pressure waveform obtained by measuring the pressure at the tip of the PAFC. Once correctly positioned, when the balloon is inflated it occludes the branch of the pulmonary artery and measures the pressure distal to

*Table 6*

| Problem | Effect on CVP |
|---|---|
| Pulmonary embolus<br>High intrathoracic pressure | High pulmonary vascular resistance – left sided pressure and function may be normal. A higher than normal CVP may be needed to ensure adequate return of blood to the left side of the heart. |
| Left heart failure | Resulting rise in pulmonary venous pressure and right sided heart strain. Initially CVP may be normal but will increase with significant failure. |
| Constrictive pericardial disease | Paradoxical rise in CVP on inspiration and fall on expiration (opposite of normal in a spontaneously breathing patient). The absolute level will be higher due to impeded filling of the heart |
| Blocked cotton wool at top of manometer | Fluid will not move in the tube to give a correct reading |
| Complete heart block | 'Cannon waves' on CVP reading – the reading will have a strong pulsatile element when the atrium contracts against a closed tricuspid valve sending the pressure wave back into the SVC |
| Tricuspid stenosis/regurgitation | Mean CVP will be higher |

it (pulmonary artery occlusion pressure or 'wedge' pressure since it is 'wedged' in the artery). With the balloon inflated there is a continuous column of fluid between the tip of the PAFC and the left atrium, without interference from heart valves and lung pathology. It is therefore a better guide to the venous return to the left side of the heart than CVP. However, it is a more invasive monitor, requires more expertise to insert, has a greater complication rate and is more expensive.

PAFC are sometimes used in patients with significant right sided valve disease, right heart failure or lung disease as the CVP may be unreliable in predicting the left atrial pressure. When connected to a computer a PAFC may be used to calculate the cardiac output using a thermodilutional technique and further guide patient management. However PAFC have not been shown to improve patient survival (see Further Reading).

**Further Reading**

Handbook of Percutaneous Central Venous Catheterisation. Rosen M, Latto IP, Shang Ng W. WB Saunders Company Ltd. 1981

Watters DA, Wilson IH. The practice of central venous pressure monitoring in the tropics. Tropical Doctor 1990; 20(2): 56-60

Connors AF et al. The effectiveness of right heart catheterization in the initial care of critically ill patients. JAMA 1996; 276(11): 889-97