Chapter

12

Vascular Access in Children

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Introduction

A substantial proportion of children will require vascular access at some time during their lives. This may be for resuscitation within minutes of being born, for intravenous antibiotics as an infant or perhaps to administer repeat courses of chemotherapy for treatment of leukaemia. This chapter will outline the routes available for vascular access, the factors influencing the choice of catheters and devices used and their associated complications. Choosing the most appropriate site and type of vascular access must be specific to each child and to their treatment requirements (see Table 12.1). The publication of 'The Michigan Appropriateness Guide for Intravenous Catheters in Pediatrics: miniMAGIC' in 2020 (see 'Further Reading') was a significant moment in paediatric vascular access. Evidence suggests that implementation of the adult version (MAGIC) published in 2015 has led to a significant reduction in inappropriate use, patient harm and costs associated with vascular access devices. It is hoped that miniMAGIC will have the same effect in children and encourage research into areas where evidence is limited.

The correct care of vascular access devices during and following insertion is extremely important and will have a major impact on functioning of the catheter as well as reducing potentially life-threatening complications. The use of care bundles incorporating evidence-based measures greatly reduces both infective and non-infective complications.

Peripheral Intravenous Catheters and Midline Catheters

Short-term peripheral intravenous access is widely used in children of all ages. Short peripherally inserted intravenous catheters (PIVC) can be used for drug delivery, fluid infusion and blood sampling.

Table 12.1 Types of vascular catheters

Catheter type	Entry site	Duration of use
Peripherally inserted venous catheter (PIVC)	Veins on hands, feet and forearms. Scalp veins in infants.	72–96 hours
Midline catheter	Basilic or cephalic veins at the antecubital fossa. Tip of catheter stops short of axillary vein.	Up to 28 days
Peripherally inserted central venous catheter (PICC)	Basilic or cephalic veins at the antecubital fossa. Long saphenous vein in infants. Tip of catheter in central vein.	Weeks to months
Umbilical catheter	Umbilical vein used within 1 week of birth.	Up to 14 days
Non-tunnelled central venous catheter	Percutaneous insertion into internal jugular, subclavian or femoral veins.	Days to weeks
Tunnelled central venous catheter	Subcutaneous tunnel with cuffed catheter into central vein.	Months to years
Totally implantable device	Port positioned on chest wall, abdomen or forearm with subcutaneous tunnelled access to central vein.	Months to years
Intraosseous cannula	Proximal anterior tibia. Distal end of femur. Medial malleolus	Up to 24 hours

Total parenteral nutrition (TPN) of sufficiently low osmolarity and non-vesicant chemotherapy can also be given via this route. PIVCs are usually sited into small veins on the hands, forearms, feet and scalp in infants. Catheters inserted over joints tend to cause more discomfort and are more prone to phlebitis, thrombosis and dislodgement. Larger veins at the antecubital fossa should be preserved if a subsequent midline catheter or a peripherally inserted central catheter (PICC) is anticipated. In neonates, the long saphenous veins at the ankle or knee may also be required for PICC insertion at a later date.

Peripheral Intravenous Catheters (PIVC)

Traditionally, peripheral catheters were used for only 72–96 hours, but insertion duration alone is not grounds for removing a functioning catheter if there is no evidence of phlebitis and it is still clinically required. PIVCs are short (2.5–7 cm) catheter over needle devices available in a wide variety of diameters (14–26G) and materials (Teflon™ and polyurethane). The choice of catheter size depends on the diameter of the intended vein and also the flow requirements. In general, small catheters cause less phlebitis, both chemical and mechanical, are more comfortable and last longer. Children requiring peripheral venous access require skilled management involving age-appropriate behavioural techniques and suitable analgesia. Poorly managed pain during cannulation causes distress at the time, more pain during future episodes and long-term phobic behaviour. Topical anaesthesia, using a eutectic mixture of local anaesthetics (EMLA™, topical tetracaine 4% gel (Ametop®) or lidocaine 4% cream (LMX 4®), is effective if given sufficient time to work, although the removal of the occlusive plastic dressings can cause significant distress. EMLA™ should not be used in preterm neonates or any other children at risk of methaemoglobinaemia. Needleless injection systems of ionised lidocaine (J-tip) are available that have the advantage of almost instant analgesia and compare favourably with EMLA. Ethyl chloride spray is effective, but its flammability precludes its use in environments with electrical equipment. Nitrous oxide (Entonox) has also been used successfully for pain control during cannulation. In difficult cases, the use of real-time ultrasound or a near-infrared or LED light device has been shown to improve success rates and decrease insertion times.

Midline Catheters

These are longer, soft, peripheral catheters made of polyurethane or silicone, usually 3 or 4 French gauge (Fr) in diameter. They are inserted into the cephalic or basilic veins at or just above the antecubital fossa through a specific micro-introducer kit, which has a sheath that is peeled apart to leave the catheter in the vein. The midline catheter is cut to the correct length and should be positioned to stop short of the axillary vein. Midline catheters cause less chemical phlebitis than peripheral catheters and hence may be used for up to four weeks. The same restriction on the osmolarity of the infusate applies.

