Guidelines

Association of Anaesthetists of Great Britain and Ireland*
Safe vascular access 2016

A. Bodenham (Chair),[1] S. Babu,[2] J. Bennett,[3] R. Binks,[4] P. Fee,[5] B. Fox,[6] A. J. Johnston,[7] A. A. Klein,[8] J. A. Langton,[9] H. Mclure[10] and S. Q. M. Tighe[11]

1 Consultant, Anaesthesia and Intensive Care, Leeds Teaching Hospitals, Leeds, UK
2 Specialty Doctor, Anaesthesia, North Manchester General Hospital, Manchester, UK
3 Consultant, Anaesthesia, Birmingham Children's Hospital, Birminham, UK
4 Nurse Consultant, Airedale Hospital, West Yorkshire, UK, and Faculty of Intensive Care Medicine, UK
5 Locum Consultant, Anaesthesia, Belfast Health and Social Care Trust, Belfast, UK
6 Specialist Registrar, Anaesthesia, East Anglia, and Group of Anaesthetists in Training, AAGBI, London, UK
7 Consultant, Anaesthesia and Intensive Care, Addenbrooke's Hospital, Cambridge, UK
8 Consultant, Anaesthesia, Papworth Hospital, Cambridge, UK
9 Consultant, Anaesthesia, Plymouth Hospitals, Plymouth, and Royal College of Anaesthetists, UK
10 Consultant, Anaesthesia, Leeds Teaching Hospitals, Leeds, UK
11 Consultant, Anaesthesia and Intensive Care, Countess of Chester Hospital, Chester, and AAGBI Council, UK

Summary

Safe vascular access is integral to anaesthetic and critical care practice, but procedures are a frequent source of patient adverse events. Ensuring safe and effective approaches to vascular catheter insertion should be a priority for all practitioners. New technology such as ultrasound and other imaging has increased the number of tools available. This guidance was created using review of current practice and literature, as well as expert opinion. The result is a consensus document which provides practical advice on the safe insertion and removal of vascular access devices.

....

....

Recommendations

1 Hospitals should establish systems to ensure patients receive effective, timely, and safe vascular access.

2 All hospitals should have specific policies for insertion and removal of vascular access devices including clear documentation from insertion to removal.

3 Clinicians should be proactive in provision of, training in and supervision of vascular access.

4 Ultrasound should be used routinely for internal jugular central venous catheter insertion. The Working Party recommends its use for all other central venous access sites, but recognises evidence is, at present, limited.

5 An understanding of landmark techniques for central venous cannulation is useful for rare occasions when ultrasound is not available or cannot be used.

6 The use of ultrasound should be considered early if arterial or peripheral venous cannulation proves difficult.

7 Intra-osseous access is useful in emergencies when intravenous access is difficult. All acute care clinicians should be familiar with techniques and have ready access to devices.

8 Clinicians should review processes to improve the safety and proficiency in vascular access and initiate regular audit to assess compliance with the standards identified in this and other guidance.

What other guideline statements are available on this topic?

There are a small number of existing national and international guidelines on vascular access [1–5].

Why was this guideline developed?

There is a need for up to date evidence-based guidance focusing on patient safety. There continues to be cases of severe morbidity and mortality related to vascular access [6, 7].

How and why does this publication differ from existing guidelines?

This is the first UK anaesthetic national guidance in this field, primarily aimed at safety of insertion and removal procedures. We also highlight organisational and training issues.

Introduction

Vascular access is the most common invasive procedure undergone by patients in secondary care. It is often poorly undertaken and is the source of considerable patient discomfort and inconvenience, as well as morbidity and mortality. Vascular access is essentially a single, often repetitive, task but providing a quality service requires more; this includes all aspects of human factors as well as education, training, audit and technical proficiency. New technology such as ultrasound and other imaging has increased the number of tools available.

Peripheral venous cannulation

Peripheral venous cannulation is the commonest, and probably the most important invasive procedure practised in hospitals. Principles are summarised in Table 1 [8–11].

An alternative and increasingly used technique is so called midline catheters [12]. These are approximately 10–20 cm long and inserted into upper arm veins with ultrasound (as with a peripherally inserted central catheter, such that the tip lies outside central veins and are used for short to medium-term access (e.g. 1–4 weeks antibiotics). They should not be used for infusions listed as requiring central venous administration.

Table 1 Guide to peripheral cannulation [8–11].

- The smallest practical size of cannula should be used.
- Needle guards to reduce needle stick injury are recommended in all procedures.
- Peripheral insertion is inappropriate for infusion of fluid with high osmolality (> 500 mOsm.l^{-1}) or low (< 5) or high pH (> 9) or intravenous access for more than 2 weeks.
- The relative safety of peripheral administration of vasopressors/inotropes is contentious, but likely to be dependent on vein size and its blood flow, infusion rate, individual drug effect and dilution. This is a good area for future studies.
- Insertion in a limb with lymphoedema should be avoided, except in acute situations due to increased risks of local infection.
- Transillumination, ultrasound and infra-red devices may be useful.
- Routine changes of peripheral cannulae at 72–96 h is not advocated.
- All cannulae must be flushed after use.

Intra-osseus access

Intra-osseus access (IO) access is useful in emergencies, when intravenous (IV) access is difficult, and is faster than central access [13]. It can be used for resuscitation fluids and drugs. All acute care clinicians should be familiar with techniques and have ready access to devices. We suspect that to date this is not the case in most centres. A number of manual and automated devices exist.

The tibia and the humerus are preferred sites. For the tibia, the insertion site is 2 cm distal to the tibial tuberosity and 1 cm medial to the tibial plateau. Care is needed to avoid the epiphyseal growth plate in children. Success is evident by: aspiration of bone marrow (painful in awake patients); saline flush with no extravasation; support of the needle by the bone cortex; and infusion under gravity alone.

Complications include: fracture; extravasation; osteomyelitis; infection; compartment syndrome; growth plate injury and pressure necrosis of the skin. Devices should be removed as soon as suitable IV access is achieved, ideally within 24 h of placement.

