Managing difficult intravenous access: obtaining and maintaining paediatric vascular access

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Abstract

Vascular access in children is often challenging, especially in difficult intravenous access (DIVA) patients. Identifying the vascular access needed and planning insertion points carefully to maximize success and minimize patient distress is key. Although some alternative treatment options are available, a wide array of treatment care pathways are reliant on vascular access. Choosing the right vascular access device, its size and insertion point to fit the needs and condition of the patient adds complexity to decision making for the clinician. This article discusses tips for and the practicalities of obtaining and maintaining vascular access in paediatric patients, with a special focus on ultrasound-guided vascular access.

Keywords Difficult intravenous access (DIVA); dynamic needle tip positioning (DNTP); paediatric cannulation; paediatric vascular access; ultrasound-guided vascular access (UGVA)

Introduction

Obtaining vascular access is key to many important hospital treatments, ranging from drug or blood product administration, parenteral nutrition administration, to blood sampling and invasive haemodynamic monitoring. However, the wide-ranging paediatric patient population present varied challenges that can add to the difficulty of both securing and retaining this critical access.

Challenges include:

1 very small vessels that increase the technical difficulty
2 vessels that may be hidden by subcutaneous tissue
3 uncooperative patients who cannot always be reasoned with
4 anxious parents and carers

While vascular access is typically preferable, given the above difficulties there are alternatives available for many treatments which may be employed in the interim or as a permanent alternative. For example, many antibiotics may be given via the enteral route, whether orally or via a nasogastric tube. Feeds and rehydration fluids may also be attempted via the nasogastric route if unable to tolerate orally. Some antibiotics may also be given via the intramuscular route. Initial blood samples may be obtained via a capillary sample (heel or finger prick). More frequent observations and non-invasive haemodynamic monitoring may be used as an alternative to invasive haemodynamic monitoring.

If the best option is still deemed to be obtaining vascular access or the patient deteriorates, the above examples allow patient treatment to continue whilst more specialist access skills are sought.

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Obtaining vascular access

There are a wide variety of vascular access routes, and often the first decision is which of these routes would best suit the clinical need of the patient.

Vascular access routes can be divided broadly into 2 categories depending on requirement (see Figure 1). While not exhaustive, this figure categorizes the majority of vascular access sites used in paediatrics:

1 venous access — used for example in delivery of fluids, drugs, parenteral nutrition, and for obtaining venous blood samples; as part of procedures such as haemofiltration or extracorporeal membrane oxygenation (ECMO) in conjunction with arterial access.
2 arterial access — used for example in frequent blood sampling and invasive haemodynamic monitoring; as part of procedures such as ECMO in conjunction with venous access.

There is also an alternative option of *intraosseous access* when intravenous access is extremely difficult and the patient is critically ill, requiring immediate venous access for treatment and resuscitation. However intraosseous access remains an interim solution and should be removed as soon as alternative intravenous venous access is obtained.

Venous access

The choice of venous access site depends on the physical attributes and current condition of the patient, the likely duration and frequency of treatment, and the properties of the fluid or medication to be administered. Guidance can often be found in the relevant drug formularies and local guidelines. Where there is uncertainty, guidance can be sought from the supporting pharmacy team.

The choice of access device is primarily governed by the venous access site. However, there may still be some options available, varying from department to department. As a rule of thumb the simplest device that meets the patient need should be used.

The choice of device size is also governed by the size of the vessel. In paediatric patients the same vessels can be highly variable depending on the age and morbidity of the patient. Visualizing, palpating the vessel, ultrasound or other tools such as transillumination devices or near-infrared light devices can help in identifying vessels and estimating their size.

In general, the vascular access device selected should have a catheter-to-vein ratio of less than 50% in paediatric patients, and less than 33% in neonates.[1] For peripherally inserted central catheters (PICCs) specifically, the catheter-to-vein ratio should be less than 33% as research has shown thrombosis risk increases at higher ratios.[1,2] Local guidance should also be followed when selecting the device size.

