Central venous access

ABSTRACT

Central venous catheterization is the placement of a catheter in such a manner that its tip is positioned within the proximal third of the superior vena cava, the right atrium or the inferior vena cava. It is indicated when access for administration of drugs or extracorporeal blood circuits and haemodynamic monitoring or interventions is needed. When inserting a central venous catheter, appropriate preparation and asepsis, positioning of the patient, and the use of ultrasound should be considered. Compared to the landmark method of localization, ultrasound can account for anatomical variations, facilitate visualization of venous puncture, and safeguard against inadvertent arterial puncture. In the Seldinger technique, which is the primary mode of central venous catheterization, a needle is passed towards the chosen vessel. Once the needle is in the vein, a guidewire is introduced through the needle into the vessel and the needle is removed. Following a small skin incision at the base of the guidewire, a dilator is advanced over the guidewire and then taken out. Subsequent to this, the central venous catheter is railroaded over the guidewire into the vein and the guidewire is withdrawn. Complications of central venous catheterization can be mechanical, infectious or thrombotic.

In 1929, the first percutaneous insertion of a central venous catheter was reported by Werner Forssman, a 25-year-old surgical resident, who punctured his own antecubital vein to centrally pass an ureteric catheter into his right atrium (Beheshti, 2011). Since then, central venous catheterization, defined as a catheter that has a tip which lies within the proximal third of the superior vena cava, the right atrium or the inferior vena cava, has become common in clinical practice. In the UK, it was estimated that 200 000 central venous catheters were inserted in 1994 (Waghorn, 1994) and this figure is likely to be even higher today.

This article gives an overview of the indications and contraindications, the anatomical sites and insertion technique for non-tunnelled central venous catheters in adults. Peripherally inserted, tunnelled and totally implantable central venous catheters are outside the scope of this article.

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Indications and contraindications

Indications for central venous catheterization include access for administration of drugs or extracorporeal blood circuits, and haemodynamic monitoring and interventions (*Table 1*). In a meta-analysis by Marik et al (2008), the correlation between central venous pressure and blood volume was demonstrated to be poor and the absolute or relative change in central venous pressure did not predict the haemodynamic response to a fluid challenge. Insertion of a central venous catheter solely to measure central venous pressure is hence not accurate and is not advised. Most of the contraindications to central venous catheterization are relative and, because of this, an individualized risk–benefit decision must be made in consultation with each patient. If a central venous catheter needs to be inserted into either the internal jugular or subclavian vein, and an unilateral pneumothorax is already present, then it should be placed onto the ipsilateral side to the pneumothorax in order to avoid the risk of potential bilateral pneumothoraces.

Consent

The process of consent itself is crucial. Informed consent must be obtained from the patient when elective central venous catheterization is to be performed and should include the indication, benefits, possible complications and their consequences as well as the potential alternatives. If central venous catheter insertion is the primary therapeutic intervention (e.g. for difficult peripheral venous access) then a signed consent form is needed, but if it is being undertaken to facilitate another procedure (e.g. for intraoperative administration of vasopressors in major surgery), then a signed consent

Table 1. Indications and contraindications for central venous catheterization

Indications	Access for drugs	Difficult or poor peripheral access Administration of long-term drugs Infusion of irritant drugs, vasopressors and inotropes Total parenteral nutrition
	Access for extracorporeal blood circuits	Plasma exchange Renal replacement therapy
	Haemodynamic monitoring and interventions	Central venous blood oxygen saturation Repeated blood sampling Temporary transvenous pacing Targeted temperature measurement
Contraindications (absolute and relative)		Patient refusal Thrombocytopenia Ipsilateral indwelling central venous access device Contralateral haemothorax or pneumothorax Vein stenosis or thrombosis Localized infection at insertion site

form is not required (Yentis et al, 2017). It is essential, however, for anaesthetists to clearly document the patient's agreement to the intervention and the discussions that led up to the agreement on an anaesthetic record, the patient's notes or standard consent form.

Should emergency central venous catheterization be needed and where the patient lacks capacity, it is acceptable to make decisions and proceed in the patient's best interests. Outside the process of consent, it is important to ask the patient if he or she can lie flat and whether he or she has claustrophobia.

Anatomy

Central venous access can be obtained at a number of anatomical sites and the anatomy related to the three most commonly selected is described below.

