I need to gain vascular access: ultrasound-guided techniques

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Abstract

Ultrasound has been used to assist line placement for many years, and it is known that ultrasound aids the placement of central and peripheral lines, both in terms of speed of access and reduction of complications. The indications for the use of ultrasound in vascular access vary. In central access, ultrasound should be used at all times unless time-critical intervention mandates otherwise, e.g. in cardiac arrest. In femoral access, it is a very useful adjunct and can be used for reliable, rapid large vein access. In peripheral access, it has a use when conventional access fails. In general terms ultrasound can be used to identify relevant anatomy prior to cannulation, or to guide the process of cannulation. This paper outlines the approaches available.

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The placing of peripheral venous, central venous and arterial catheters are routine in emergency medicine practice. Ultrasound has been used to assist line placement for many years, and it is known that ultrasound aids the placement of central and peripheral lines, both in terms of speed of access and reduction of complications.[1,2] The National Institute for Health and Clinical Excellence[3] has highlighted the need for the use of ultrasound to guide central venous access cannulation, and it is this recommendation that has partly driven the wider use of ultrasound in emergency medicine.[4]

The indications for the use of ultrasound in vascular access vary. In central access, ultrasound should be used at all times[5] unless time-critical intervention mandates otherwise (e.g. in cardiac arrest).[3] In femoral access, it is a very useful adjunct and can be used for reliable, rapid large vein access. In peripheral access, it is useful when conventional access fails. This may be in an ill patient who is peripherally shut-down, or in an intravenous drug user whose veins are damaged. Additionally, it may help the insertion of a long-line peripheral cannula. In all these instances, the basilic vein medial to the biceps above the elbow is usually accessible and patent.

The use of a central cannula is immensely helpful when assessing filling pressures in cases where there is significant potential for misjudging intravenous fluid resuscitation. This is particularly the case in the elderly whose physiology allows a much narrower margin of error. An ultrasonic alternative is to assess the inferior vena cava as it passes through the diaphragm. This can give an indication of the load on the right side of the heart. If the diameter is >2.5 cm with minimal collapse this is indicative of increased right atrial pressure (e.g. Cor pulmonale, fluid overload). A diameter of <1.5 cm with complete collapse is indicative of being under filled, and a useful indicator of hypovolaemic shock.[6]

Ultrasound in emergency medicine has become a point-of-care tool, often referred to as 'bed-side ultrasound'. It has two main aims:

(1) To identify relevant anatomy prior to cannulation;
(2) To use ultrasound to guide the process of cannulation.

Anatomical considerations

The difference between veins and arteries can be determined by compressibility, i.e. veins compress readily and arteries do not. When the transducer is used to compress neck structures, the internal jugular vein (IJV) is obliterated while the artery remains non-compressed (Figure 1). Meanwhile, if the patient carries out a Valsalva manoeuvre, the IJV dilates (Figure 2). Furthermore, the shape of the vessels is different. Arteries tend to be circular in transverse view, with muscular walls, whereas veins are often oval.

The neck

The right side of the neck is usually selected to avoid theoretical risk of damage to the thoracic duct, which lies on the left. The thoracic duct ascends through the mediastinum and enters into the left IJV. While injury to the thoracic duct is unlikely, it can produce a chylothorax, which is a