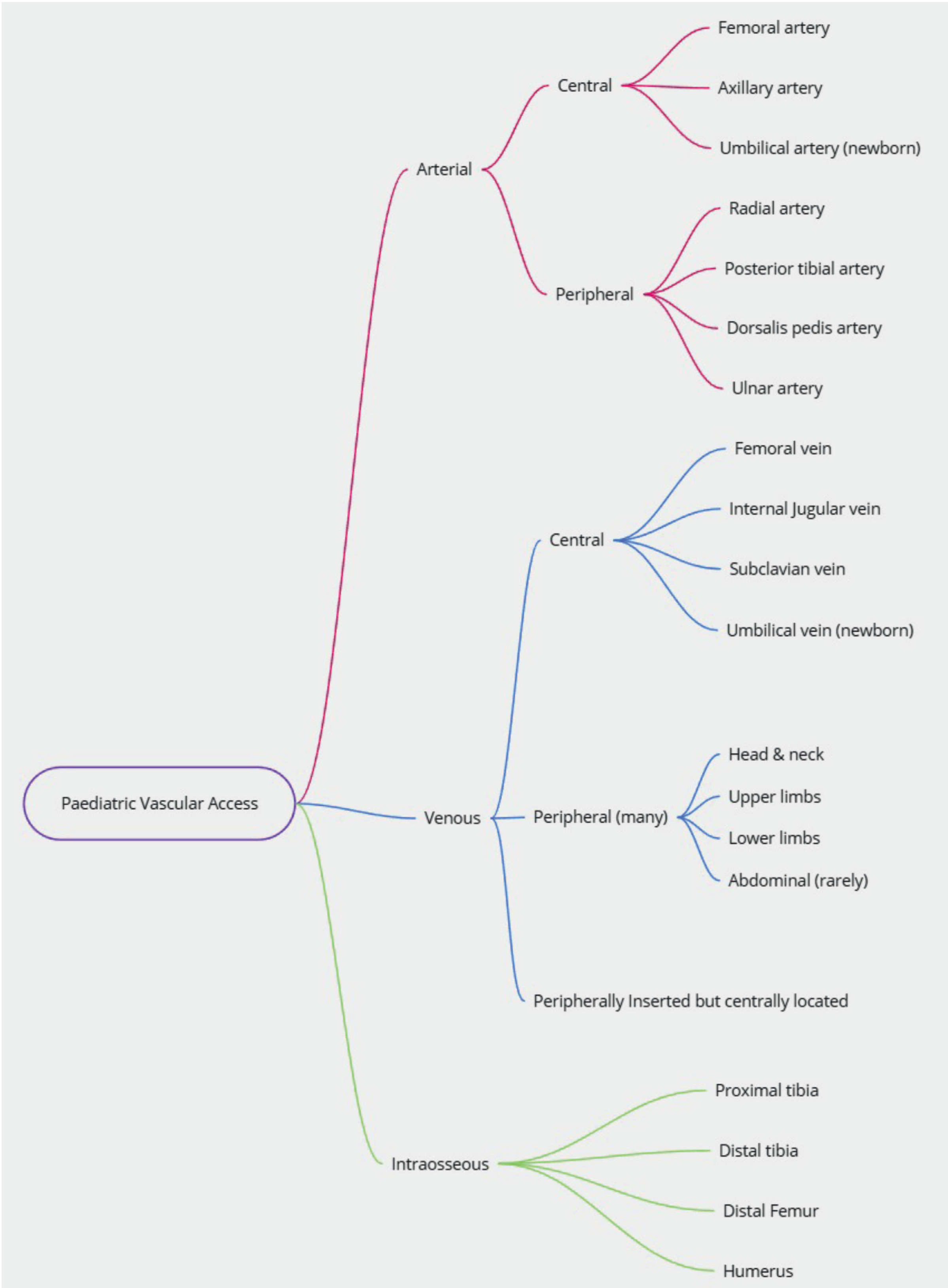

Figure 1 Paediatric vascular access sites.

Other considerations that may change vessel choice include prior repeated cannulations and extravasation damage, injuries affecting the preferred vascular site, fixed contractures to certain limbs, patient position requirements, and patient preference.

Consideration should be given not only to the present but also the future vascular access requirements of the patient. Access devices may deteriorate or fail, often suddenly or at critical moments. This can disrupt treatment or outright endanger a patient in the worst cases. A careful balance needs to be struck between mitigating such risks through contingency access versus potentially unnecessary and painful medical procedures. For example, the risk to a critically ill patient of a singular vascular access device failing far outweighs the potential negative aspects of having multiple access points inserted.

Peripheral venous access

Peripheral cannulae: the hands, wrists, forearms, antecubital fossae, feet and ankles are commonly used sites for peripheral venous cannulation, as well as the scalp in babies. Scalp cannulae may be more challenging to stabilize and have increased risk of extravasation.[3] Other sites for peripheral cannulation include the external jugular, axillary and abdominal veins. In less mobile children, with typical veins a well-secured peripheral cannula can last for 3–4 days, but survival time is influenced by factors including the type of infused fluid and the rates administered.