Table 2. Advantages and drawbacks of the different anatomical sites of central venous catheterization

	Advantages	Drawbacks
Internal jugular vein	Carotid artery directly compressible if punctured Decreased rate of catheter insertion failure Decreased incidence of catheter malposition Permits ambulation	Awkward for patient Risk of pneumothorax
Subclavian vein	Decreased incidence of symptomatic catheter-related deep venous thrombosis Decreased risk of infection Comfortable for patient Permits ambulation	Difficult to apply direct pressure to the subclavian artery if punctured Increased rate of catheter insertion failure Increased incidence of catheter malposition Increased incidence of pneumothorax
Femoral vein	Femoral artery directly compressible if punctured Pneumothorax not a risk	Impairs patient mobility Increased incidence of symptomatic catheter-related deep venous thrombosis Increased risk of infection

Internal jugular vein

The internal jugular vein follows a course from the jugular foramen in the base of the skull, running under the anterior border of the sternocleidomastoid muscle from the mastoid process to between the clavicular and sternal heads of the sternocleidomastoid muscle. It is contained within a sheath with the carotid artery medial to it.

Subclavian vein

The axillary vein, formed from the brachial and basilic veins, passes behind the clavicle and becomes the subclavian vein at the outer border of the first rib. It crosses the first rib in the subclavian vein groove and lies upon the pleura where it meets the internal jugular vein to become the brachiocephalic vein at the medial aspect of the anterior scalene muscle.

Femoral vein

The femoral vein follows a course parallel and medial to the femoral artery in the femoral triangle, whose boundaries include, superiorly, the inguinal ligament, medially, the medial border of the adductor longus muscle and laterally, the medial border of the sartorius muscle. Both vessels are contained within the femoral sheath with the femoral nerve lateral to and outside it. This configuration of nerve, artery and vein from lateral to medial is almost constant at the level of the inguinal ligament.

Choice of anatomical site

Choosing the most appropriate anatomical site for central venous catheter insertion depends on many factors including the indication, contraindications, previous line insertion sites with associated stenosis or thrombosis, intended duration of use, and anticipated future sites of insertion (e.g. avoidance of the subclavian vein in patients dependent on dialysis) (*Table 2*).

Central venous catheters are more commonly inserted through the internal jugular route than the other sites because of the ease of ultrasound imaging. Catheterization of the internal jugular vein has been discouraged in patients with brain tumours, cerebral haemorrhage and head injuries who are at risk of intracranial hypertension because of the possible impairment in cerebral venous return. Evidence for this has been conflicting (Vailati et al, 2012), but the internal jugular vein is still commonly avoided in these clinical situations. Compared to the subclavian route, where it is difficult to apply pressure after attempted cannulation owing to interference from the clavicle, the femoral site is more suitable in patients with coagulopathy as it is directly compressible.

Earlier studies demonstrated a higher risk of catheter-related bloodstream infections when the femoral was compared to the internal jugular route, but later trials found no difference in the rate of infectious complications between the femoral, internal jugular and subclavian sites (Marik et al, 2012). In a meta-analysis by Ge et al (2012), the internal jugular and subclavian routes had similar risks of catheter-related complications. Relative to the subclavian route, the femoral route was associated with a higher risk of catheter colonization and thrombotic complications. No differences were shown between the femoral and internal jugular sites in catheter colonization, catheter-related bloodstream infections and thrombotic complications, but fewer mechanical complications occurred in the femoral sites.

Type of central venous catheter

Choosing the most appropriate type of central venous catheter depends on several factors including the indication, anatomical site of insertion and intended duration of use. If multiple points of access, or ports, are needed, as is normally the case for patients cared for in the intensive care unit, a triple, quad or quin lumen central venous catheter should be inserted. However, increasing the number of ports can result in a smaller diameter lumen and a decrease in the maximum rate at which fluids can be administered through each port.

In the situation of massive haemorrhage and renal replacement therapy, large bore catheters are required such as a trauma line or a vascath respectively. Furthermore, pulmonary artery sheaths can be inserted to facilitate the floating of either a pulmonary artery catheter or pacing wires. The central venous catheter length is selected based on the anatomical site of insertion as this influences the depth to which it is inserted.