Complications

The commonest complication of PIVCs is phlebitis. This presents as redness, swelling, induration and pain around the insertion site of the catheter and necessitates removal. Phlebitis is an inflammatory reaction that is not primarily an infective process, although secondary infection may occur. The incidence of catheter-related blood infection (CRBI) from peripheral catheters is about 0.2–0.5 per 1,000 catheter days. Midline catheters have a lower infection rate of around 0.1–0.2 per 1,000 catheter days. Subcutaneous extravasation of infusate is another common complication with PIVCs. This is a particular problem in neonates, where the incidence may be as high as 90%. Serious tissue damage with subsequent scarring may occur, especially with TPN and calcium-containing infusates. Rapid identification of the extravasation and treatment with injection of hyaluronidase (500–1,000 units) and 0.9% saline irrigation can prevent tissue loss. All hospitals should have a readily accessible protocol for the acute management and follow-up of extravasation injuries. Significant venous thrombosis is rare with PIVCs. Catheter fracture and air embolism are also rare but potentially serious complications.

Peripherally Inserted Central Catheters (PICC)

PICCs are small diameter catheters (1.2–5 Fr) made of silicone or polyurethane. The larger catheters may have two or three lumens to allow separation of incompatible infusates. PICCs allow access to the central circulation without exposing the patient to some of the serious insertion

complications of direct approaches to the central veins. The dilution of the infusate by the larger volume of blood in the central veins makes them suitable for the administration of TPN and hypertonic solutions. They are also useful in the presence of coagulopathies and low platelet count, as bleeding at the insertion site is rarely a serious problem and usually responds to direct pressure. Local infection and venous thrombosis proximal to the insertion site are contraindications to PICC insertion.

PICCs are most commonly inserted percutaneously into the cephalic, basilic or brachial veins in the arm. The long saphenous vein at the ankle or knee or the superficial temporal vein can be used in neonates and infants. Lower limb insertion sites in neonates have been shown to prolong catheter function and decrease overall complications when used for TPN. Real-time ultrasound is useful and allows the basilic and brachial veins to be accessed above the antecubital fossa. The insertion kits are similar to that of midline catheters, incorporating a split sheath introducer or splitable needle for the smallest catheters. The vein can be accessed by direct cannulation or by fine needle access and the use of a Seldinger wire microintroducer set. Most PICCs are cut to length prior to insertion using surface landmarks for the final tip position. Groshong^{TM} PICCs have a special valve near their tip that allows fluid to be injected or aspirated but is closed when not in use and hence must be cut to length at the hub end.

The tip of the PICC ideally is positioned in the lower third of the superior vena cava (SVC) from upper limb veins or in the proximal inferior vena cava (IVC) from the long saphenous vein. The use of surface landmarks with blind insertion results in a satisfactory tip position in only about 15% of cases. With fluoroscopic guidance, this can be increased to 90%. If fluoroscopy is not used, a post-insertion chest radiograph must be performed to verify tip position. Newer electrocardiogram (ECG) tip position confirmation systems can be used to navigate and track the tip of catheters to the low SVC. These are very accurate, but their current license in children requires a post-insertion chest radiograph. If the tip is in the right atrium, it must be withdrawn to avoid atrial perforation and cardiac tamponade, which has a mortality rate of over 80%. This is a particular concern in neonates having TPN or hypertonic glucose infusions and was the subject of a warning from the UK Department of Health in 2001. The PICC tip can be advanced significantly by adduction of the arm, and this may precipitate serious cardiac dysrhythmias. A non-central tip position markedly increases the risk of vessel thrombosis. The reported incidence of thrombosis associated with PICCs varies widely, from around 4% if clinical signs are used to up to 25% with surveillance venography. The cephalic venous system is reported to have a much higher thrombosis rate than the basilic system, probably owing to its tortuous course. Thrombus formation at the tip of the PICC can cause blockage requiring removal. This is a particular problem in neonates due to the small diameter of the catheters used. A continuous infusion of heparin at 0.5 IU kg^{-1} h^{-1} significantly reduces catheter occlusion. Another common problem is when the catheter flushes well, but blood withdrawal is not possible; this is known as a partial withdrawal occlusion (PWO). In these cases, the instillation of thrombolytics such as urokinase may restore function and avoid premature catheter removal.

The incidence of CRBI for outpatient PICCs is around 1.0 per 1,000 catheter days. For inpatient PICCs, the rate of infection is much higher at about 2.1 per 1,000 catheter days. Other serious complications of PICCs include catheter fracture with associated catheter or air embolism. Catheter rupture is associated with the flushing of small catheters with syringes smaller than 10 ml, as these can generate extremely high pressures. There are now PICCs available made of material with sufficient strength to be used for contrast injection for computed tomography (CT) scans. These CT-compatible PICCs remove the need for additional venous access for scans, as they are more resistant to fracture.

Umbilical Vein Access

Central venous access in the newborn can be gained via the umbilical vein immediately after birth and for the first few days of life. The umbilical vein is a single, large, thin-walled vessel compared with the smaller paired muscular umbilical arteries. It gives off several large intrahepatic branches before converging with the left portal vein and continuing as the ductus venosus. This joins the IVC with the hepatic vein. An understanding of the anatomy of the umbilical vein is crucial for avoiding some of the

more serious complications associated with the use of an umbilical vein catheter (UVC).