Arterial access

Relative contraindications include severe peripheral vascular disease, coagulopathy and local synthetic grafts. There is no evidence to support routine rotation of sites. Compression of radial and ulnar arteries to assess collateral perfusion (Allen's test) is unreliable. Ultrasound can be used to assess vessel patency and size.

Methods of insertion include: catheter-over-needle; and catheter-over-wire, i.e. Seldinger or modifications. A meta-analysis [14] suggested that radial arterial cannulation with ultrasound is more successful on first attempt. Major procedural complications (e.g. permanent ischaemic damage, sepsis, pseudoaneurysm) are reported to occur in < 1% of cases and are similar for radial, femoral and brachial sites. Some studies have found a higher incidence of catheter-related infection in femoral sites. However, arterial cannulation is generally considered safest at a suitable peripheral site if possible.

There have been UK national alerts on severe hypoglycaemia from misdirected administration of insulin when glucose solutions are used to flush arterial lines. The most recent AAGBI guidelines recommend saline ± heparin as the only safe solution to flush catheters [15].

Insertion & removal of central venous catheters (CVCs)

Device choice

This depends on: patient diagnosis; the intended treatment (irritant drugs normally require CVC); and patient choice. Devices should have the appropriate number of lumens required for the planned usage aiming to avoid the risks of additional catheter placements [16]. Smaller diameter devices, if appropriate, reduce vein trauma on insertion and thereafter. Parenteral nutrition requires a dedicated lumen. Fixed-length catheters: 15 cm for right internal jugular vein (IJV), 20 cm for left internal jugular or right axillary/subclavian vein, and 24 cm for left axillary/subclavian or femoral vein, are the usual minimum selection length for adults. See Table 2 for different features [16, 17].

Route of access

Central venous catheters

The internal jugular vein route may have a lower risk of mechanical complications than the subclavian [1]. Recent work shows catheter-related bloodstream infection rates are lower in patients in critical care using the subclavian rather than IJV or femoral routes [18]. Although the groin may have a higher microbial colonisation rate, tunnelling devices away from the groin may reduce such risks. Some perceived differences in complication rates may disappear with optimal catheter tip positioning between insertion sites. The right internal jugular/femoral route provides a straighter course to central veins, making catheter positioning easier without X-ray guidance. The external jugular vein is an alternative visible vein, but central catheter positioning can be difficult.

Peripherally inserted central catheters (PICCs)

These should be used with caution in patients at risk of ipsilateral lymphoedema and those who may require an arterio-venous fistula. The basilic and brachial veins may have a lower thrombosis rate than the cephalic vein. Ultrasound use may avoid damage to the median

Table 2 Some features of different central venous catheter devices, all suitable for multiple infusions including vein-damaging substances. Adapted from [16, 17].

	Features	Common use	Duration/comments
Non-tunnelled	One to six lumens. Insertion to subclavian, IJV or femoral veins. Some suitable for extra-corporeal treatments.	Short-term CVC. Central venous pressure and ScvO2.	Up to 7–10 days. Routine replacement not required.
Tunnelled	One to three lumens. Insertion to subclavian, IJV or femoral veins (entry). Tunnelled to exit site. Dacron cuff anchors device.	Frequent long-term access. Haemodialysis/extra-corporeal treatments.	Months/years. Lower infection than non-tunnelled catheters.
Total implanted (Ports)	One to two lumens. Insertion to subclavian, IJV, femoral or upper arm veins (entry). Tunnelled to port.	Frequent long-term access Complex to insert/remove. Uses needle access.	Months/years. Lower infection than tunnelled catheters. Least lifestyle disruption
Peripheral insertion (PICCs)	One to three lumens. Insertion to basilic, cephalic and brachial veins.	Simpler and safer to insert.	1–6 months, or longer. Suitable for short-term use.

IJV, internal jugular vein; ScvO2, central venous oxygen saturation.

nerve and brachial artery. Use of upper arm veins avoids the elbow flexure.

Catheter tip position

A poorly positioned catheter tip may increase the risk of complications, e.g. thrombosis, erosion and pericardial tamponade [19]. The position of the tip moves with respiration and patient position. Upper body CVCs should be positioned with the tip parallel to the vessel wall, usually in the lower superior vena cava (SVC) or the upper right atrium (RA). Common sites for tip misplacement include: high SVC; internal jugular vein; angled at vein wall; low RA; right ventricle; innominate vein and subclavian vein.

Assessment of tip position includes: post-insertion chest X-ray, real-time fluoroscopy, and ECG guidance. Stenosis or distortion of great veins is common in disease states particularly with prolonged CVC placement. Unusual congenital variants (e.g. left SVC) exist [20]. Misplacement can be reduced by the following: use of the right IJV or femoral veins and pressure over the IJV may reduce the incidence of IJV malposition when inserting PICCs or subclavian lines. Catheters and guidewires may pass centrally more easily on inspiration as thoracic structures change shape. Ultrasound can confirm catheter position with supraclavicular, transthoracic and transoesophageal echocardiographic views. Electrocardiograpy and electromagnetic guidance

are increasingly used to guide catheter tip positioning as per recent guidance [21]. Fluoroscopy $\pm$ X-ray contrast remains the gold standard for imaging.

Most misplaced CVCs are easily identified on chest X-ray, but signs can be subtle [20]; judicious use of contrast via the catheter (linogram) is helpful. The limitations of single plane X-ray imaging must be appreciated. Clues to misplacement include: pain on injection; difficulty in aspirating blood from one or more lumens; or an abnormal pressure waveform, or arterial pattern blood gas on sampling. Management of misplaced catheters within central veins includes: using the device if it is safe to do so; manipulating the position under X-ray guidance; or replacement, using fluoroscopic guidance or other imaging as required. Misplacement outside veins is considered later under complications.

Removal of CVCs

Devices should be removed when they are no longer required or are causing problems. The patient should lie flat with the exit site below the heart to reduce risks of air embolus. Firm digital pressure should be applied for at least 5 min, followed by an occlusive dressing. Routine culture of tips is not considered necessary. Persistent bleeding may require a skin stitch.

