

The where, what and how of paediatric central venous access

Gray RM, MBChB, DA, FCA(SA)

Specialist Anaesthetist, Red Cross Children's Hospital, University of Cape Town

Correspondence to: Rebecca Gray, e-mail: rebecca.gray@uct.ac.za

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Abstract

This review aims to help practitioners positioning central venous catheters (CVCs) in paediatric patients to make informed decisions about the site, insertion technique, type of catheter to use, and care of the CVC.

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Introduction

The insertion of a central venous catheter (CVC) into a paediatric patient is technically challenging and fraught with acute and chronic complications. Considering the available evidence, for each individual patient, practitioners must make rational decisions about the site and type of catheter to use and insertion technique, as well as prolonged catheter care. This review specifically considers percutaneously placed, non-tunnelled CVCs. Certain recommendations may be relevant to tunnelled central venous (CV) lines or CV lines that are inserted by the cut-down technique. The three veins that are most commonly used for cannulation are the internal jugular, subclavian and femoral. These will all be considered.

Avoiding acute complications

Arterial puncture at the internal jugular or femoral site can be controlled easily with pressure. The subclavian artery lies behind the clavicle. Bleeding from this site is more difficult to control. If arterial puncture occurs in the same pass as venous puncture, the possibility of arteriovenous fistula formation arises. This risk may be reduced by using ultrasound guidance to visualise the artery and vein during placement, or Doppler to identify the position of the artery prior to femoral cannulation.

Arrhythmias are commonly detected on electrocardiograms as the guidewire passes through the right atrium and into the right ventricle. In the context of electrolyte disturbances or congenital heart disease, these may be sustained. Electrolyte disturbances should be corrected preoperatively. The presence of the guidewire across the

right ventricular outflow tract may trigger spasm in this area of the myocardium and lead to a cyanotic episode in children with a reactive right ventricular outflow tract and ventricular septal defect.

Cardiac perforation with or without tamponade is more likely in neonates and premature babies when the dilator may have inadvertently been advanced too far, or the tip of the guidewire may have perforated the thin-walled right atrium. This risk is reduced by taking particular care with dilator advancement, avoiding the straight end of the guidewire, or using a flexible straight-tipped guidewire and not advancing the guidewire against resistance.

Haemothorax and pneumothorax are more probable with the subclavian approach.

Thoracic duct injury may occur during attempted left subclavian or internal jugular vein cannulation. *Brachial plexus injury* may occur with a very posterior approach to internal jugular vein cannulation.

Air embolism can occur in a spontaneously breathing patient. It is more common with cannulation of the subclavian or internal jugular vein, but is less likely when these veins are accessed with the patient in the Trendelenburg position. Guidewire or catheter fragment embolus can be avoided through the application of a meticulous technique.

Because of the anatomy of the subclavian vein, *misplacement of a CVC* therein is particularly common. This is especially true of the right side, where its angles are acute and a CVC is likely to be advanced up the internal jugular vein. When the right subclavian vein is cannulated, turning the patient's head towards the right during guidewire

advancement may reduce the risk of misplacement into the internal jugular vein. This complication is not limited to the subclavian approach. Cannulations of the intrathecal space from the internal jugular vein approach,¹ and an epidural vein from a femoral approach in neonates, have been described.² Fluoroscopic guidance during guidewire and catheter advancement is advised in a patient who has experienced repeated CVC misplacements.

Avoiding maintenance-related complications

Thrombosis and infection are the most common serious maintenance-related complications of CVCs. Many factors combine to increase the risk of occurrence of these.

Thrombosis

The presence of a CVC is the most important acquired trigger in the development of deep vein thrombosis and venous thromboembolism (VTE) in children. It has been reported that > 90% of VTE in neonates and > 50% of VTE in older children is associated with a CVC.³ Depending on the method employed to detect thrombus and whether asymptomatic patients are investigated, the incidence of CVC-related thrombosis in children can vary from 8-35%.⁴ Imaging modalities are explored in Table I.

CVCs trigger thrombosis because of:^{4,6}

- Vessel wall damage at the insertion site.
- Obstruction to the flow, causing stasis.
- Irritation of the vessel wall by the infusate.
- The presence of a foreign surface in a vessel.

The incidence of new thrombus formation decreases after four days, possibly because of re-epithelialisation of the injured vessel wall. Thrombus that is already present will continue to propagate and new thrombi may still form. Several studies have shown a relationship between the incidence of catheter-related thrombosis (CRT) and the site of insertion. CVCs that are placed in the subclavian and femoral veins have a similar incidence of thrombosis, although femoral thrombi are more likely to be symptomatic.⁶⁻⁹ CVCs that are placed in the internal jugular vein are less likely to be associated with thrombus formation. In the case of subclavian vein cannulation, trauma, from kinking of the vessel onto the cannula as it is pinched between the clavicle and the first rib with arm movement, may be a contributing factor. The cannulated femoral vein may be similarly affected, as the vessel is compressed onto the cannula

Table I: Quality of imaging modalities for thrombus detection⁵

Imaging modality	Comments
Venography	Gold standard May miss certain internal jugular vein thrombi
Doppler ultrasound	Sensitive to internal jugular vein thrombi Improving for subclavian vein thrombi Poor at identifying asymptomatic femoral vein thrombi Tends to underestimate incidence
Echocardiography	Best for intracardiac thrombus

when leg movement kinks the vessel under the inguinal ligament.⁸ The degree of vessel occlusion by a catheter predisposing to thrombosis is directly related to the size of the catheter relative to vessel diameter.⁹⁻¹¹ Of the commonly accessed vessels, the femoral vein is the smallest, with the least flow, which may explain the increased incidence of femoral vein thrombi.