When a UVC is used for immediate resuscitation of a neonate at birth the position of the tip cannot be verified radiologically before use, and this is the only indication for a low catheter. With the umbilicus cut to 1–2 cm the tip must not be advanced beyond 3–5 cm below the skin to avoid intrahepatic placement. UVC tips positioned within the liver have been associated with liver abscess, liver necrosis and hepatic vein thrombosis leading to portal hypertension. UVCs in the portal venous system have been implicated in causing colonic perforation and necrotising enterocolitis. UVCs should not be inserted in the presence of omphalitis, an omphalocele or peritonitis.

For elective catheter placement the ideal tip position is just above the diaphragm in the IVC below the right atrium. There are graphs and formulae available to estimate catheter length based on umbilical to shoulder distance and weight. On a chest radiograph, the catheter should be visible just to the right of the vertebral column at the level of T9–10 vertebrae above the diaphragm. Malpositioned catheters can cause cardiac perforation, cardiac arrhythmias, thrombotic endocarditis and pulmonary infarction. Great care must be taken to avoid air embolism when inserting and using UVCs because of the negative pressure in the thorax during inspiration. Haemorrhage from the umbilical stump can be a problem at insertion. This is best controlled by a circular ligature around the umbilical stump, which is subsequently released to avoid necrosis.

There are both single- and double-lumen UVCs available between 3.5 and 5 Fr in size. Double lumen catheters decrease the need for additional venous access and are not associated with a significant increase in complications. Catheters with side holes should be avoided unless being used specifically for exchange transfusion as they have a higher incidence of thrombotic complications. Correctly sited high UVCs can be used for blood sampling, drug and fluid administration, TPN and hyperosmolar infusates. They can also be used for measuring central venous pressure (CVP).

Infection of UVCs occurs in up to 15% of patients and is related to prematurity, insertion duration and catheter handling. Prophylactic antibiotics do not seem to have a role in preventing infection. As well as a cause of general sepsis, infected UVCs can also cause widespread infective emboli. Transfer of infective emboli between the venous circulation and the systemic circulation can occur through a patent foramen ovale. UVCs should be removed as soon they are no longer required and should not be left in place for more than 14 days.

Short-Term Central Venous Access

Secure access to the central venous system is often required during major surgery and during admissions to intensive care. This is usually provided by short- term non-tunnelled central venous catheters (CVC) made of a relatively stiff material such as polyurethane with a wide choice in diameter (3–8.5 Fr), length and number of lumens (one to five). The choice of catheter type and insertion site is determined by balancing the clinical need against the risk of insertion complications. Multiple lumen catheters are useful for drug infusions, especially if inotropic support is required. They also facilitate the measurement of CVP and venous blood sampling. Larger-diameter catheters should be used if rapid fluid administration is required as the flow is proportional to the fourth power of the radius. The length of the catheter is dependent on the size of the child and the insertion site. The tip of these short-term catheters must be in either the IVC or the SVC. Because of the risk of cardiac perforation, the tip must not lie within the heart. For short-term haemodialysis and haemodiafiltration, there are special large bore double lumen catheters that are designed for high flow rates without causing haemolysis.

Access to the central venous circulation is associated with an increased risk of bleeding both during catheter insertion and at the time of removal. The platelet count should be known prior to insertion and a clotting screen performed if there is a risk of coagulopathy. Traditionally a platelet count of greater than $50 \times 10^9\,l^{-1}$ has been used as a safe level, but there are studies of CVC insertions with platelet counts as low as $20 \times 10^9\,l^{-1}$ without any significant increase in haemorrhagic complications.

The most common insertion sites for short-term CVCs are:

- The femoral vein
- The internal jugular vein
- The external jugular vein
- The subclavian vein

For multi-lumen catheters, the Seldinger technique is utilised. Most catheter insertion kits have a J-tip Seldinger wire. In neonates and infants, the radius of the J-tip may be greater than the diameter of the vein, impeding advancement of the wire; often the other end of the wire is a soft straight tip, which may be easier to insert.

It is recommended that all short-term central catheters are connected to a pressure transducer to exclude arterial placement. This should be done prior to dilation of the vein if there is any suspicion of arterial puncture. Blood gas analysis is not helpful to differentiate between arterial and venous placement, especially if the child is hypoxic or supplementary oxygen is being administered. Full asepsis should be used during insertion.

Femoral Vein

This is the most common site for short-term central venous access in children. The femoral approach has the major advantage of consistent anatomy with the vein found medial to the femoral artery and accessed below the inguinal ligament. There is no risk of pneumothorax in contrast to insertion sites in the neck. The major insertion complication is arterial puncture, which occurs in up to 10% of insertions using surface landmarks and femoral arterial pulsation as guidance. The use of ultrasound significantly reduces arterial puncture rates and decreases the number of insertion attempts. Bleeding from attempts at femoral venous access is usually easily controlled by digital pressure, but there are reports of substantial retroperitoneal bleeding causing cardiovascular collapse. The femoral vein is the preferred site for short-term haemodialysis catheters owing to the straight course of the femoral vein to the IVC. It is also the best route for CVC insertion during emergency resuscitation, as cardiopulmonary massage does not have to be interrupted during placement.