Procedure

Preparation and asepsis

Many institutions now have prepackaged central venous catheterization insertion packs which contain most of what is needed (*Table*

Table 3. Checklist of equipment needed before performing central venous catheterization	
Non-sterile	Hat and mask
Sterile	Gown and gloves, ultrasound probe cover and gel
	Ultrasound machine with linear array probe
	Skin preparation for sterilization, such as 2% chlorhexidine in 70% isopropyl alcohol
	Fenestrated drape
	Syringes
	Gauze
	Needles
	Lidocaine
	0.9% normal saline
	Central venous catheter set, including needle, guidewire, scalpel, dilator and central venous catheter
	Three-way taps
	Sutures
	Dressing impregnated with an antimicrobial
	Sterile dressing

3). It is crucial to be aware of exactly what is included in such packs, as this varies from hospital to hospital, and further equipment can be added if required (*Figure 1*). An experienced assistant is required to help with monitoring, positioning and maintenance of a sterile field. Full monitoring, comprising pulse oximetry, three-lead electrocardiogram and non-invasive blood pressure, should be applied from the outset and should not interfere with the sterility of the procedure.

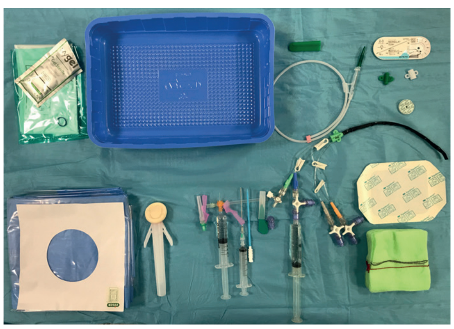

Figure 1. Layout and setup of the equipment required for central venous catheterization.

In a collaborative cohort study, implementation of a bundle of evidence-based interventions, such as hand washing, full barrier precautions to include hat, mask, sterile gown, gloves and drapes during insertion and cleaning the skin with chlorhexidine, led to a reduction in catheter-related bloodstream infections in 103 intensive care units in the USA (Pronovost et al, 2006). Similar results were demonstrated in a 2-year stepped intervention programme, Matching Michigan, in 196 intensive care units in the UK (Bion et al, 2013), where it is therefore recommended as standard practice.

Positioning

If access through the internal jugular route is intended, positioning the patient in a head down (Trendelenburg) position increases the filling and cross-sectional lumen of the internal jugular vein, facilitating catheterization (Mallory et al, 1990). In certain clinical situations, such as respiratory failure, placing the patient head down may not be possible and an individualised risk–benefit decision must be made. If it is required, then the patient can be put in a Trendelenburg position once the equipment has been prepared and the skin has been draped, minimizing the time spent in this position. The head down position has the additional benefit of decreasing the risk of air embolus on catheterization of the internal jugular vein. Once the central venous catheter has been inserted, the patient can be placed in a sitting position before securing the catheter with sutures.

Should central venous catheterization of the femoral site be planned, positioning the patient in a head up (reverse Trendelenburg) position with the leg abducted and externally rotated has the same effect on the femoral vein. In the case of the internal jugular route, imaging studies have shown that rotation of the patient's head to the contralateral side progressively increased the overlap of the internal jugular vein and the carotid artery, underlining the importance of using ultrasound to assess the ideal degree of head rotation and the optimal approach to the internal jugular vein (Miki et al, 2014).

Ultrasound

Central venous catheterization was traditionally achieved with landmark techniques that were based on a knowledge of anatomical structures and the palpation of arteries known to reside next to veins. Unlike landmark methods, however, ultrasound can account for anatomical variations and confirm vein patency, potentially avoiding inadvertent arterial puncture and unsuccessful catheterization.

In a meta-analysis by Brass et al (2015), the use of ultrasound compared to landmark techniques for central venous catheter insertion via the internal jugular was associated with an increase in the overall and the first attempt success rate and a decrease in the number of attempts and the time until successful catheterization, as well as a reduction in the total rate of complications. Ultrasound can thus provide an increased margin of quality and safety in central venous catheterization. In recognition of this, the National Institute for Health and Care Excellence (2002) recommends use of ultrasound guidance for insertion of a central venous catheter into the internal jugular vein.

