Central venous cannulation: ultrasound techniques

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Abstract

Central venous cannulation is commonly undertaken by a range of specialities in diverse clinical settings. Central veins may be cannulated by the landmark, ultrasound-guided or open surgical cut-down techniques. Complications of central venous catheter (CVC) insertion are common and may lead to significant morbidity and very occasional mortality. Two-dimensional ultrasound-guided central venous catheter placement has been shown by randomized controlled trials to be superior to the landmark technique. It reduces both the number of needle passes required for successful placement and the incidence of complications. Constant needle-tip visualization is a challenge for the novice operator. The UK National Institute for Health and Care Excellence (NICE) has recommended since 2002 that following appropriate training, clinicians should use ultrasound wherever practical in both elective and emergency internal jugular vein catheterization. Most clinicians would now recommend its use for all routes of access.

Keywords Central venous catheter; femoral; jugular; subclavian veins; ultrasound; venous cannulation

Royal College of Anaesthetists CPD Matrix: 2A04

Learning objectives

After reading this article, you should be able to:

- list the indications for central venous cannulation and describe the commonly used insertion sites
- explain the advantages of ultrasound-guided CVC insertion
- describe the limitations of the technique and potential pitfalls for the novice operator
- understand the importance of needle-tip visualization and avoidance of arterial cannulation

Indications for central venous access

Central venous catheters (CVCs) are commonly inserted to facilitate monitoring (i.e. central venous pressure, cardiac output) or delivery of drugs (e.g. vasopressors, chemotherapy agents) into the central circulation. CVCs also allow provision of total parenteral nutrition, renal replacement therapy, extracorporeal membrane oxygenation (ECMO), venovenous bypass (VVBP) in liver transplantation or transvenous cardiac pacing.

Methods of cannulation

The traditional 'landmark technique' relies on using surface anatomical features and palpable arterial pulses as a guide to deeper structures. Ultrasound guidance may be direct or indirect.[1] Direct guidance uses ultrasound to visualize the needle entering the vein in real time. Indirect guidance describes using ultrasound to confirm the position of a patent vein prior to cannulation. Although less demanding for the novice, it does not provide all the advantages of direct techniques. Central veins may also be cannulated by a surgical cut down.

Complications of CVC insertion

Complications from attempted CVC insertion are common. Depending on case mix and operator skill, up to 10% of attempted cannulations lead to a complication. Complication rates correlate to the number of needle passes and may lead to significant morbidity and occasional mortality.[2] Common complications include arterial puncture, haematoma and pneumothorax.

Ultrasound technology

Two-dimensional ultrasound uses high-frequency sound, reflected from tissue interfaces, to generate an image of superficial structures. Fluid-filled structures such as blood vessels appear dark. Air, bone and needles are hyperechogenic and appear bright. Structures deep to air or bone will not be visualized (acoustic shadowing). Low-frequency sound penetrates deeper than high frequency, but produces lower-resolution images. Central veins are generally accessed within a few centimetres of the skin, so high-frequency (7.5–10 MHz), high-resolution probes are used. Two-dimensional ultrasound may be combined with Doppler imaging (Duplex) to show blood flow and direction. This can be useful in differentiating arteries from veins (Table 1).

Distinguishing features of arteries and veins under ultrasound

Arteries	Veins
Pulsatile	Non-pulsatile
Not easily compressed, visualization improves with compression	Easily compressed
Round	Elliptical
Characteristic pulsatile Doppler signal	Characteristic more continuous Doppler signal change shape on respiration/valsalva

Table 1

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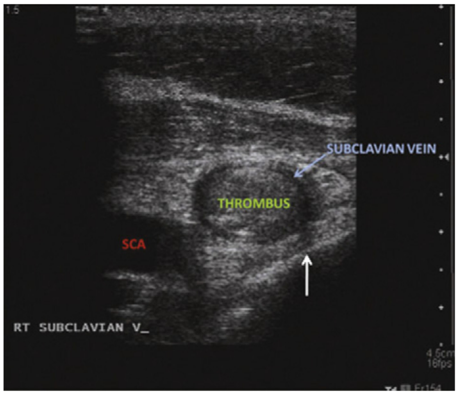

Figure 1 Non-compressible thrombus completely blocking the right subclavian vein. More commonly there will be a crescent of thrombus partially blocking the vein. White arrow, chest wall/pleura; SCA, subclavian artery.