Internal Jugular Vein

This is the next most common site to be used for short-term CVCs. It requires a higher level of technical expertise and practice compared with the femoral route. The anatomy of the internal jugular vein is more variable than that of the femoral vein. The relationship of the vein to the common carotid artery changes with age:

- In most infants, the vein either partially or completely overlies the artery at the level of the cricoid cartilage; rotating the head away from the midline increases the incidence of overlap.
- In older children and adults, there is substantial variation in position of the vein.
- In up to 5% of adults, the internal jugular vein lies medial to the common carotid artery, contrary to traditional teaching.

The use of the common carotid artery as a landmark for CVC insertion is therefore potentially flawed in many patients, and arterial puncture rates are between 5% and 15%. The dome of the lung lies posterior to the vein in the neck, and this approach is associated with pneumothorax rates of around 0.5–1%. The use of ultrasound significantly reduces arterial puncture, improves success rates and decreases insertion duration. Ideally, ultrasound should be used for visualisation during insertion rather than only for pre-insertion orientation. In the United Kingdom, National Institute for Health and Care Excellence (NICE) has recommended that ultrasound be used for every elective CVC insertion into the internal jugular vein in both adults and children. The size of the internal jugular vein can be increased by a head-down position, Valsalva manoeuvre or hepatic compression. The right internal jugular vein has a much straighter course to the SVC than the left side and is the preferred route. The left internal jugular vein should be avoided in children with a persistent left SVC as this usually drains to the coronary sinus.

External Jugular Vein

This is more superficial than the internal jugular vein, although it is extremely variable in size and position. It can be used for short-term CVCs. Advancing a Seldinger wire down the vein through the clavi-pectoral fascia into a central vein can be problematic, and hence it is not often used for this purpose. The risk of pneumothorax is small but not negligible with this approach.

Subclavian Vein

This is the continuation of the axillary vein from the upper limb. It becomes the subclavian vein at the outer border of the first rib and then arches up over the rib in front of the lung, anterior to and slightly below the subclavian artery. It joins the internal jugular vein to form the brachiocephalic vein and

then combines with the opposite brachiocephalic vein to form the SVC. The clavicle overlies the subclavian vein for a substantial part of its extrathoracic course. From this description of the anatomy, it can be seen that the vein is a deep structure in close proximity both to the lung and subclavian artery. It cannot be visualised easily with ultrasound due to the overlying clavicle. Accessing the subclavian vein percutaneously requires a high degree of skill and expertise, and it is the approach associated with the highest failure rate. Of note:

- Damage to the vein or artery is not easily amenable to external pressure, and catastrophic bleeding can occur, especially if the blood collects in the pleural cavity.
- Pneumothorax rates are between 0.5% and 2% for this approach. The space between the clavicle and first rib is narrow in infants and small children and restricts the size of the catheter used.
- It can be difficult to dilate the tract to the vein, and pinching of the catheter can occur, causing pain, catheter malfunction and catheter damage.
- Because of the angle of entry of the subclavian vein into the thoracic cavity, the Seldinger wire is required to negotiate a 90° corner to enter the SVC. This can result in wire misplacement in around 10% of insertions with final catheter tip position in the opposite subclavian vein or either of the internal jugular veins. A chest radiograph should always be performed to verify catheter tip position.

Short-term non-tunnelled CVCs are extremely useful in critically ill children but are associated with many complications (see Table 12.2). The most common delayed complications are CRBI and venous thrombosis. Bloodstream infection rates are 3.4–11.3 per 1,000 catheter days, depending on the pre-existing patient risk factors. Children with burns and neonates less than 1,000 g are at the highest risk of CRBI. In children, there is not a great difference between infection rates at different insertion sites as opposed to adults, where the femoral route has a much higher infection rate. Thrombosis of the vein or around the catheter can occur in 2–35% of patients. In children with diabetic ketoacidosis, the use of the femoral vein for CVCs has been associated with a thrombosis incidence of around 50%, so this route should probably be avoided in these patients if possible. The recorded incidence is much higher if active surveillance is undertaken rather than relying on clinical signs. The presence of a catheter in a small vein may cause venous congestion of the distal venous system. This is particularly noticeable in neonates and infants with femoral catheters.

Table 12.2 Complications of percutaneous central venous catheter insertion

Immediate (usually within 24 hours)	Long term
Pneumothorax	Local infection at insertion site
Haemothorax	Bloodstream infection
Haemopneumothorax	Venous thrombosis and occlusion
Hydrothorax secondary to fluid	Arterio-venous fistula infusion
Chylothorax secondary to thoracic duct damage	Arterial false aneurysm formation
Arterial puncture with local haemorrhage	
Arterial endoluminal damage with flap occlusion	
Arterial thrombosis	
Arterial embolism	
Damage to great veins with massive haemorrhage	
Local haemorrhage at insertion site	
Cardiac perforation with tamponade	
Pericardial effusion	
Cardiac arrhythmias	
Pneumomediastinum	
Air embolism	
Catheter embolism	
Wire embolism	

Long-Term Central Venous Access

Some children will require central venous access for a period longer than a month. Consideration should be given early in their treatment to the

insertion of a long-term central venous access device to avoid the trauma, both physical and emotional, of multiple short-term catheters. Cytotoxic chemotherapy, prolonged antibiotic therapy and parenteral nutrition are the most common indications in children. The devices used for long-term access are divided into skin-tunnelled catheters (STC) and implantable injection ports.