Cuffed devices/ports need surgical cut-downs as they develop complex adherent fibrin sleeves and scar tissue [22]. Fibrin sleeves are frequently left behind

within the vein (seen as 'ghosts' on ultrasound). Very long-term catheters may become attached to the wall of SVC/right atrium and cannot be removed by traction alone; cutting off and leaving in situ or surgical removal may be required. Devices can become knotted within veins. Seek advice from vascular surgery or interventional radiology if difficulties occur.

Procedures in coagulopathic patients

In the presence of a coagulopathy, a more experienced operator should insert the CVC, ideally at an insertion site that allows easy compression of vessels. Femoral access may have a lower risk in this situation. Routine reversal of coagulopathic abnormality is only necessary if platelet count $< 50 \times 10^9.l^{-1}$, activated partial thromboplastin time > 1.3 times normal and/or international normalised ratio > 1.8, as the risk of haemorrhage is not increased [23]. In selected patients, different thresholds for correction may be acceptable.

Bleeding risks of insertion and removal vary with the site, size of device, and operator experience. The risks of correction (e.g. infection, lung injury, thrombosis) may exceed that of local bleeding, and it may be preferable to give blood products if problems occur, rather than prophylactically.

Difficult central venous catheter insertion

Difficult access occurs frequently [24] and is more likely with previous multiple attempts, insertion site scars and long-term access. Distended superficial collateral veins suggest deeper vein blockage or stenosis. Doppler ultrasound of great vessels gives limited imaging of the subclavian vein and SVC; contrast venography/CT/MRI may be indicated, dependent on urgency.

If difficulty is predicted, insertions should be performed under X-ray control with appropriate radiation protection [25]. High-resolution ultrasound should be used with colour Doppler to study flow. Input from interventional radiology and surgery may be needed.

A 'difficult access' trolley is useful, with additional instruments, X-ray contrast, sterile drapes and ultrasound probe covers, standard (18G) and micro-puncture needles (20-21G), and compatible guidewires (0.018″ and 0.32″).

Guidewires come in various lengths, with different coatings and tips (e.g. straight, angled, soft tip or full

'J'). It is best to be familiar with a small range. Catheters of 12–24 cm length should be available for adults. Guidewires should be checked for damage and adherent clot removed with a wet swab. A selection of compatible dilators and peel-away sheaths is needed.

Use of a 4–5 Fr introducer sheath allows manipulation of guidewires while minimising the risk of damaging the wire or vein; it also acts as a conduit for contrast injection or advancement of specialist catheters/wires.

X-ray contrast is used to image vascular anatomy, identify complications and confirm line position/patency. It may cause anaphylaxis. Contrast nephropathy is unlikely in doses used for venous access [26].

Paediatric CVC insertion

Provision of CVCs for neonates through to adolescents is challenging, despite similar techniques to adults. Children are more likely to be seen with congenital cardiac anomalies and there is a large range in the size of vessels, which impacts on procedures and complications [27]. Most procedures will be conducted under general anaesthesia, except for peripherally inserted central catheters.

Catheter choice depends on: vein calibre; indication; duration of use; severity of illness and operator experience. Neonatal long lines down to 28G are available. Umbilical venous catheters remain popular for short-term use in neonates, despite high complication rates. Non-tunnelled, 5–6 cm long, 4.5-Fr triple-lumen CVCs are available for neonates. Tunnelled cuffed Broviac catheters for long-term use are available down to 2.7Fr [28].

A full range of sizes of equipment is required. Operators must be familiar with equipment and procedures. Typical guidewires are narrower 0.021″ (0.032″ used in adults), and prone to kinking, particularly during advancement of dilators. The diameter of a 'J' tip may impede advance in a narrow vein. A less curved tip is preferable. Skin dilators tend to be shorter and narrower.

X-ray imaging of fine catheters is challenging, and contrast may be required. There are few data on the use of electromagnetic or ECG guidance to identify CVC tip position in children. X-ray guidance remains standard.

Chlorhexidine of varying strengths is used for skin antisepsis before CVC insertion in infants, but efficacy and safety data comparing solutions is lacking so definitive guidance cannot be given. Chlorhexidine, in particular 2%, has been associated with skin erythema and burns in premature infants and caution is advised in this group; the use of excessive quantities and pooling on the skin should be avoided [29]. Many centres use a 0.5% solution as an alternative.

Ultrasound-guided paediatric CVC insertion has been shown to be superior to landmark techniques [30]. Superficial vessels and lack of fat allows excellent imaging. Probes need a small footprint for full skin contact. Veins are prone to compression by the probe and access needle, which risks transfixion and damage to adjacent structures.

Small children are less likely to understand the importance of their CVC with risks of damage, nor the risks associated with replacing devices. Implanted ports may not be tolerated by needle phobic children. Rapid growth in small children may lead to the tip migrating.

Peripheral access can be challenging and limit placement of devices. Loss of peripheral veins is a serious issue in chronic illness. Prolonged use of CVCs may lead to central vein thrombosis with difficult or impossible access. Open surgical cut-down remains a common technique in paediatric surgery and often leads to central vein occlusion near the entry site.

Prevention, recognition and management of central venous catheter complications

Deaths related to CVCs are often accompanied by poor documentation [4]. All hospitals should have clear, specific policies for insertion and documentation of CVCs (type, insertion site and tip position), and education on complications and their management.

Publications suggest complication rates of 1–26% [31]. However, most series are small and lack precise denominators. Appropriate training and surveillance should avoid and identify most complications. Discussion here is limited to more serious, well-recognised complications (Table 3), which vary in frequency depending on patient, catheter and operator experience. There are many other reported rarer complications listed as case reports in the literature. There is an increased focus in the UK to reduce the risks of invasive procedures including universal adoption of WHO style theatre checklists, definition of so called 'Never Events' (see later), and most recently the introduction of local and National Safety Standards for Invasive Procedures (NatSSIPs) [32]. Central venous access and more central arterial cannulation would be considered to be within this latter category of invasive procedure.