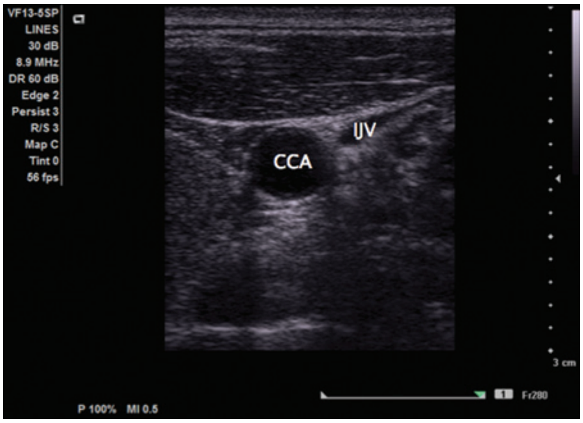

Figure 1 IJV compressed

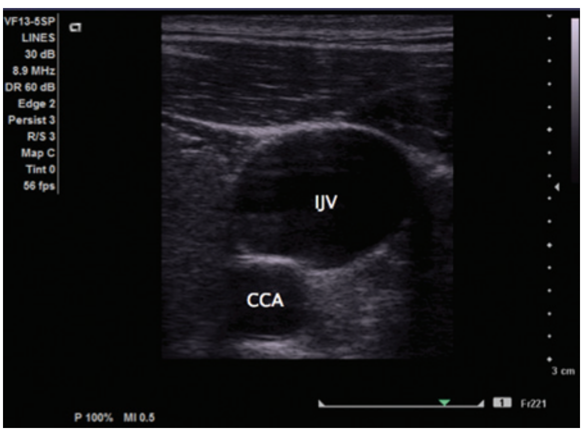

Figure 2 Valsalva and internal jugular vein

significant problem.[7] Traditionally, the approach was defined by finding the apex of the triangle formed by the confluence of the sternal and clavicular parts of the sternocleidomastoid muscle (Figure 3). Note that excess head rotation can begin to reduce the IJV diameter and is best avoided. In ultrasound-guided central venous cannulation (CVC), the exact approach can be determined by direct visualization of the anatomy. The approach is still within the triangle, but an optimal site can readily be selected. It is important to palpate the location of the two parts of the sternocleidomastoid muscle, and to recognize them by ultrasound imaging, as a needle should not be introduced through their muscle bulk.

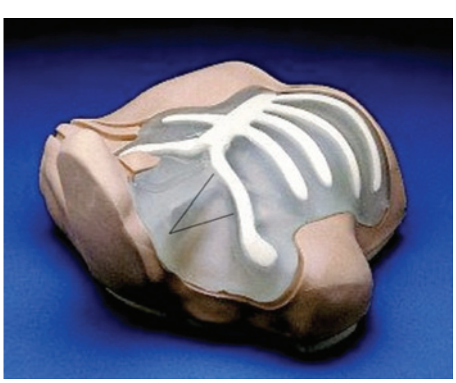

Figure 3 Classical approach to central venous cannulation

The groin

In the groin the location of the femoral vein is straightforward, i.e. medial to the artery (Figure 4). Its depth varies, and ultrasound location aids speed and efficacy of cannulation. The inguinal ligament is an important landmark, and keeping immediately below it will avoid inadvertently cannulating the great saphenous vein.

The basilic vein

Peripheral cannulation can be attempted at any site, but the basilic vein is a good choice as it is almost always patent. It tends to lie between 5 and 10 mm below the skin, and is found in the recess created by the medial border of the biceps muscle (Figure 5). The brachial artery should be positively identified as it may lie very close to the basilic vein.

Ultrasound to guide the process of cannulation

In all cases, a linear, high frequency (e.g. 10 MHz) transducer should be selected. A small transducer, such as a hockey stick transducer, is ideal. The machine should be set to a depth of around 5 cm for central access, 4 cm for femoral and 3 cm for basilic cannulation. Time gain control should be straight. In all cases avoid zoom or the skin surface will not be seen. Most machines have a vascular pre-set, which should be selected.

Ultrasound guidance or ultrasound-assisted procedures can be performed using ultrasound in one of the two ways, i.e. static or realtime. In the static approach, anatomic structures are identified and an insertion position is identified with ultrasound. This may be marked on the skin. The cannulation then proceeds as it would without ultrasound and is not performed with the transducer imaging the needle being introduced or entering the vessel. Its use is merely to demonstrate the position of the vessel. In

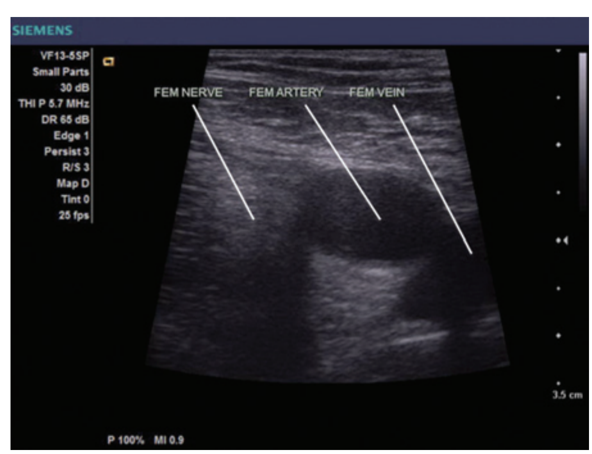

Figure 4 Right groin

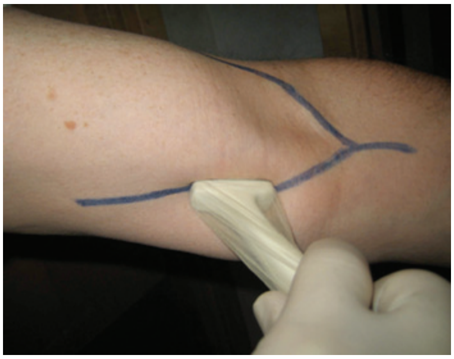

Figure 5 Location of basilic vein

most instances this is suboptimal, and not recommended. In the realtime approach, the ultrasound transducer is placed in a sterile covering and the procedure is performed with simultaneous ultrasound visualization of the cannulation. This is recommended, and for many trainees, this may be the first use of ultrasound in order to carry out an intervention. There are new skills sets to learn, and two key technical issues when introducing a needle into tissue with the hope of seeing it on the screen. These are as follows:

(1) *Parallelism* is a function of the physical characteristics of a linear transducer. The needle tip is identified by the transducer array only if it sits within the tolerances of the lateral and slice thickness resolution. This is illustrated in Figure 6, with typical tolerances being around 5 mm for slice thickness. This means that the operator needs to keep the needle within this narrow slice thickness for it to be visualized;
(2) *The angle of approach* of the needle into the tissue is critical. If this is too steep, the reflected sound does not return to the transducer, and consequently no image is seen. Angles less than 60° to the skin are needed to see the needle, and the smaller the angle, the better the image, as shown in Figure 7. A steep angle is to be avoided also as the guidewire has to turn a tight angle on entry to the vessel. An angle of less than 45° is ideal, but this will give a longer track to the vein which means that a short needle may not reach it.

These techniques can be used in children,[8,9] and ultrasound-guided femoral cannulation can be rapid and extremely helpful in the very sick child. The groin is often readily available while the neck is often not (due to airway manoeuvres). Caution is advocated in significantly hypovolaemic patients as negative pressures result in flat veins, with increased technical difficulty. Treatment of hypovolaemic shock has always been viewed as technically challenging through a central line as the principal intravenous route. However, using ultrasound, CVC is not difficult in the hypovolaemic patient using a 30° head down tilt.[10]

General technique

All invasive procedures should employ standard sterile techniques to diminish the risk of infection. For venous access using realtime ultrasound, a sterile transducer cover should always be used. While it may be reasonable to attempt peripheral and femoral access by skin marking and no realtime ultrasound (especially in cardiac arrest[11]), this is not acceptable for internal jugular cannulation.

On a very practical note, it is helpful to stabilize the transducer with one finger touching the skin. Unless this is done, the slippery nature of the gel will inevitably mean that the transducer slowly drifts resulting in loss of the screen image. Similarly, it is important to learn to watch the screen, not the hands.

The first skill to acquire is to be able to recognize the vein in transverse section, and to distinguish it from the artery by virtue of its compressibility. From here, the transducer is rotated to allow visualization of the vein in longitudinal section. Obviously, this entails knowing the transducer orientation on the screen.

Venous cannulation can be carried out using a single or dual operator technique. It is recommended that initially the trainee works with the trainer in a dual operator technique, with the ultrasound carried out by the trainer, and the cannulation by the trainee. Besides the obvious training benefit, this also frees up both hands for the trainee. It also significantly reduces the risks of the transducer sliding off the area of work and onto the floor. The consequences of dropping a transducer are more than inconvenience and loss of sterility – crystals may be broken in the transducer resulting in permanent, and expensive, damage.

In realtime cannulation there are two accepted approaches:

- The short axis, transverse approach allows only a cross-section of the needle to be visualized by the ultrasound

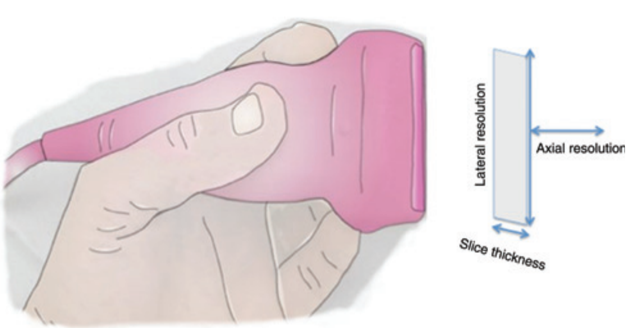

Figure 6 Parallelism

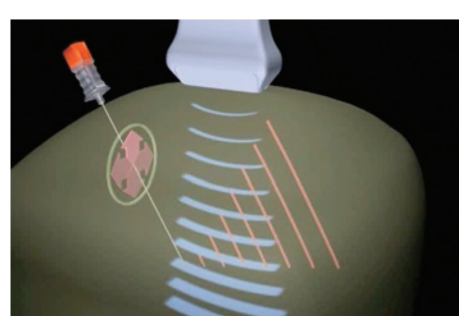

Figure 7 Angle of approach

beam and may lead to errors in depth perception of the needle. The acoustic shadow can lead to confusion. The potential of the scan is not optimized by this approach;
- The long axis orientation allows the operator to trace the entire path and angle of the needle from the entry site at the skin and into the vessel. The long axis orientation is the preferred approach by the author.