These catheters are usually made of soft silicone but can be made of polyurethane. Polyurethane catheters are stiffer, hence can have a larger lumen with the same external diameter allowing higher flow rates. They do not soften as much as silicone catheters in the blood at body temperature and thus are associated with a higher incidence of thrombosis, although this is less so with third-generation polyurethane catheters. The catheters may be open-ended or have a valve system such as the Groshong™ two-way valve.

Long-Term Skin-Tunnelled Catheters

These have a Dacron™ cuff that is situated in the subcutaneous tunnel 3–4 cm from the exit site. Subcutaneous tissue grows in and around the cuff over a period of a few weeks. This secures the catheter in place, so no other external fixation is required. It also acts as a barrier to infective agents ascending the tunnel to cause bloodstream infections. The catheters may be single lumen, such as the small Broviac™ catheters (2.7 or 4.2 Fr) or larger double or triple lumen Hickman/Leonard™ style catheters (7–12 Fr).

Implantable Ports

These are made of plastic or titanium so that they are MRI compatible (see Figure 12.1). The port is usually placed in a pocket fashioned on the chest wall and secured to the fascia with non-absorbable sutures to avoid rotation in the pocket. Less commonly, the port can be sited on the forearm or the upper abdomen. The port is attached to a tunnelled subcutaneous catheter (6–10 Fr) and is accessed percutaneously with a special Huber-type needle. This has a non-cutting atraumatic tip with a side hole to avoid damaging the diaphragm of the port. Ports are available as either high or low profile to aid palpability with varying thickness of subcutaneous tissue. Double-lumen ports are available, but they are rarely used in children. The implantable port system has the advantage of being a sealed system once the percutaneous needle is removed. They are associated with less local and systemic infection, and the child can swim and bathe freely when the port is not accessed.

Skin-tunnelled catheters are better for more intensive treatments, such as bone marrow transplantation, when multiple lumens are required. They are also preferred in needle-phobic children, as accessing an implantable port is not completely painless even with local anaesthetic creams. In children less than one year of age and in those with very little subcutaneous fat, there is a higher incidence of skin erosion over the port site; skin-tunnelled catheters may be more suitable in these cases.

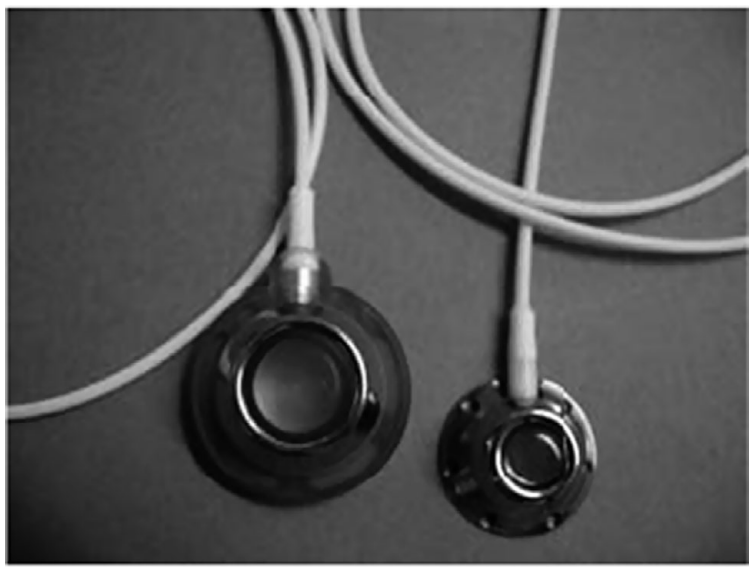

Figure 12.1 Portacath for long-term vascular access.

Insertion

Long-term catheters can be inserted either by open surgery or by a percutaneous technique and will require fluoroscopic support. Most children will require general anaesthesia for a port or tunnelled catheter insertion, although some older children will tolerate a percutaneous insertion with sedation and local anaesthesia. Open surgery can be used for accessing the internal and external jugular veins as well as the femoral vein. The subclavian vein is not suitable for open access. For the internal jugular and femoral veins, the catheter is inserted through a venotomy under direct vision with the vessel controlled between two vascular slings. The external jugular vein can be divided and tied off with the soft catheter threaded down the proximal segment.