Infection
Central venous catheter-associated bloodstream infection can be life-threatening, and is increasingly regarded as a measure for quality of care. Treatment should adhere to local guidance and may include CVC removal [33].

Thrombosis/thrombo-embolism
Thrombosis related to CVCs has a reported incidence of 3–32% [1], reflecting variations in definition and imaging, and frequent asymptomatic cases. Prevention measures include: insertion of the narrowest-bore catheter possible for treatment needs; placement of the tip in lower SVC/high right atrium; and early removal.

Evidence suggests that peripherally inserted central catheters are associated with increased peripheral and central thrombosis [34]. The femoral route may be

Table 3 Complications of central venous catheter insertion.

- Infection
  - Localised or bloodstream.
- Thrombosis/thromboembolism
  - Symptomatic or asymptomatic
- Perforation of vessels and myocardium
  - Arterial puncture/tear
  - Arterial cannulation
  - Venous injury/tear
  - Myocardial perforation/cardiac tamponade.
- Pleural collections.
  - Pneumothorax
  - Haemothorax (haemoperitoneum)
- Cardiac arrhythmias
- Air embolism
- Guidewire/catheter embolism
- Catheter occlusion
- Catheter breakage/leak/extravasation
- Bleeding elsewhere.
- Central venous stenosis
- Neurological injury

associated with a higher thrombosis risk [18, 19]. Some retrospective (but not prospective) studies show an increased thrombosis risk when the subclavian vein is used long-term [1]. Anticoagulation is not currently recommended for asymptomatic thrombosis [1], or as prophylaxis, except for patients at high risk (e.g. previous DVT or PE) [35].

Thrombosis may present with a poorly functioning line; a swollen limb; signs of SVC obstruction; pain over the insertion site; or central embolism. Symptomatic thrombosis is usually treated with full anticoagulation. Removal of a functioning CVC depends on the clinical situation, and ease of re-insertion.

Perforation of great vessels and myocardium

These complications usually occur at insertion and may cause serious morbidity or mortality. Meticulous technique, vigilance and early recognition prevent progression to catastrophe. Bleeding may be evident externally, but may also be covert, into pleurae, pericardium, and peritoneum. Once a vessel is perforated then the guidewire, dilator or catheter may pass into any adjacent structure or organ, commonly the pleural space, pericardium, mediastinum or lung in the upper body.

Arterial puncture

Accidental arterial puncture is reduced with routine use of ultrasound guidance [1, 36]. It is usually evident by bright red, pulsatile blood, but confusion may occur in infants and emergency situations. Manometer tubing can be attached to a needle or cannula to differentiate venous from arterial placement. Ultrasound imaging can confirm the guidewire in the proximal vein before dilatation. A PO_2 consistent with arterial blood is strongly suggestive but may reflect atrerio-venous shunting. All tests have flaws; a fuller discussion is available elsewhere [2].

Needle puncture is managed by removal and digital pressure. Ultrasound imaging may define the size of the haematoma, vessel injury and patency. Puncture of the carotid artery, even with a 21G 'searching' needle, may cause stroke, particularly with existing arterial disease [37]. If the needle also traverses a vein, there is potential for an aterio-venous fistula. An expanding neck haematoma in the neck may

fatally compromise the airway [38–40], and require tracheal intubation and surgical intervention. Haemorrhage associated with the femoral route may be concealed in the retroperitoneum. Tense haematomas elsewhere may require surgical evacuation/repair to prevent local pressure effects.

Accidental arterial cannulation

The incidence is estimated as 0.1–1% [1]. There may be excessive bleeding along the guidewire or on passing dilators and introducers. Activation of high-pressure alarms on infusion pumps and retrograde flow within catheter/infusion sets are suggestive. Chest X-ray may show an abnormal catheter path (to the left mediastinum), but not if the catheter is in the right carotid or ascending aorta which are adjacent to the internal jugular vein and SVC. An arterial waveform upon pressure transduction (check settings are for arterial range) confirms arterial positioning. Contrast injection will demonstrate arterial flow and CT shows the catheter course. Carotid artery cannulation carries a higher risk of morbidity and mortality than at other sites, because of the risk of stroke and local pressure effects from haemotoma.

Larger catheters/dilators (6Fr or greater) should be left in place and their safe removal discussed urgently with interventional radiologists or vascular surgeons. Management of smaller catheters depends on the insertion site, presence of arterial disease or thrombus, and coagulation status; catheters (5Fr or less) are routinely removed from the femoral artery following radiology procedures. This is followed by direct pressure for 10 min, or until haemostasis is achieved, then six hours bed rest. Such guidance can be followed up for accidental femoral artery catheterisation. Interventional radiologists and surgeons should be consulted before removing larger devices, any arterial catheter from the neck or chest, or from any site in an anticoagulated patient [39]. Routine anticoagulation following short-term accidental carotid or other artery catheterisation is not recommended.

Venous tears

This is caused by trauma during insertion or later erosion of the vein wall. Prevention includes meticulous insertion technique; avoidance of advancing guidewires

and dilators against resistance; and firmly holding guidewires during dilation and catheter advancement. Poorly positioned catheters need to be repositioned, e.g. left-sided upper body CVCs that abut the SVC at an acute angle. Narrow-bore soft catheters and dilators are less likely to cause perforation.

Venous injury may manifest as a haematoma, bleeding or extravasation into the mediastinum, pleura, peritoneum, pericardium or other space. It may cause haemodynamic compromise, cardiac tamponade, haemothorax or pleural effusion [38, 40]. The catheter should remain in situ until a vascular surgical or interventional radiology opinion has been obtained.