Peripheral midline: midline catheters are now commonly used in paediatrics. These are shorter than a peripherally inserted central catheter (PICC) line, but longer than a normal peripheral cannula. A midline catheter is a peripheral venous device. It is peripherally inserted and then threaded proximally via the modified Seldinger technique (see below) so that the tip of the midline is in a larger and deeper part of the vein. The advantage of a midline is its potential to indwell up to 1 month if well-maintained, therefore reducing the need for repeated cannulation in patients requiring short to medium term therapy. For example, when used for elective two-week courses of antibiotic treatment in children with cystic fibrosis, these lines last for 10–14 days.

Seldinger technique and modified Seldinger technique

Two techniques are commonly used for central venous catheterization: the wire-through-thin-wall-needle technique (*Seldinger technique*) and the catheter-over-the-needle-then-wire-through-the-catheter technique (*modified Seldinger technique*). The modified Seldinger technique uses a shorter guidewire to allow the catheter to be passed into the lumen of the vessel rather than directing the catheter into its final position. This is the preferred technique particularly in smaller paediatric vessels and for neonates.

Central venous access

Central venous catheters (CVCs): these devices are indicated for short-term therapy (expected dwell time approximately 1 week) when central-strength drugs or nutrition are required that are unsuitable for peripheral venous infusion. These catheters are available with multiple lumens (usually three but up to five lumens in larger sizes). Common insertion sites include the internal jugular vein and the femoral vein.

Peripherally inserted central catheters (PICCs): peripherally inserted central catheters (PICCs) are devices that are inserted where the duration of therapy is likely to be between 2 weeks and 2 months, and they may be inserted and removed without the need for general anaesthetic. PICCs are advanced from a peripheral insertion site until the catheter tip lies in the distal third of the superior vena cava, or at the cavo-atrial junction. PICCs inserted through the lower limb should terminate in the inferior vena cava.[3]

The preferred insertion site for PICCs is the basilic vein. In the lower limb, the course of the long saphenous vein may be used in non-ambulant patients.[3] Ultrasound-guided is the preferred method of insertion.

External catheters: external catheters are placed in a central vein using either an open surgical cut-down technique or percutaneously via the Seldinger technique. The catheter is then tunnelled away from the vein insertion site to a skin exit site. A cuff is then mounted on the line within the tunnel, into which subcutaneous tissue grows over time, and this stabilizes the line, and acts as a protective barrier.

These catheters are usually inserted when the duration of therapy is likely to exceed 2 months. The ideal tip position of CVCs is generally the same as that of PICC lines.[3]

Implantable vascular access devices (Portacath): the portacath is a port system implanted into a subcutaneous pocket and comprises a thin catheter connected to a reservoir. Once implanted, the portacath requires less maintenance and allows the patient more freedom than other catheters. A self-sealing membrane covers the reservoir. It is accessed through the skin using a special needle.

Portacaths are used in paediatric patients with chronic conditions who require intermittent venous access over a long period of time.[3]

Umbilical venous catheter: an umbilical venous catheter is an option for newborn babies within the first 7–10 days of life. It is not suitable for neonates with abdominal wall defects, or with gastrointestinal conditions.

Arterial access

There is less device variety in arterial lines compared to venous catheters. The choice of arterial device size is still governed by the size of the vessel. Palpating the vessel may help to determine the size in relation to the device. Ultrasound may alternatively be used.

The common sites used for arterial access are listed in Figure 1. In newborn babies, the umbilical artery may be cannulated. In paediatric patients, small cannula over needle devices or midline devices requiring the modified Seldinger technique are usually used. Numerous studies have confirmed the efficacy of ultrasound guidance for arterial cannulation in paediatric patients.[4] The posterior tibial and dorsal pedis arteries are alternative access sites to the radial artery in paediatric patients.[5] The brachial artery is not usually cannulated due to a lack of collateral arterial vessels, which increases the risk of ischemic injury to the distal upper limb.

The femoral artery (and more rarely the axillary artery) is used when there is difficulty obtaining peripheral arterial access or there is a specific indication for central arterial access.

Intraosseous access

Intraosseous (IO) access can be gained rapidly with a high success rate to facilitate urgent resuscitative treatment.

The most common site for paediatric IO access is the anteromedial aspect of the proximal tibia. The distal tibia is used in older children due to less cortical thickening. Alternative sites include the proximal humerus and the distal femur.