For percutaneous insertion, access to the vein is identical to that for short-term catheters with the use of a Seldinger wire and ultrasound when using the internal jugular or femoral vein. The subclavian vein can also be accessed with the percutaneous technique, but due to the narrow space between the clavicle and first rib, the child usually needs to be above 20 kg for catheters of 7 Fr and larger. Whichever percutaneous insertion site is chosen, the position of the Seldinger wire should be confirmed with fluoroscopy prior to dilation. The catheter is then tunnelled up from the exit site for Hickman/Broviac lines or from the subcutaneous port site to a position next to the Seldinger wire. An integral vein dilator and peel-away sheath are inserted over the Seldinger wire, with great care being taken not to push the stiff dilator in too far or beyond the end of the wire. Serious damage to the mediastinum or heart with fatal consequences can occur if this system is misused. The wire and dilator are removed to leave the sheath in the vein. The soft catheter is inserted via the sheath, which is then peeled away, leaving the catheter in the vein. It is possible for large quantities of blood or air to flow rapidly through the peel-away sheath if the lumen is not well controlled.

The ideal position for the catheter tip of soft, long-term catheters is still controversial. There have been rare reports of cardiac perforation in neonates having TPN infusions with the tip positioned within the right atrium. In larger children, this is much less of a concern, and the catheters tend to function better if the tip is placed in the upper-right atrium. The catheter can be cut to length using the intermammary line as the surface landmark for the right atrium. A better technique for use with the Seldinger wire is to position the tip of the wire in the desired position, confirmed by fluoroscopy. The amount of wire on the exterior is then measured and deducted from the known length of the wire (usually 50 cm) to give the exact length for the catheter to be cut. This technique cannot be used for Groshong™ tip catheters, which are tunnelled backwards from the insertion site to the exit site or port. Fluoroscopy should always be used to confirm the final position of the catheter tip. It is not necessary to routinely perform a chest radiograph after insertion if fluoroscopy has been used, as this exposes the child to unnecessary radiation. A chest radiograph should be performed if there are any cardiorespiratory symptoms or signs postoperatively.

The insertion complications for long-term catheters are similar to those outlined for short-term catheters (see Table 12.2), with the addition of vascular damage and haemorrhage that can occur with any open surgery. The major long-term complications are CRBI, venous thrombosis and catheter malfunction. The incidence of CRBI for long-term venous catheters is around 1.5–3 per 1,000 catheter days for Hickman-type catheters and around 0.1–1 per 1,000 catheter days for implanted ports. There is no evidence that the use of prophylactic antibiotics at the time of insertion decreases the risk of infection.

The intravascular portion of a long-term catheter is rapidly covered in a fibrin sheath that can occlude the catheter tip. This can cause infusate to track back along the catheter and cause subcutaneous extravasation despite the catheter being intact. This can be confirmed by injection of X-ray contrast solution with fluoroscopy. Fibrin sheath or thrombus formation at the catheter tip or in the catheter lumen can sometimes be dissolved by fibrinolytic therapy. This involves the instillation of urokinase 5,000 IU ml^{-1} or alteplase 1 mg ml^{-1} into the dead space of the blocked lumen using a negative pressure technique. A three-way tap is connected to the catheter, and an empty 10 ml syringe used to generate a negative pressure within the lumen. The tap is then opened to the syringe containing the fibrinolytic agent, which is aspirated into the lumen by negative pressure and left in place for two to four hours or overnight. The catheter must then be carefully aspirated to

remove any clots or remaining fibrinolytic agent prior to being flushed with saline or heparinised saline, depending on hospital policy. This procedure can be repeated if necessary, but if it is not successful the catheter should be removed. Massive thrombus formation can occur at the catheter tip, within the central veins or in the right atrium. This may present as pulmonary emboli, vena cava obstruction or cardiac insufficiency. The diagnosis is confirmed by ultrasound or echocardiogram. It can usually be treated effectively with systemic anti-coagulation and catheter removal, but occasionally cardiac surgery for open removal is required.

Care Bundles for Venous Catheters

CRBI is a major source of morbidity and mortality in hospitalised patients, with a substantial social and economic cost. Additional hospital expenses in the United Kingdom related to a patient acquiring a CRBI have been estimated at over £15,000. Bloodstream infections account for around 6% of all hospital infections, with an estimated 42.3% of these being related to central venous catheters. Confirmation of CRBI requires the same organism to be isolated from peripheral blood culture as well as from the device in a patient with clinical signs of bacteraemia. Colonisation of venous catheters is present when an organism can be isolated from the internal lumen or the subcutaneous external surface of the catheter in the absence of clinical signs of bacteraemia. The micro-organisms that colonise venous catheters are responsible for most CRBI, with contamination occurring at the time of insertion or by migration along the catheter track. Contamination can also occur by the transfer of micro-organisms during handling of the catheter hubs. Catheter colonisation and infection by haematogenous spread from distant sites is thought to be rare. A 2006 UK prevalence study showed that coagulase-negative staphylococci were the most commonly isolated organism from all types of intravenous catheters (35%). Staphylococcus aureus was the second most common (25%), with methicillin-resistant organisms (MRSA) accounting for 40–45% of these infections. Candida species and enterococci are also common infective agents causing CRBI.