Myocardial perforation/cardiac tamponade

This can be caused by trauma from guidewires or dilators during insertion, or later erosion by a catheter. Presentation is usually acute but may be delayed until infusion of fluids via the catheter. The incidence is reduced by careful insertion techniques. Infants and those with dilated cardiomyopathy or previous cardiac surgery are at higher risk. Guidewires should be advanced gently and not beyond 20 cm (less in children) without imaging. Dilators should only be inserted as far as required to create a tract to the vessel. Traditionally, it was advocated that catheter tips should lie above the pericardial reflection but this is frequently not possible, particularly with left-sided catheters.

There may be signs of obstructed shock, an abnormal pressure wave, or cardiac arrest. Chest X-ray may show an enlarged cardiac outline, which can be confirmed with echocardiography. Management involves attempted fluid aspiration through the catheter, urgent pericardiocentesis or surgical intervention [40].

Pneumothorax

The incidence of pneumothorax is 0.3–2.3%, highest with the subclavian route [1, 34]. It is typically caused by needle penetration of the visceral pleura. Prevention includes avoiding the subclavian vein, particularly during early training, and using ultrasound guidance [41]. Recognising a pneumothorax can be difficult. It may be invisible on initial post-procedure imaging. Staff

and patients should be warned to report late signs and symptoms.

Treatment options include: observation; administration of supplemental oxygen; and aspiration; or tube drainage. Minimal or asymptomatic collections (up to 30% of the pleural cavity) may not require drainage in spontaneously breathing patients.

Haemothorax

This may occur with central vein or arterial trauma [42]. The pleurae are low-pressure spaces, where a large volume of blood can accumulate. Catheters crossing from a vein or artery into the pleura (or other space) may be wholly or partially occluding the hole and bleeding may worsen on removal. Further accumulation of fluid/blood may occur if the catheter is used for infusion, resuscitation or dialysis.

There may be clinical signs of respiratory and/or circulatory failure. Chest X-ray, CT or ultrasound imaging shows a dense pleural effusion, and aspiration/drainage of blood confirms the diagnosis. Resuscitation with drainage and repair of the damaged vessel may be required.

Cardiac arrhythmias

Arrhythmias may be precipitated by guidewires or catheters stimulating the heart [43]. They are usually caused by insertion beyond the predicted length of catheter for that insertion site, and usually settle on guidewire/catheter withdrawal. Electrocardiographic monitoring throughout all upper body CVC insertions is advisable.

Venous air embolism

Air embolism may be fatal and occur at any time from insertion to removal. The incidence may be as high as 0.8% [42]. Prevention requires careful insertion/removal techniques, secure fixation and safe handling when accessing the catheter. Presentation ranges from subtle neurological, respiratory or cardiovascular signs to shock, loss of consciousness and cardiac arrest. Chronic forms may exist. If suspected, damaged catheters should be clamped, pressure and wet dressings applied, and occlusive dressings used. Head-down, left lateral tilt and attempted aspiration of air via the line may be useful.

Guidewire and catheter embolus

This risk is increased during difficult or multiple cannulation attempts of the same vessel, or the presence of an inferior vena cava filter [44]. Preventative measures include minimising the length of guidewire advanced, and maintaining hold of the outside section. Guidewire counts or mandatory witnessed documentation of guidewire removal may help identify unaccounted wires during insertion. Retained guidewires are usually asymptomatic and recognised incidentally on X-ray. Guidewire retention is now categorised as an NHS Never Event [45].

Catheter embolism occurs more often with long-term devices. Catheter and port hub connections may fracture/disconnect. Compression of the catheter between the first rib and clavicle may result in 'pinch-off' [46]. Catheters are at risk during removal, especially cuffed/implanted devices.

Both complications need referral for urgent radiological or surgical retrieval.

Catheter occlusion

Occlusion may be due to thrombus, fibrin sheath or precipitation within the catheter. The incidence of catheter occlusion may be reduced by adhering to standard procedures for accessing CVCs and managing failing lines. A Cochrane review of heparin solutions reported no reduction in intracatheter thrombus [47]. Occlusion is recognised by inability to aspirate or flush one or more catheter lumens. It is common, and often managed by a local protocol. A 'linogram' may identify a kinked catheter, aberrant tip position or a fibrin sheath with reflux of contrast. Thrombolytics can be used to clear the lumen or surrounding thrombus [48]. In the case of precipitants, strong acid or alkali has been used to unblock devices.

External catheter breakage

The portion of a CVC outside the body has the potential to be cut, broken or split. Breakage is more common in long-term lines. They may be repaired according to local policy, or replaced.

Extravasation injury

Injury caused by leakage of infusate is usually associated with catheter damage or withdrawal (placing a luminal hole outside the vein), or vein perforation. Rarely, fluid backtracking along a fibrin sheath may be the cause. High-risk infusates include those with high or low pH, high osmolality, vasopressors and chemotherapy agents.

Secure fixation is important to minimise withdrawal, which may be identified by the loss of a venous waveform from the proximal lumen of the catheter. Correct placement of the catheter tip will help prevent venous erosion and ensure an adequate length of catheter within the vein.

Leakage of infusate at the insertion site suggests extravasation; this may be painful and cause tissue damage. There may be a lack of clinical effect of infusions. Chest X-ray may reveal a migrated catheter, or a pleural effusion. Management of extravasation depends on the nature of the infusate; protocols for extravasation should be followed. Plastic surgical referral may be needed if tissue injury occurs.

Nerve injury

This is uncommon [42]. Peripheral or cranial nerves may be injured. The internal jugular vein is near the brachial plexus and the vagus. The subclavian vein is near the brachial plexus. In the upper arm, the median nerve is adjacent to brachial veins and the medial cutaneous nerves of forearms next to the

Table 4 Principles of infection prevention for vascular access.

For peripheral venous access:
- Thorough hand washing
- Non-sterile gloves
- Skin disinfection with 2% chlorhexidine in 70% alcohol
  For peripheral arterial access. As above but this will generally require sterile gloves to allow procedural palpation of the artery, and direct handling of needle, guidewire and catheter.