Linear array probes are high frequency transducers and, as the penetration of the tissues is inversely related to frequency, superficial anatomical structures are well imaged. In view of this, they are most appropriate for real time guidance of central venous catheterization. Ultrasound probes have a small physical notch, the index mark, which can correspond to an indicator on the ultrasound monitor, but different probes are marked differently (Saugel et al, 2017). It is essential to confirm the orientation of the probe, in other words how each side of it relates to the medial and lateral aspects of the patient, before commencing the procedure.

On the ultrasound screen, blood vessels are black or anechoic as they transmit ultrasound well, muscles appear as hypoechoic masses with hyperechoic fascia and bones are white or hyperechoic with a black acoustic shadow below them as they reflect ultrasound well (Hatfield and Bodenham, 2005). Arteries can be seen to pulsate and are difficult to compress with the ultrasound probe while veins are non-pulsatile and collapse or expand depending on the patient position, phase of respiration, ultrasound probe pressure and volume status of the patient.

The chosen vein can be imaged and catheterized in either a transverse or short axis probe orientation and an out of plane view of the needle, or a longitudinal or long axis probe orientation and an in plane view of the needle. In the former approach, the relationship of the vein to surrounding anatomical structures can be better seen (*Figure 2*), but the needle is only

Table 4. Insertion technique for a central venous catheter
Explain the procedure to the patient and obtain informed consent
Check blood tests to exclude thrombocytopenia and coagulopathy
Apply full monitoring to include pulse oximetry, three-lead electrocardiogram and non-invasive blood pressure
Insert a peripheral cannula if possible, should it not already be present
Position patient
Connect the ultrasound machine to electrical power and then set it up
Consider a pre-procedural scan to account for anatomical variations and confirm vein patency
Put on hat and facemask before hand washing and scrubbing up into sterile gown and gloves
Lay out all equipment on a trolley, ordered in sequence of use
Prepare central venous catheter by connecting a three-way tap at the proximal end of each port and flushing with 0.9% normal saline to minimize the risk of air embolus
Clean skin in and around the intended site of insertion and allow to dry
Establish sterile field with fenestrated drape
Place sterile ultrasound gel on probe and inside of probe cover and cover probe and part of connecting electrical cable with sterile probe cover
Apply further ultrasound gel to skin and scan proximally and distally and from side to side in the transverse or longitudinal axis on ultrasound, identifying the vein of interest and surrounding structures as well as examining for the optimal needle insertion point
Infiltrate local anaesthetic (lidocaine at a maximum dose of 3 mg/kg without adrenaline) to site of intended skin puncture
Advance needle or cannula slowly towards the vein under ultrasound guidance with gentle and steady aspiration on a syringe connected to the needle
If the needle or cannula cannot be seen with ultrasound, do not blindly advance the needle but manoeuvre the probe as appropriate until the needle is visualized
After the needle is seen to puncture the vein on ultrasound and non-pulsatile venous blood is aspirated with the syringe, remove the syringe and occlude the proximal end of the needle. If using a cannula rather than a needle, slide the cannula over the needle and verify aspiration of blood
Introduce the guidewire with its atraumatic curved end (J tip) through the needle or cannula and into the vein
Hold on to the proximal end of the guidewire until it has been removed from the patient
Remove the needle or cannula
Confirm the correct position of the guidewire in the vein with the short and long axis views on ultrasound
If atrial or ventricular arrhythmias occur on the electrocardiogram, withdraw the guidewire until they terminate
Position the dilator ready for use and make a small incision at the base of the guidewire
Advance the dilator only until a loss of resistance is perceived and not beyond its shoulder to create a tract from skin to vein
Take out the dilator and apply firm pressure at the entry site with gauze
Pass the central venous catheter over the guidewire and withdraw the guidewire until it protrudes from the end of the line
Advance the central venous catheter into the vein to the required depth
Remove the guidewire
Confirm the aspiration of blood from each port of the central venous catheter and follow with a flush of 0.9% normal saline
Suture the central venous catheter to the skin using four-point suturing
Apply antimicrobial and sterile dressings and use the paper section of the dressing to indicate the date of insertion
Dispose safely of all sharps
Document procedure in full, including the occurrence of any complications
For internal jugular and subclavian central venous catheters, request and review a chest X-ray, checking for a pneumothorax and the position of the line