An evidence base compiled over the past few years resulted in the publication in 2014 of updated guidelines 'EPIC3: National Evidence-Based Guidelines for Preventing Healthcare-Associated Infections in NHS Hospitals in England'. These guidelines have been used to produce care bundles for both central venous catheters and peripheral intravenous cannulae ('NHS Improvement 2017 and Department of Health 2007, High Impact Interventions'; see Appendices 1 and 2). The concept of a care bundle is that it brings together all the scientifically based interventions that, when used together, improve clinical outcome. The care bundles are divided into insertion actions and ongoing care actions and are designed to be used in their entirety; assessment of compliance requires all elements to be completed for each patient. For these to be successful, there must be a proactive education programme for all staff involved in the care of intravenous catheters.

Concern has been raised that the use of care bundles has led to earlier removal of CVCs and increased use of peripheral venous cannulae on ICUs when patients still require venous access. This may be associated with an increased risk of phlebitis and subsequent CRBI. It is very important that peripheral cannulae are inspected daily and assessed for phlebitis using a visual infusion phlebitis (VIP) score as part of the ongoing care action. A VIP scoring system is invaluable in recording the daily state of peripheral cannula insertion sites (see Appendix 3).

Intraosseous Access

Obtaining vascular access in emergency paediatric resuscitation can be extremely difficult due to collapsed small veins, which may be impossible to visualise because of overlying fat. This is frequently the case in infants with septic shock and trauma. The tracheal route offers an alternative emergency route for drug administration but requires the child to have a tracheal tube in situ. The absorption of drugs administered via the tracheal route is variable, and the amount of fluid permitted by this route is limited. The highly vascularised intraosseous (IO) space functions as a non-collapsible vein into which nearly all resuscitation drugs and unrestricted volumes of fluids can be infused.

The insertion of an IO cannula is painful, and if the child is not unconscious then local anaesthesia should be used. The best anatomical insertion site is the anteromedial aspect of the proximal tibia

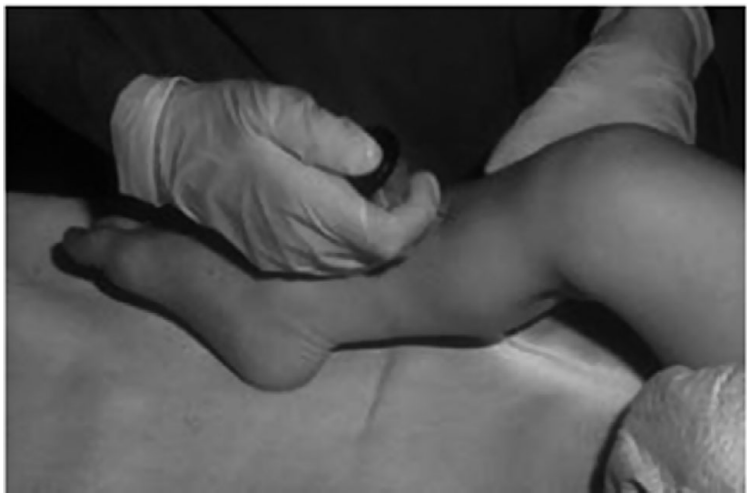

Figure 12.2 Intraosseous needle insertion on the antero-medial aspect of the proximal tibia.

2–3 cm below the tibial tuberosity (see Figure 12.2). The tip of the needle should be directed away from the growth plate. Other insertion sites are the distal end of the femur 3 cm above the lateral condyle and the medial malleolus at the ankle. The sternum is not recommended in children. Contraindications to IO access are a proximal fracture or severe soft tissue injury; in these cases, the contralateral side should be used. A history of osteogenesis imperfecta or osteoporosis is associated with a higher risk of bone fracture.

There are commercially available IO cannulae of variable size (14–18G) and design; some have a cutting bevel designed for a rotating insertion technique. Bone marrow aspirate needles can be used as an alternative. In neonates and small infants, spinal needles have been successfully used but they tend to bend easily with the harder bones of older children. Any cannula used should have a central stylet to avoid plugging of the lumen with bone particles. Whatever the device or site chosen, a twisting technique is employed with sustained pressure until a sudden give is felt as the tip of the needle enters the medulla after passing through the harder cortex. Mechanical devices such as the EZ-IO® are available for use in children. Blood aspirated from the needle can be used for glucose and electrolyte estimation, cross-match and culture. Full blood count will reflect the marrow cell population rather than peripheral blood.

Infusion of fluids into the IO space requires higher pressure than normally used in intravenous infusions. Boluses of fluid can be given by syringe or the use of a pressurised system. All current resuscitation drugs and antibiotics can be given safely by the IO route. The IO route is extremely safe when used in short-term resuscitation, with complications in less than 1% of patients. Compartment syndrome requiring fasciotomy has been reported as well as injury to the growth plate, bone fracture and local haematoma formation. Osteomyelitis is a rare complication. Local extravasation is rarely serious unless vasoconstrictors or thiopentone are involved, when necrosis of the overlying skin may occur. Formal venous access should be established as soon as feasible to allow the IO access to be removed.

Key Points

- Vascular access is an essential element of paediatric medical practice, but it is associated with a high complication rate.
- The choice of vascular access must be specific to each patient to balance the risks against the clinical requirements.
- The insertion complications of vascular access are potentially life-threatening, hence operators must be adequately trained and supervised for these procedures.
- There should be local protocols and care bundles for every type of vascular access.
- There should be an effective audit process in place to monitor complications from vascular access.