Power-driven IO drills are now used to insert IO needles quickly and efficiently. The appropriate needle size is determined by the depth of subcutaneous tissue overlying the bone at the insertion site. This is typically estimated by manual palpation.

IO needles should not be used on the same site within 24 hours, fracture sites, diseased bone or bones with metalwork. IO access is considered as central venous access for drug administration.[3]

It is important to continuously monitor the limb for signs of extravasation. IO needles are an interim measure used for their success rate and speed, and should be replaced once intravenous venous access is obtained and always within 24 hours.

Skin preparation prior to vascular access

Once the best site and appropriate device for vascular access have been selected, it is important that the site is appropriately prepared using aseptic techniques to reduce the risk of infection and prolong the lifespan of the device. This is especially true for the insertion of central venous or arterial devices, where infection would present particular danger for the patient.

Chlorhexidine with alcohol is primarily used for skin decontamination and preparation. However care should be taken in neonates and infants who have been observed to be particularly sensitive. A lower concentration of chlorhexidine, with or without 70% alcohol preparation is used to mitigate this.[3]

Pain management for vascular access

Options for pain management in paediatric patients include local anaesthetic creams and vapo-coolant sprays. Distraction techniques, breastfeeding and sucrose solutions are also employed to relieve distress. A play therapist can be effective for supporting older children. Reducing any trauma associated with vascular access improves patient experience and makes future attempts easier to perform.

Tetracaine 4% cream is most commonly used and is licensed for children over one month. It should be applied at least 30–45 minutes before the procedure to be effective. Once active, the site will be numb for four to six hours. This cream causes vasodilatation to the applied area and can result in temporary redness.

A mixture of 2.5% lidocaine and 2.5% prilocaine cream can be used in children above one year. It should be applied at least an hour before the procedure. The site will remain numb for up to two hours. This cream causes vasoconstriction to the applied area and can result in temporary whiteness.[3]

Local anaesthetic creams should not be used on wounds, broken skin, eczematous skin and areas of mucous membranes.

Vapo-coolant sprays can be used instead of or as a complement to local anaesthetic creams.

Rapid cooling of the skin temporarily results in reduced pain sensation. After spraying the skin for several seconds, about 1 minute of pain reduction will ensue, during which time the procedure should swiftly be performed.[3] Vapo-coolant sprays may cause vasoconstriction which can make line insertion slightly more technically difficult.

Tips for cannulation success

The ideal outcome would be for a clinician to select suitable vessel(s) and device(s) for cannulation, achieve vascular access quickly on the first attempt with minimal discomfort, and for the vascular access device(s) to remain patent and in situ throughout the duration of treatment without incident.

While this ideal isn't always achievable, careful planning and well-honed technical skills can substantially improve the likelihood of this favourable and sometimes critical outcome.

The remainder of the article describes tips and techniques to aid in this endeavour.

The majority of these tips apply to venous cannulation as the need for arterial cannulation is less common in paediatrics outside of paediatric or neonatal intensive care units.

Know your patient (and their parent or carer)

- Engage with your patient and their parent or carer.
- Explain the need for vascular access and obtain consent.
- Has your patient experienced vascular access attempts before? If so, what worked well last time, and what didn't work well?
- If this is the first experience, try to understand what may calm or distract your patient.
- Use age-appropriate measures and pain relief (ensuring time is allowed for it to be effective) to make the process as smooth as possible in non-emergency situations.
- Survey your patient for potential sites of vascular access, and identify the best site(s) for insertion, depending on the patient's access requirement.
- Assess if it is likely that your patient will have difficult intravenous access (DIVA).
- If your patient is scoring as a DIVA patient, pay extra attention when surveying for potential sites of vascular access and consider if additional support may be required.
- Contraindications to accessing a particular site include: distorted local anatomy, skin infection or injury overlying the insertion site, thrombus within the intended vessel, or other indwelling intravascular hardware within the intended vessel.
- Ensure your patient's target limb is anchored on a suitable flat surface or positioned in a way that is optimal for vascular access insertion.
- Try to avoid vascular access on joints and other areas prone to dislodgement. These are often also uncomfortable for a conscious patient.
- Assess how compliant your patient is likely to be during vascular access insertion and seek help as required. A young child will most likely require support to firmly secure the access site whilst an older child may remain sufficiently still during the process.

- In some cases, sedation or anaesthesia may be necessary to safely achieve vascular access. This would typically be in cases where your patient may be a danger to themselves or the clinical team, or has a history of severe distress from such procedures.