Advantages of ultrasound

Ultrasound can identify aberrant anatomy or thrombosed/stenosed vessels (Figure 1). In both scenarios, alternative access sites should be sought and useless needle passes avoided. Ultrasound can detect valves or collapsed veins. Valves are avoided by adjusting the needle insertion point. Empty veins are more easily cannulated following fluid resuscitation, head-down positioning, IPPV/PEEP or Valsalva manoeuvre. Ultrasound may identify guidewire or catheter misplacement, for example imaging the neck during subclavian vein cannulation may identify retrograde passage into the internal jugular vein. Arteries accompanying the major veins are easily visualized with ultrasound. In well-filled veins, real-time ultrasound allows the operator to cease forward movement of the needle once the anterior wall is penetrated and the needle-tip lies within the lumen, avoiding posterior vein wall puncture and haematoma formation. Vessel transfixion may be unavoidable when cannulating an empty vein. The pleura lies immediately posterior to the subclavian vessels and is easily visualized by ultrasound (Figure 1); it is also at risk from a low internal jugular approach.

Limitations of the technique

All new clinical skills have an associated learning curve and ultrasound-guided cannulation does not easily grant novices immediate success. Adequate training, practice and supervision are required to gain competence. An appreciation of how 2D images relate to 3D anatomy is essential. Constant visualization of needle-tip position may initially be difficult to maintain and loss of the needle-tip view risks complications.

Insertion sites

The internal jugular vein (Figure 2) is a superficial structure lying adjacent to the carotid artery. It is often the most convenient site of access in the anaesthetized patient. There is wide variability in the relationship (including overlap) between artery and vein and some patients will have a dominant venous circulation on one side of the neck.

The subclavian vein is preferred in the head-injured patient (minimal effect on intracranial pressure) or for prolonged access. The clavicle restricts visualization of the subclavian vein, but by moving a short distance laterally, the axillary artery and vein may be visualized (Figure 3). Further laterally, the operator will note a greater distance between vein and pleura, reducing the risk of pneumothorax. This advantage is balanced by a smaller diameter and deeper vessel compared with a more medial approach. It may be difficult to visualize and access the vein in obese or muscular patients. Supraclavicular approaches are also used.

The femoral vein is favoured in those unable to tolerate head-down positioning. Traditional teaching suggests the superficial femoral artery does not cross the femoral vein until several centimetres below the inguinal ligament. Radiological studies have shown crossover is higher than commonly appreciated.[3] Ultrasound allows verification of anatomy and accurate first pass puncture of the common femoral vein.

High-frequency ultrasound can identify peripheral veins in the limbs. This is useful in the obese or intravenous drug user and may facilitate central venous access with a peripherally inserted

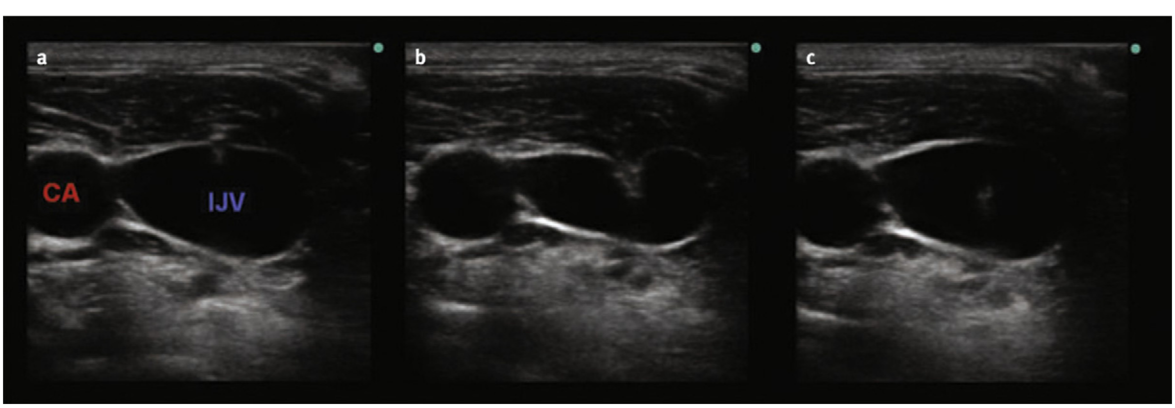

Figure 2 Cross-sectional view of right internal jugular vein (IJV) and carotid artery (CA) with needle introduced in the short axis. (**a**) Needle tip is seen just indenting the anterior vein wall. (**b**) Needle further indents the vein wall but the tip is still covered by vein wall which is 'tented' into the lumen, no blood can be aspirated. (**c**) Needle tip has passed through the vein wall to lie within lumen, vein has re-expanded and correct position is confirmed by free aspiration of blood. The green dot in the upper right-hand corner of each image is an orientation marker. The probe is correctly orientated when a palpable marker on the probe is on the same side as the green dot on display. This ensures that right and left in the image correspond correctly to medial and lateral on the patient.