Further Reading

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Appendix 1 Central Venous Catheter Care Bundle

Modified from: Department of Health 2007 and NHS Improvement 2017. High Impact Intervention No. 1. Central venous catheter care bundle. http://data.parliament.uk/DepositedPapers/Files/DEP2008-0037/DEP2008-0037.pdf.

CR-BSI: catheter- related blood stream infection.

Insertion Actions

Catheter Type

- Use a single lumen catheter unless indicated otherwise.
- Consider an anti-microbial impregnated catheter if the catheter is to be used for one to three weeks and risk of CR-BSI is high.

Insertion Site

- Subclavian or internal jugular.

Skin Preparation

- Preferably use 2% chlorhexidine gluconate in 70% isopropyl alcohol. Allow to dry.
- If the patient is sensitive to chlorhexidine, use povidone-iodine.

Personal Protective Equipment

- Gloves are single-use items and should be removed and discarded immediately after the care activity.
- Eye/face protection is indicated if there is a risk of splashing with blood or body fluids.

Hand Hygiene

- Decontaminate hands before and after each patient contact.
- Use correct hand hygiene procedures.

Aseptic Technique

- Gown, gloves and drapes should be used for the insertion of invasive devices.

Dressing

- Use a sterile, transparent, semi-permeable dressing to allow observation of the insertion site.

Safe Disposal of Sharps

- A sharps container should be available at point of use and should not be overfilled; do not disassemble the needle and syringe; do not pass sharps from hand to hand.

Documentation

- Date of insertion should be recorded in the notes and on dressing if possible.

Ongoing Care Actions

Hand Hygiene

- Decontaminate hands before and after each patient contact.
- Use correct hand hygiene procedure.

Catheter Site Inspection

- Observe the site for signs of infection, at least daily.

Dressing

- Ensure transparent dressing is intact, dry and adherent.

Catheter Access

- Use aseptic technique and swab ports or hub with 2% chlorhexidine gluconate in 70% isopropyl alcohol prior to accessing the line for administering fluids or injections.

Administration Set Replacement

- Replace set immediately following administration of blood and blood products.
- Replace administration set after 24 hours following administration of TPN (up to 72 hours if there is no lipid).
- Replace all other sets within 96 hours.

No Routine Catheter Replacement

Appendix 2 Peripheral Intravenous Cannula Care Bundle

Modified from Department of Health 2007 and NHS Improvement 2017. High Impact Intervention No. 2. Peripheral intravenous cannula care bundle. http://data.parliament.uk/DepositedPapers/Files/DEP2008-0037/DEP2008-0037.pdf.

Insertion Actions

Hand Hygiene

- Decontaminate hands before and after each patient contact and before applying examination gloves.
- Use correct hand hygiene procedure.

Personal Protective Equipment

- Wear examination gloves if there is a risk of exposure to body fluids.
- Gloves are single-use items and should be removed and discarded immediately after the care activity.
- Gowns, aprons, eye/face protection are indicated if there is a risk of splashing with blood or body fluids.

Skin Preparation

- Use 2% chlorhexidine gluconate in 70% isopropyl alcohol. Allow drying.
- If patient is sensitive to chlorhexidine, use povidone-iodine.

Dressing

- Use a sterile, semi-permeable, transparent dressing to allow observation of insertion site.

Documentation

- Date of insertion should be recorded in notes and on dressing when possible.

Ongoing Care Actions

Hand Hygiene

- Decontaminate hands before and after each patient contact.
- Use correct hand hygiene procedure.

Continuing Clinical Indication

- Check that all intravenous cannulae and associated devices are still indicated.
- If there is no indication, then the intravenous cannula should be removed.

Site Inspection

- Observe the site for signs of infection, at least daily.

Dressing

- An intact, dry, adherent transparent dressing should be present.

Cannula Access

- Use 2% chlorhexidine gluconate in 70% isopropyl alcohol and allow it to dry prior to accessing the cannula for administering fluid or injections.

Administration Set Replacement

- Replace the set immediately after administration of blood or blood products.
- Replace all other fluid sets after 96 hours.

No Routine Cannula Replacement

- No need for routine replacement provided that the cannula is still clinically indicated and there are no signs of infection.

Appendix 3 Visual Infusion Phlebitis (VIP) Score

From: Jackson A. Infection control; a battle in vein infusion phlebitis. *Nursing Times* 1994; 4:68–71.

Appearance	Score	Comment	Action
IV site appears healthy	0	No signs of phlebitis	Observe
One of the following evident: slight pain or redness near IV site	1	Possible first signs of phlebitis	Observe
Two of the following evident: pain near IV site, erythema, swelling	2	Early stage of phlebitis	Resite cannula
All of the following evident: pain along cannula, erythema, induration	3	Moderate phlebitis – consider treatment	Resite cannula
All of the following evident, and extensive: pain along cannula, erythema, induration, palpable venous cord	4	Advanced phlebitis or start of thrombophlebitis	Resite cannula, consider treatment
All of the following are evident, and extensive: pain along cannula, erythema, induration, palpable venous cord, pyrexia	5	Advanced stage of thrombophlebitis	Initiate treatment, resite cannula