Know your equipment and environment

- Find a well-lit procedural space to attempt vascular access.
- Prepare your workspace such that all required equipment is within reach during the procedure. Special focus should be placed on selecting the appropriate vascular access device(s).
- Ensure appropriate support is engaged and on hand.
- Might blood samples be required? Consider taking these opportunistically at the same time as obtaining vascular access, as this is more efficient and typically less distressing to the patient.
- Be familiar with your kit and any resources you intend to use ahead of time. Demonstrating a lack of familiarity with equipment undermines patient or parent/carer confidence.

Know yourself

- The best way to improve is to practice.
- Engage with senior professionals and training programmes as required.
- Paediatric vascular access is not always straightforward. Ensure that you have planned adequate time for the procedure and any snags that may occur.
- Ensure you are prepared to perform the procedure. Hunger, needing the toilet and other distractions can reduce concentration and success rates.
- Reassess after each unsuccessful attempt. Consider if you should choose a different site, enlist specialist support or stop for now. Review your patient and their parent/carer, as they may also need a break.
- Vascular access is fine work and it can be frustrating particularly in unsuccessful attempts, especially with a non-compliant patient. It is important to remain professional and polite throughout; take a break yourself if needed.
- Review failed attempts in retrospect and consider how you might overcome this in the future. Failed attempts are however inevitable regardless of skill or training level.

Managing DIVA in children

Failed vascular access attempts lead to delays (sometimes life-threatening) in medical treatment, extended stays in hospital, wastage of healthcare resources, and increased stress for paediatric patients and their parents or carers.

In their 2008 paper (Derivation of the DIVA score: a clinical prediction rule for the identification of children with difficult intravenous access), Yen et al. developed a scoring system to effectively predict patients in whom it would be difficult to obtain intravenous access (see Table 1 for a DIVA scoring assessment).[6] Points are added for each question from the assessment to give a score out of 10.

A patient with a DIVA score of 4 or above, or a history of difficult intravenous access is considered to have potentially challenging intravenous access. There is a much greater chance of a failed initial attempt in DIVA patients.[6] This score highlights the need to plan these access attempts more carefully, or call for advanced support earlier when attempting cannulation in these DIVA patients.

Ultrasound-guided vascular access (UGVA)

Benefits of UGVA

Ultrasound guidance is the standard for obtaining central venous access. Whilst UGVA is less commonly used in obtaining peripheral vascular access, it is swiftly gaining prominence and is particularly useful in paediatrics especially for DIVA patients.

Studies have demonstrated the benefits of an ultrasound-guided approach in paediatric vascular access, including improved success rates, reduction in failed attempts, and number of complications.[4,5]

The key benefit of UGVA is that potential vascular access sites can be visualized prior to and during attempts. Details are visualized by a combination of 2-dimensional ultrasound imaging, colour and Doppler mode imaging.

Uniquely, UGVA allows a vascular "mapping survey" of the course of a target vessel to determine the optimal position for cannulation, and any potential complications.

When working with extremely small vessels or challenging DIVA patients, UGVA can facilitate vascular access in situations nigh on impossible with conventional technique.

Performing UGVA

The two primary views for visualizing vessels are: the short-axis (SAX) and the long-axis (LAX) view. In the SAX view the ultrasound beams intersect the target vessel vertically, while in the LAX view the ultrasound beams intersect the target vessel longitudinally.

Further to this, the advancing catheter can be viewed in 2 primary planes: in-plane (IP) and out-of-plane (OOP).

DIVA scoring assessment

Assessment	Score		
Is vein visible after tourniquet?	Yes = 0		No = 2
Is vein palpable after tourniquet?	Yes = 0		No = 2
What age is the patient?	3 years or older = 0	1–2 years = 1	Less than 1 year = 3
Was the patient born premature?	No = 0		Yes = 3

Add the points for each question to give a score out of 10.

Table 1

In IP the whole catheter shaft is visualized on the ultrasound display as it approaches the target vessel. In OOP only the needle tip of the catheter is visualized on the ultrasound display as it approaches the target vessel.[5]

In UVGA, we typically combine SAX with OOP or LAX with IP to facilitate cannulation (see Figure 2 for illustration).

SAX-OOP can be performed as a *static* or *dynamic technique*.

In the *static technique*, a specific target point in the vessel is viewed in cross section, and the catheter is advanced using this visual and intuition until part of the catheter appears on screen. In a successful attempt, the tip of the catheter needle would appear in the centre of this target point within the vessel before the rest of the procedure is then completed.