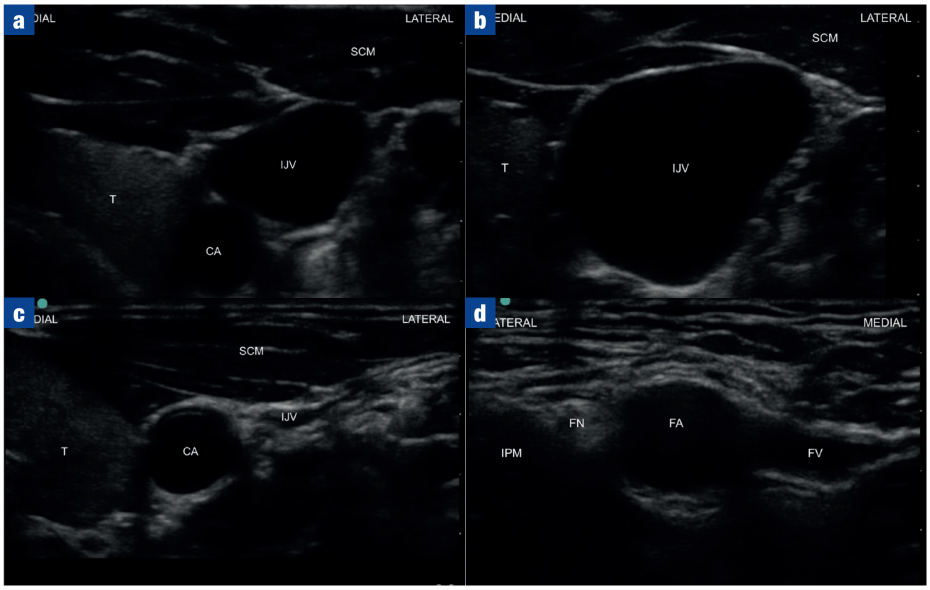

Figure 2. Ultrasound image in a short axis/transverse view of the right internal jugular vein **(a)** with no compression, **(b)** head down tilt and **(c)** compression and **(d)** of the left femoral vein, showing the anatomical relations of nearby structures and the effect of simple manoeuvres on the cross-sectional lumen of the vein. CA = carotid artery; FA = femoral artery; FN = femoral nerve; FV = femoral vein; IPM = iliopsoas muscle; SCM = sternocleidomastoid muscle; T = thyroid gland.

TOP TIPS

- Familiarize yourself with the equipment needed for central venous catheterization.
- Optimally position the patient.
- Learn the relevant anatomy and sonoanatomy.
- If the needle cannot be seen on ultrasound, do not blindly advance it.
- Monitor the electrocardiogram for arrhythmias, particularly when the guidewire and central venous catheter are inserted.
- Once the guidewire has been inserted, hold on to it until it has been removed from the patient.

visualized as an echogenic dot. In the latter approach, the whole needle including the tip can be seen, decreasing the risk of unintended penetration of the posterior vessel wall.

Technique

In the Seldinger technique, a thin-walled needle is passed slowly towards the chosen vein with gentle and steady aspiration on a syringe connected to the needle (*Table 4*). After the needle has been seen to puncture the vein on ultrasound and venous blood is aspirated, disconnect the needle from the syringe. At this point, high velocity and pulsatile blood flow from the needle indicates inadvertent puncture of an artery, such as the carotid artery in the case of attempted cannulation of the internal jugular vein. If the blood flowing from the needle is venous in nature, the base of the needle must be occluded to prevent any air entrainment and a metal guidewire should be introduced with its atraumatic curved end, the J tip, through the needle and into the vein. It should pass easily, but remember never to let go of the proximal end of the guidewire until it has been removed from the patient for fear of guidewire retention, a serious and largely preventable safety incident listed as a never event (NHS Improvement, 2018). Once the vein has been punctured, gentle pressure should be applied with sterile gauze at the puncture site, particularly after dilatation, to prevent unnecessary blood loss.

Following insertion of a central venous catheter, a hydrophilic foam dressing impregnated with chlorhexidine, such as Biopatch, is commonly used to cover the entry site to reduce the risk of catheter-related bloodstream infections (National Institute for Health and Care Excellence, 2017).