For central vascular access devices:
- Aseptic hand washing
- Sterile gown, gloves, hat, facemask
- Surface disinfection with 2% chlorhexidine in 70% alcohol (or povidone iodine in those sensitive to chlorhexidine), with air-drying
- Large sterile barrier drapes
- preference for upper extremity catheters

Once sited: appropriate anchorage and dressings; aseptic access techniques; daily site review; and removal at the earliest opportunity.

basilic vein. Ultrasound needle guidance should reduce such risks.

Infection control

The recent Michigan-Keystone project in 103 ICUs in the US reported major reductions in central venous catheter (CVC) bloodstream infections from 7.7 to 1.4 per 1000 CVC-patient days [49]. In the UK, the similar 'Matching Michigan' project resulted in a reduction from 3.7 to 1.5 infections per 1000 CVC-patient days over 20 months [50]. Recent guidelines provide comprehensive evidence-based recommendations to minimise such infections. Detailed recommendations on catheter selection, insertion site, anchorage and dressings, replacement, removal, management and personal protection can be found elsewhere [51, 52]. In the absence of actual or suspected infection, there is no evidence to support the routine changing of central venous catheters. Key messages are summarised in Table 4. Anaesthetists should compare their insertion techniques and use of devices with these standards.

Training and experience

Descriptions of the competency levels required for CVC insertion during training and assessment methods are listed in the current Anaesthesia and ICM Curricula (annex F, ICM in anaesthesia) (www.rcoa.ac.uk). Competencies for ultrasound guidance have been produced [53].

Current training includes: simulation based teaching (part-task trainers); apprenticeship models; and courses (local/national, basic/advanced).

The Working Party recommends:

- Phantom or manikin simulation techniques should be routinely available to improve novice technique.
- There should be regular training updates for skill retention, especially for procedures seldom performed (e.g. IO).

Consent and medicolegal aspects

Consent should follow local and national guidelines [54]. Written consent is usual for a standalone procedure or if particular risks are evident. The proposed side and route of access should be explained, as well as the potential need to move to other sites. In practice,

much will be verbal as part of a wider discussion of provision of anaesthesia or critical care. While any adverse event may lead to a complaint or litigation, certain serious complications are evident in closed claim analyses highlighted in the complications section [38–40]. Early recognition of the problem, referral to surgery or interventional radiology for help, and correct management of complications is essential for a safe outcome.

Use of in situ long-term devices

Many patients already have such devices in situ, e.g. Hickman tunnelled cuffed type, Groschong valved-type, dialysis catheters, peripherally inserted central catheters, and ports. With appropriate infection control, such devices can be used for resuscitation, anaesthesia or critical care. The risks/benefits of inserting additional CVCs should be assessed. Staff should learn about such devices and stock port access needles (Huber type).

Blood should be aspirated and discarded if concentrated heparin solution locks are in place. Fibrin sleeves may cause obstruction or an extravasation risk. Valved catheters preclude CVC pressure monitoring. Some devices are CT power-injection compatible (e.g. 325 psi rating).

Ultrasound guidance

This has been well covered in the literature. Recent consensus is that where the technology is affordable (e.g. in the UK), it should be used routinely for internal jugular CVCs (unless in emergency or other unusual situations), and early in other procedures (arterial and peripheral venous), if difficult [36]. Ultrasound makes many steps safer including: evaluation of puncture site; recognition of local pathology; avoidance of the use of seeker needles, needle guidance; verification of guidewire/catheters in a vessel; information on central tip position and recognition of complications.

Two recent Cochrane analyses [55, 56] concluded a benefit for using ultrasound for CVCs by the internal jugular vein, but not femoral or axillary/subclavian routes. The Working Party believe the latter is likely to relate to a lack of adequate studies, rather than an inherent failure of ultrasound at other sites, and recommends that ultrasound guidance should be used for

all routes of access where the vessel cannot be seen directly or palpated.

Operators need to be adequately trained and experienced, and use a high-resolution device. It takes considerable time and practice to become fully competent in such techniques, and national guidance on training has not quantified this [53].

Technology is moving quickly developing fast with smaller, cheaper, simpler to use, higher resolution machines. The efficacy and cost-effectiveness of echogenic needles, electromagnetic sensors, needle guides and other aids is at present unknown and should be a focus for future studies.

In the UK, given the wide availability of ultrasound, the Working Party believe it is not practical for staff to continue to be trained to become fully competent in all CVC landmark techniques. The only situations where ultrasound cannot be consistently used are extensive air emphysema and unavailability of a device in emergencies. An understanding of landmark techniques is useful for rare occasions when ultrasound is not available or not able to be used. Landmark techniques will still be used in countries where ultrasound is not available.

Service provision for vascular access

The Working Party suggests that all acute hospitals should provide the following for all age groups: local algorithms/guidance for recognition and management of complications; systems to improve procedures, training, documentation and equipment.

Anaesthetists may have a prominent role, but multiple disciplines are involved, depending on the organisation and treatments provided. Services can be nominally divided into acute and elective care as below.

Acute care

Hospitals should organise and provide the following:

1 Timely (24/7) reliable insertion of peripheral venous cannulae in all acute locations. This should not necessarily be the sole responsibility of resident medical staff.
2 Immediate insertion of peripheral IV or intra-osseous access is required in emergencies.
3 Timely (24/7) insertion of peripheral arterial cannula in specialised locations (high-dependency unit, ICU, theatres).
4 Timely (24/7) insertion of short-term CVCs in specialised locations (high-dependency unit, ICU, theatres).

Elective care

5 Hospitals must organise and provide the following: Timely (within 1–3 days) insertion (and removal) of long-term CVCs in specialised locations (wards, theatres, radiology) via a dedicated service. This has been highlighted in the context of total parenteral nutrition administration [4].

All acute hospitals will have requirements for long-term or repeated short-term central venous access, both in the NHS and independent sector. There are varied models dependent on local workload, including: theatre or radiology suite-based, either ad hoc in an acute setting or on separate standalone lists; ward-based models, e.g. nurse-led peripherally inserted central catheter service.