In the *dynamic technique*, also referred to as *dynamic needle tip positioning (DNTP)*, the same specific target point in the vessel is identified. However, the ultrasound probe is moved dynamically to follow the needle tip in cross section as it enters the skin on its journey to the target site. By making extremely fine movements to the probe such that the tip appears and disappears (see Figure 3a vs 3b), the clinician can ensure that it is the catheter needle tip that they are tracking, and not the catheter shaft. In a successful attempt, the tip of the catheter needle would appear in the centre of this target point within the vessel (see Figure 3e). The needle tip is flattened slightly and may then be progressed along the vessel whilst tracking, until more of the catheter is inserted. The additional insertion reduces the risk of the catheter becoming dislodged during needle withdrawal. As the needle tip has been tracked throughout, the clinician can be more confident of a successful insertion.[5]

The dynamic SAX-OOP approach has the steepest learning curve as working in cross section is less intuitive for most people and the dynamic technique consists of a series of very fine and precise movements. However, it offers a distinct advantage particularly in very small vessels as it focuses on hitting a specific

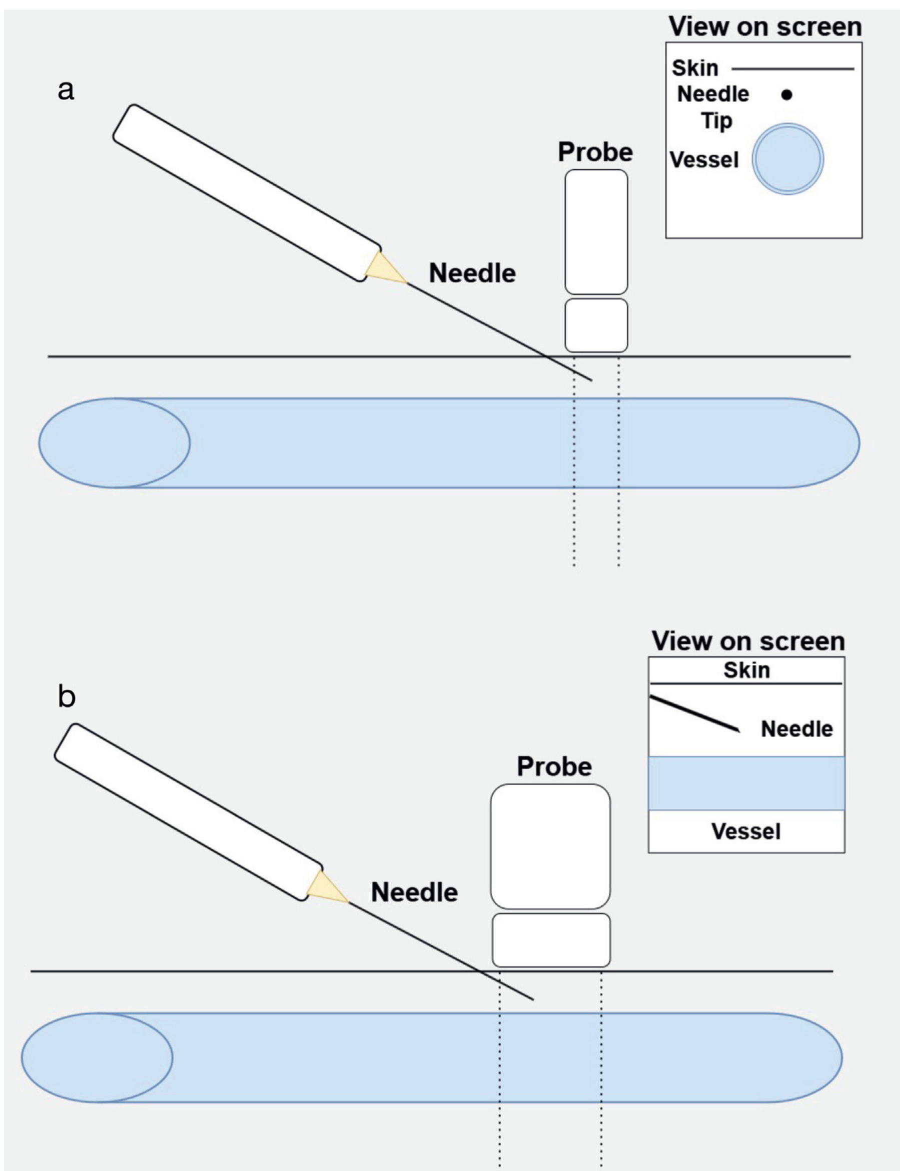

Figure 2 The SAX-OOP view (**2a**) and LAX-IP view (**2b**) in ultrasound-guided vascular access. Note the 90 degree change in rotation of the ultrasound probe and plane of the approaching catheter to achieve these two different views.