Before starting, the following items should be assembled:

- Sterile drapes, gloves and mask;
- Preferred Seldinger cannula;
- A sterile sheath for the ultrasound transducer;
- Standard gel within the sheath and sterile gel outside (can use catheterization lignocaine);
- Set ultrasound to 10 MHz linear transducer. It should default to approximately 4 cm depth;
- Local anaesthesia.

Positioning the patient

For CVC, position the patient at a 30° head-down angle,[10] with only a little neck rotation and no extension.[12] This maximizes venous filling, and reduces the risk of air embolism. For femoral cannulation, the patient should be about 5° head-up. This ensures filling of the vein without undue pressure. In peripheral cannulation, the technique is most facilitated by the upper limb being extended and externally rotated, or by the hands being beneath the patient's head.[13]

Specific techniques

Using local anaesthesia, the needle is introduced through the skin bevel uppermost, where it can be observed indenting the vein (Figure 8). Then with a little pressure, it can be seen entering the vein. It is common at this stage for the needle to impinge on (or penetrate) the rear wall of the vessel (Figure 9), and the operator should take care at this point to withdraw it so that the needle tip is clearly within the lumen (Figure 10). Blood should be readily aspirated at this stage, and the wire should then be fed through the needle. Observe the progress on the screen, and check it remains in the lumen. Then feed the cannula over the wire, secure the line and, in the case of CVC, check the line position with a chest radiograph.

Clinicians should be aware that soon after a vessel is entered, if successful cannulation does not occur, a small clot may form in the lumen of the cannula. This can result in subsequent failure to get any flash-back, even when the cannula is correctly placed. Priming the cannula with heparinized saline can minimize this, but will not prevent it.

General management

Always maintain sterility. Always maintain line security. Apart from having vascular lines pulled out by accident,

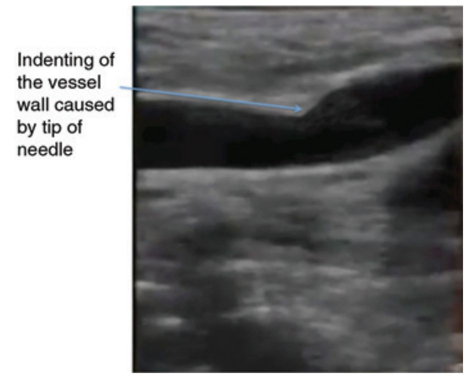

Figure 8 Indenting of the vessel wall

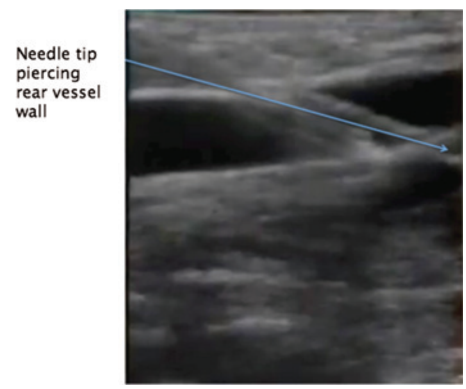

Figure 9 Needle piercing rear wall

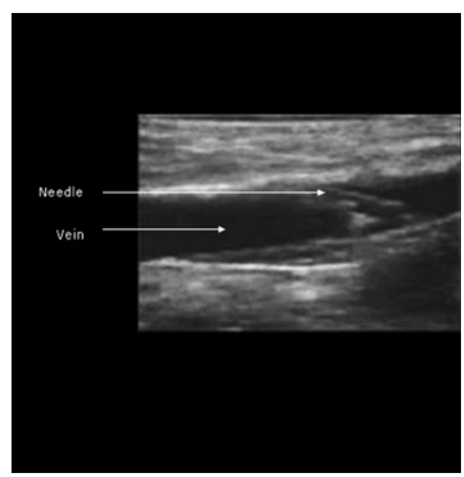

Figure 10 Needle within lumen

significant bleeding or air embolism may occur through careless line care. In patients who are hypovolaemic, once some fluid is introduced, the venous system becomes more accessible to conventional cannulation.

Pitfalls

There are a number, but the following are to be kept in mind at all times:

- Air embolism;
- Loss of sterility;
- Dropping the transducer (so use a second operator/ helper while you gain experience[14]);
- L→R disorientation on the screen;
- Not filling the vein by using head down;
- Vein compression by the transducer or too much neck rotation.

DECLARATIONS

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All clinical images have been anonymized.

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