Facilities needed include: procedure room; high-resolution ultrasound; ECG guidance; fluoroscopy; radiographer; admitting, discharge and recovery areas. The cost-effectiveness of different models has not been studied in depth. Savings are possible by rationalising services, avoiding treatment delays, failed procedures, and facilitating hospital discharge and outpatient therapy.

Audit

The vascular access organisations, and individual practitioners, should initiate regular audit processes to assess compliance with the standards identified in this guidance. Specialist Societies and Colleges should consider national audit to set benchmarks (e.g. the NAP process).

Acknowledgements

Bard and B Braun for consultancy work/speaker fees. AK is the Editor-in-Chief of *Anaesthesia*, and this manuscript has undergone additional external review as a result.

References

1. Frykholm P, Pikwer A, Hammarskjöld F, et al. Clinical guidelines on central venous catheterisation. *Acta Anaesthesiologica Scandinavica* 2014; **58**: 508–24.
2. Task Force on central venous access. Practice guidelines for central venous access: a report by the American Society of Anesthesiologists. *Anesthesiology* 2012; **116**: 539–73.
3. Dariushnia SR, Wallace MJ, Siddiqi NH, et al. Quality improvement guidelines for central venous access. *Journal of Vascular and Interventional Radiology* 2010; **21**: 976–81.
4. NCepod. A Mixed Bag. An enquiry into the care of hospital patients receiving parenteral nutrition. http://www.ncepod.org.uk/2010report1/downloads/PN_report.pdf (accessed 24/08/2015).
5. Standards for infusion therapy. The Royal College of Nurses, 2010. http://www.bbraun.it/documents/RCN-Guidlines-for-IV-therapy.pdf (accessed 24/08/2015).
6. http://www.nrls.npsa.nhs.uk/patient-safety-data/organisation-patient-safety-incident-reports/ (accessed 17/10/2015).
7. Hove LD, Steinmetz J, Christoffersen JK, et al. Analysis of deaths related to anesthesia in the period 1996–2004 from closed claims registered by the Danish Patient Insurance Association. *Anesthesiology* 2007; **106**: 675–80.
8. NHS Injectable Medicines Guide. http://medusa.wales.nhs.uk/ (accessed 19/08/2015).
9. Heinrichs J, Fritze Z, Klassen T, Curtis S. A systematic review and meta-analysis of new interventions for peripheral intravenous cannulation of children. *Pediatric Emergency Care* 2013; **29**: 858–66.
10. Webster J, Osborne S, Rickard CM, New K. Clinically-indicated replacement versus routine replacement of peripheral venous catheters. *Cochrane Database Systematic Reviews* 2013; **30**: CD007798.
11. Bowman S, Raghavan K, Walker IA. Residual anaesthesia drugs in intravenous lines – a silent threat? *Anaesthesia* 2013; **68**: 557–61.
12. http://www.rch.org.au/uploadedFiles/Main/Content/anaes/a_procedural_guide_to_midline_insertion.pdf. (accessed 17/10/2015).
13. Anson JA. Vascular access in resuscitation. Is there a role for the intraosseous route? *Anesthesiology* 2014; **120**: 1015–31.
14. Shiloh AL, Savel RH, Paulin LM, Eisen LA. Ultrasound guided catheterization of the radial artery: a systematic review and meta analysis of randomized control trials. *Chest* 2011; **139**: 524–9.
15. Woodcock TE, Cook TM, Gupta KJ, Hartle A. Arterial line blood sampling: preventing hypoglycaemic brain injury. *Anaesthesia* 2014; **69**: 380–5.
16. Bishop L, Dougherty L, Bodenham A, et al. Guidelines on the insertion and management of central venous access devices in adults. *International Journal of Laboratory Hematology* 2007; **29**: 261–78.
17. O'Grady NP, Alexander M, Burns LA, et al. Guidelines for the prevention of intravascular catheter-related infections. *Clinical Infectious Diseases* 2011; **52**: e162–e193.
18. Parienti J-J, Mongardon N, Mégarbane, et al. Intravascular Complications of Central Venous Catheterization by Insertion Site. *New England Journal of Medicine* 2015; **373**: 1220–9.
19. Ge X, Cavallazzi R, Li C, Pan SM, Wang YW, Wang FL. Central venous access sites for the prevention of venous thrombosis, stenosis and infection. *Cochrane Database of Systematic Reviews* 2012; **3**: CD004084.
20. Gibson F, Bodenham A. Misplaced central venous catheters: applied anatomy and practical management. *British Journal of Anaesthesia* 2013; **110**: 333–46.
21. NICE medical technology guidance 2015 [MTG24]. The Sherlock 3CG Tip Confirmation System for placement of peripherally inserted central catheters. https://www.nice.org.uk/guidance/mtg24 (accessed 24/08/2015).
22. Hudman L, Bodenham A. Practical aspects of long-term venous access. *Continuing Education in Anaesthesia, Critical Care and Pain* 2013; **13**: 6–11.
23. Kander T, Frigyesi A, Kjeldsen-Kragh J, Kalsson H, Rolander F, Schott U. Bleeding complications after central line insertions: relevance of pre-procedure coagulation tests and institutional transfusion policy. *Acta Anaesthesiologica Scandinavica* 2013; **57**: 573–9.
24. Massicotte MP, Dix D, Monagle P, Adams M. Central venous catheter related thrombosis in children: analysis of the Canadian Registry of Venous Thromboembolic Complications. *Journal of Paediatrics* 1998; **133**: 770–6.
25. Miller DL, Vañó E, Bartal G, et al. Occupational radiology protection in interventional radiology: a Joint Guideline of the Cardiovascular and Interventional Radiology Society of Europe and the Society of Interventional Radiology. *Cardiovascular Interventional Radiology* 2010; **33**: 230–9.
26. Royal College of Radiologists. Standards for Intravascular Contrast Agent Administration in Adult Patients. Second Edition. https://www.rcr.ac.uk/sites/default/files/.../BFCR(10)4_Stand_contrast.pdf (accessed 24/08/2015).
27. Breschan C, Platzer M, Jost R, Stettner H, Likar R. Size of internal jugular vs subclavian vein in small infants: an observational, anatomical evaluation with ultrasound. *British Journal of Anaesthesia* 2010; **105**: 179–84.
28. Arul GS, Livingston H, Bromley P, Bennett J. Ultrasound-guided percutaneous insertion of 2.7Fr tunnelled Broviac lines in neonates and small infants. *Pediatric Surgery International* 2010; **26**: 815–8.
29. Medicines and Healthcare products Regulatory Agency, UK. Chlorhexidine solutions: reminder of the risk of chemical burns in premature infants. www.mhra.gov.uk/Safetyinformation/DrugSafetyUpdate/CON468292 (accessed 17/10/2015).
30. Gallagher RA, Levy J, Vieiraet RL, et al. Ultrasound assistance for central venous catheter placement in a pediatric emergency department improves placement success rates. *Academic Emergency Medicine* 2014; **21**: 981–6.
31. Nolan JP, Smith RN. Central venous catheters. *British Medical Journal* 2013; **347**: f6570.
32. Morano SG, Coppola L, Latagliata R, et al. Early and late complications related to central venous catheters in haematological malignancies: a retrospective analysis of 1102 patients. *Mediterranean Journal Hematological Infectious Diseases* 2014; **6**: e2014011.
33. NHS England patient Safety Domain. National Safety Standards for Invasive Procedures 2015. https://www.england.nhs.uk/patientsafety/never-events/natssips/ (accessed 08/01/2016).