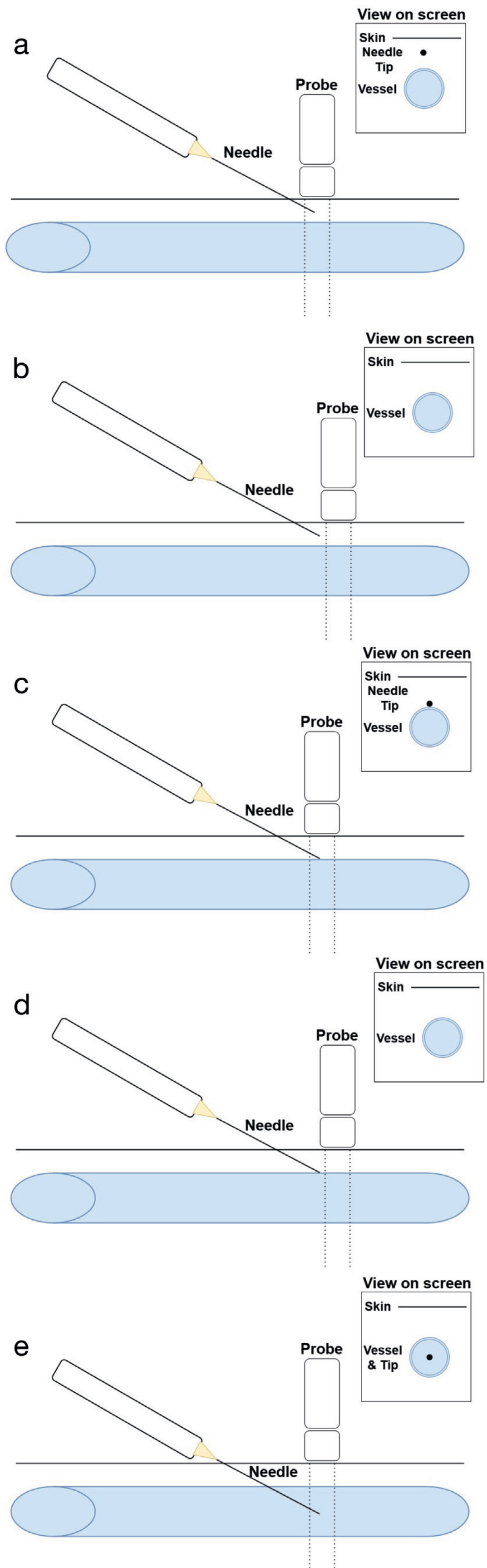

Figure 3 The DNTP journey: what a clinician should see on the ultrasound screen as they progress through the procedure.

optimal (wide and straight) point of the vessel which an experienced practitioner will have carefully selected. It is also clearer when the needle tip reaches the centre of the vessel in this view.

In very small patients, either SAX-OOP approach also offers some practical advantages in peripheral vascular access as limb length is often insufficient to effectively use the LAX-IP approach.

By contrast, the LAX-IP approach is easier to learn and track in real time as it involves less ultrasound probe repositioning. However, as the needle tip may drift out of plane (and therefore out of view) as it advances, it can lack the extreme precision often critical in small paediatric vessels.

UGVA is innately more challenging in smaller patients. Well-defined training and regular practice is the key to gaining and maintaining competence in this access method, especially for the dynamic SAX-OOP approach (dynamic needle tip positioning (DNTP)).

Tips to further improve UGVA success

Positioning: the patient's position can also be optimized to increase success chances by ensuring that the positions of the operator, the patient and the ultrasound machine are in a *straight axis* (see Figure 4, blue dashed line) to facilitate optimum potential for successful cannulation. An assistant should ideally be present to hold the patient's limb firmly in place throughout the process.

Tourniquet: if using a limb vessel for venous cannulation, apply a tourniquet proximal to the desired needle entry point, as proximal as is practical for the limb.

Vascular mapping: scan your target vessel proximally and distally. "Vascular mapping" helps to assess vessel patency along the vessel course, and to determine optimal position for cannulation.