Depth, position and confirmation of placement

Various methods are available for estimating the ideal depth of insertion. Czepizak et al (1995) proposed the following formulae, height (cm)/10 – 1 cm for catheterization of the right internal jugular vein and height (cm)/10 + 4 cm for catheterization of the left internal jugular vein. Kim et al (2011) suggested a topographical measurement using surface anatomy for catheterization of the internal jugular vein, where the central venous catheter is placed with its own natural curvature over the draped skin to follow a course from the point of skin puncture, through the ipsilateral clavicular notch, so that the tip of the catheter lies at the insertion point of the right second costal cartilage to the manubriosternal joint. Overall, however, the catheter should be inserted to up to 16 cm, 20 cm and 15–20 cm for right internal jugular vein catheterization, left internal jugular vein catheterization and femoral vein catheterization respectively.

It is widely accepted, despite being the subject of much debate, that the tip of the catheter should ideally be positioned within a large central vein, parallel to the long axis of the vessel, with the tip outside the pericardial reflection (Gibson and Bodenham, 2013). This reduces the risk of perforation and, should perforation occur, cardiac tamponade. If the tip of the catheter is placed too proximal, the risk of thrombosis is increased. In the case of central venous catheterization of the internal jugular and subclavian routes, a chest X-ray should be reviewed to confirm the absence of a pneumothorax and the position of the catheter above the level of the carina, ensuring placement above the pericardial sac (*Figure 3*) (Smith and Nolan, 2013). Furthermore, blood gas analysis and transduction of the catheter can facilitate confirmation of its venous placement.

Complications

Consideration of the anatomy of the commonly used veins can explain the complications that can occur. Potential complications can be classified as immediate or delayed and further subclassified into mechanical, infectious or thrombotic (*Table 5*). Subsequent to central venous catheterization of the internal jugular route with ultrasound, an overall complication rate of 4% has been reported (Brass et al, 2015). Clinical signs are unreliable in the diagnosis of central venous catheter infection (Smith and Nolan, 2013). Fever is the most sensitive but is not specific, while inflammation or pus at the exit site of the catheter is more specific but less sensitive. If there is any suspicion of this, an individualized risk–benefit decision should be made with regard to potential removal of the catheter.

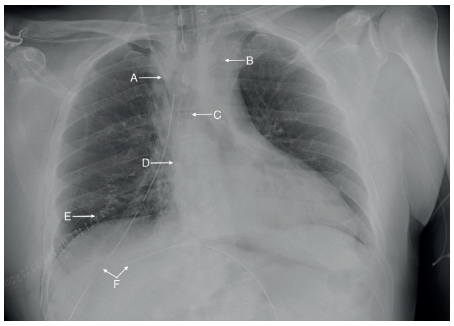

Figure 3. The ideal position of a central venous catheter in the internal jugular vein on a chest X-ray. A: central venous catheter; B: peripherally inserted central catheter; C: carina; D: right atrium; E: surgical staples; F: chest drains.

Conclusions

All doctors will encounter patients who either need or have had a central venous catheter inserted as it is a common procedure with a wide range of indications. However, it is not free of potential complications and therefore appropriate training and awareness of risks are vital. **BJHM**

Conflict of interest: none.

Table 5. Complications of central venous catheterization

Immediate	Infectious	None
	Mechanical	Arterial puncture Haemorrhage Intra-arterial placement of catheter Haemothorax Pneumothorax Arrhythmia Injury of thoracic duct Cardiac tamponade
	Thrombo-embolic	Air embolism Guidewire embolism
Delayed	Infectious	Colonization of catheter Catheter-related bloodstream infection
	Mechanical	Erosion or perforation of vessel Fracture and embolism of catheter Venous stenosis Cardiac tamponade
	Thrombo-embolic	Air embolism Catheter-related thrombus Pulmonary embolism

CURRICULUM CHECKLIST

This article addresses the following requirements from the general internal medicine training curriculum:

- Delivering effective resuscitation and managing the acutely deteriorating patient.
- Managing an acute unselected take.

KEY POINTS

- Central venous catheterization is common in clinical practice with a wide range of indications.
- Choosing the most appropriate type of central venous catheter depends on factors including the indication, site of insertion and intended duration of use.
- The Seldinger technique tends to be the primary mode of central venous catheterization.
- Use of ultrasound for insertion of central venous catheters has been associated with an increase in quality and safety.
- Despite being a relatively safe procedure, complications can occur with the insertion of central venous catheters, varying in frequency depending on the anatomical site.

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