34. Pikwer A, Akeson J, Lindgren S. Complications associated with peripheral or central venous routes for central venous cannulation. *Anaesthesia* 2012; **67**: 65–71.

35. Akl EA, Ramly EP, Kahale LA, et al. Anticoagulation for people with cancer and central venous catheters. *Cochrane Database of Systematic Reviews* 2014; **10**: CD006468.

36. Lamperti M, Bodenham AR, Pittiruti M, et al. International evidence-based recommendations on ultrasound-guided vascular access. *Intensive Care Medicine* 2012; **38**: 1105–17.

37. Reuber M, Dunkley LA, Turton EP, Bell MD, Bamford JM. Stroke after internal jugular venous cannulation. *Acta Neurologica Scandinavica* 2002; **105**: 235–9.

38. Domino KB, Bowdle TA, Posner KL, Spitellie PH, Lee LA, Cheney FW. Injuries and liability related to central vascular catheters. A closed claims analysis. *Anesthesiology* 2004; **100**: 1411–8.

39. Pikwer A, Acosta S, Kolbel T, Malina M, Sonesson B, Akeson J. Management of inadvertent arterial catheterisation associated with central venous access procedures. *European Journal Vascular and Endovascular Surgery* 2009; **38**: 707–14.

40. Bodenham A. Reducing major procedural complications from central venous catheterisation. *Anaesthesia* 2011; **66**: 6–9.

41. Peris A, Zagli G, Bonizzoli M, et al. Implantation of 3951 long-term central venous catheters: performances, risk analysis, and patient comfort after ultrasound-guidance introduction. *Anesthesia and Analgesia* 2010; **111**: 1194–201.

42. Nayeemuddin M, Pherwani AD, Asquith JR. Imaging and management of complications of central venous catheters. *Clinical Radiology* 2013; **68**: 529–44.

43. Stuart RK, Baxter JK, Shikora SA, et al. Reducing arrhythmias associated with central venous catheter insertion or exchange. *Nutrition* 1992; **8**: 19–21.

44. Abdel-Aal AK, Saddekni S, Hamed MF. Guide wire entrapment in a vena cava filter: techniques for dislodgement. *Vascular and Endovascular Surgery* 2012; **47**: 115–23.

45. NHS England, Never Events List 2015/16. www.england.nhs.uk/wp-content/.../03/never-evnts-list-15-16.pdf. (accessed 24/08/2015).

46. Wu C, Fu J, Feng P, et al. Catheter fracture of intravenous ports and its management. *World Journal of Surgery* 2011; **35**: 2403–10.

47. Lopez-Briz E, Ruiz Garcia V, Cabello JB, Bort-Marti S, Carbonell Sanchis R, Buris A. Heparin versus 0.9% sodium chloride intermittent flushing for prevention of occlusion in central venous catheters in adults. *Cochrane Database of Systematic Reviews* 2014; **10**: CD008462.

48. Van Miert C, Hill R, Jones L. Interventions for restoring patency of occluded central venous catheter lumens. *Cochrane Database of Systematic Reviews* 2012; **4**: CD007119.

49. Pronovost P1, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *New England Journal of Medicine* 2006; **355**: 2725–32.

50. Bion J1, Richardson A, Hibbert P, et al. 'Matching Michigan': a 2-year stepped interventional programme to minimise central venous catheter-blood stream infections in intensive care units in England. *British Medical Journal Quality Safety* 2013; **22**: 110–23.

51. Loveday HP, Wilson JA, Pratt RJ, et al. EPIC 3: national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England. *Journal of Hospital Infection* 2014; **86**: S1–S70.

52. Association of Anaesthetists of Great Britain and Ireland. Infection Control in Anaesthesia. *Anaesthesia* 2008; **63**(1027–3): 6.

53. Moureau N, Lamperti M, Kelly LJ, et al. Evidence-based consensus on the insertion of central venous access devices: definition of minimal requirements for training. *British Journal of Anaesthesia* 2013; **110**: 347–56.

54. AAGBI. Consent for Anaesthesia 2006. www.aagbi.org/sites/default/files/consent06.pdf (accessed 24/08/2015).

55. Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF. Ultrasound guidance versus anatomical landmarks for internal jugular vein catheterization. *Cochrane Database of Systematic Reviews* 2015; **1**: CD006962.

56. Brass P, Hellmich M, Kolodziej L, Schick G, Smith AF. Ultrasound guidance versus anatomical landmarks for subclavian or femoral vein catheterization. *Cochrane Database of Systematic Reviews* 2015; **1**: CD011447.