Catheter size: the determination of catheter size should be based on:

(1) the relationship between target vessel diameter and catheter diameter

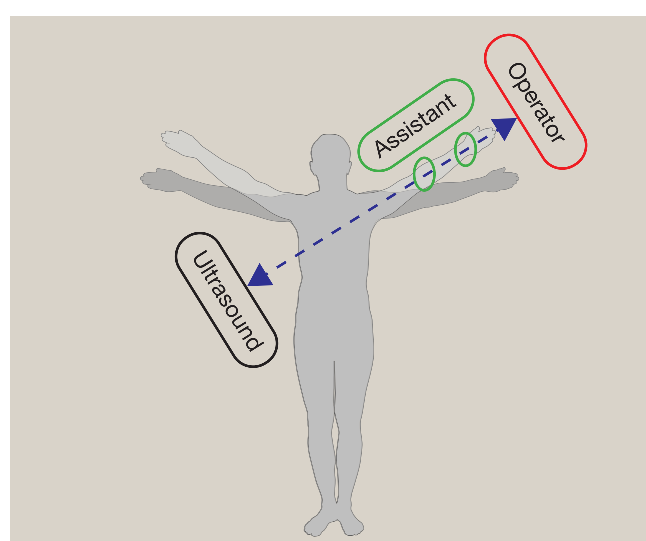

Figure 4 Positioning in a straight axis.

(2) the catheter travel distance from skin to the target vessel

An additional reason for difficult intravenous access

Patients who have had repeated vascular access device insertions may reach the point where there are limited insertion sites remaining not marred by occlusion or stenosis. In this situation, even the most experienced clinicians may struggle to obtain vascular access.

Carefully planning subsequent vascular access attempts to preserve the limited sites remaining and considering less commonly used vessels can help to alleviate this challenging situation. Once vascular access is obtained, extra care should also be taken to protect these especially precious catheters.

In the most extreme cases, the skills of an interventional radiologist, or a paediatric surgeon may be required.

Multidisciplinary paediatric vascular access teams

In some children's hospitals multidisciplinary vascular access sub-teams have been created to facilitate expert, efficient and rapid vascular access provision.

Maintaining vascular access

Some tips for maintaining vascular access once it has been obtained

- Ensure that the catheter is adequately secured with adhesive dressing. Additional dressing or bandage may be added to protect the access site.
- Ensure the vascular care bundle is appropriate to the vascular access devices used in your department, and that practice and training are well embedded.
- Educate the patient, parent or carer regarding the importance of the vascular device remaining in situ.
- Midlines, PICCs and central lines should be continuously infused or locked with heparin saline solutions, according to local protocol.
- Where possible, do not attempt to "bleed back" cannulas or midlines, particularly in DIVA patients, as this increases the risk of catheter occlusion and extravasation.
- Do not write off an existing vascular access point until you have personally assessed the patient and confirmed that it has definitively failed and cannot be revitalized (e.g. by repositioning, flushing the catheter, etc.)

Complications in general for vascular catheters include extravasation, leakage, thrombosis of the vessel, occlusion of the catheter, dislodgement, infiltration, phlebitis, and infection. In some instances, phlebitis will improve after 24–36 hours following treatment with ibuprofen and after instillation of a low dose of hydrocortisone through the line. Additional complications associated with central venous catheters (CVCs) and PICC lines include central venous thrombosis, CVC-related infections, malpositioning and mechanical complications such as occlusion or breakage. Careful surveillance of catheters in paediatric patients is important to mitigate any potential complications associated with vascular access.

Conclusion

Obtaining and maintaining vascular access is more challenging in the paediatric patient population, but remains a critical area of competence given the breadth of both diagnostic and therapeutic treatment that relies upon it. The increased challenge underscores the need for appropriate training, emphasizing careful consideration and planning to select the best vascular access option(s), as well as good practice in maintaining the access once it is obtained. This is especially true for the subpopulation of difficult intravenous access (DIVA) patients. Ultrasound guided vascular access (UGVA) is increasingly being employed for peripheral vascular access, and can substantially improve success rates when clinicians are trained to apply it effectively. UGVA can facilitate vascular access in situations nigh on impossible with conventional technique.

There is a wide array of practices that can be employed to help obtain and maintain vascular access. These can be learned individually, but should ideally be embedded into culture, training programmes and vascular care bundles across multidisciplinary teams. The patient remains the centre of all medical practice, and improving vascular access skills and success rates results in wide ranging improved outcomes and experience for the patient. ◆

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