Multiple insertion attempts will cause greater vessel wall damage, leading to increased risk of thrombus formation. This has been correlated with operator experience. An oft-quoted paper suggests that operators with > 50 insertions have 50% fewer complications than less experienced operators.¹² However, other studies that examined the correlation between operator experience and the frequency of CVC-related complications have not shown this to be the case always.^{7,13} This may be because more experienced operators are called upon to perform the more difficult insertions where the likelihood of success at the first attempt is reduced.

Heparin-bonded catheters have been shown to decrease catheter-related thrombosis and infection in children.^{14,15} The sample sizes were relatively small in these studies and there was a tendency to favour the femoral vein for insertion. Heparin-bonded lines also reduce infection by decreasing thrombus formation.

The use of continuous heparin infusions (50-100 IU/kg/day) to prevent thrombosis or to prolong the use of CVCs in children has been shown to be safe and effective in studies that examined peripherally placed central catheters^{16,17} and centrally placed catheters, specifically in neonates and infants.¹⁸ Although a decreased incidence of thrombosis was reported in groups who received the heparin infusion, this was generally diagnosed with ultrasound (a modality with limited success in the detection of subclavian vein thrombi, where many of the lines were placed). There was no increased incidence of thrombocytopenia. The incidence of heparin-induced thrombocytopenia in children is reportedly the same as that in adults (1-5%), but in the only published cohort study, the outcome in afflicted patients was less severe (no loss of life or limb).¹⁹

Prophylactic anticoagulation is not yet recommended in all children who have had CVCs inserted, but may be considered in children with other risk factors for thrombus formation.³

In summary, the risk of CRT may be reduced by:

- Cannulating the internal jugular vein.
- Choosing the smallest appropriate heparin-bonded catheter.
- Running a heparin infusion post-insertion.
- Removing the catheter as soon as it is no longer required.

Infection

CVC-related infection (Table II) significantly increases patient morbidity and length of stay in an intensive care unit and hospital, as well as mortality. Adult mortality rates as a result of CVC-related infection vary, but are reported to be as high as 30%.²⁰ Paediatric data are scarce.

Table II: Definitions of CVC-related infections

Catheter-related blood stream infection	The presence of a systemic infection and evidence that implicates the central venous catheter as its source
Catheter colonisation	Significant growth of microorganisms on either the endo- or extraluminal surface beneath the skin in the absence of systemic infection

Organisms may colonise the catheter from the extraluminal route (skin commensals invade the tract during insertion or subsequently, in the days that follow), the intraluminal route (catheter hub and lumen contamination when the catheter is inserted over the guidewire or subsequently, in the days that follow with hub manipulation) or, more rarely, by haematogenous spread from a remote site.

The incidence of catheter contamination is difficult to establish and varies significantly between studies. Reasons for this include the following:

- Difficulty in confirming contamination while the catheter is in place.
- Quality of care between units may vary.
- Varying number of lumens and manipulations.
- Varying number of blood aspirations.
- Type of therapy administered, e.g. total parenteral nutrition (TPN).
- Duration of placement.

Maximal sterile barrier precautions, including cap, mask, gown and gloves for the operator, and full-body drape for the patient, with only the insertion site exposed, are essential. Skin preparation should be with 2% chlorhexidine in alcohol.²¹

A transparent, gas-permeable dressing should be applied to the CVC and changed if it becomes damp, loosened or soiled.

Ointments that are applied to the insertion site encourage fungal colonisation and infection²² and are not recommended. Antibiotic ointments assist in the development of resistant organisms and may interfere with the integrity of polyurethane catheters.

An aseptic no-touch technique is essential for all dressing changes and hub manipulations. Hub manipulations, including the administration of drugs and aspiration of samples, should be preceded by hub decontamination with chlorhexidine or iodine in alcohol, or 70% alcohol, which should be allowed to dry. The infusion of TPN and blood products through a CVC, and aspiration of blood samples from it, increases the risk of infection of that line. TPN should be administered through its own dedicated lumen.²⁰ The longer a CVC is in place, the higher the likelihood of infection, and dwell times of > 10 days are associated with a significant increase in CVC-related infection.^{23,24} The CVC should be removed when it is no longer required.

Routine catheter exchange, after a predetermined period of time, has not been shown to reduce rates of catheter-related blood stream infection (CRBSI). Guidewire exchange is not recommended. It is only acceptable when attempting to resolve a mechanical complication. A new pair of sterile gloves should be donned when handling a new CVC. A blood sample should be drawn at the time of exchange and the old catheter should be sent for microbiological examination. Various characteristics of the catheter that is selected for use may influence the risk of CVC-related infection. Polyvinyl chloride catheters are associated with greater colonisation and infection rates than those manufactured from Teflon™ or polyurethane.²⁵

Evidence suggests that antimicrobial-impregnated CVCs are effective in reducing CVC-related infection.^{20,26,27} However, they are not recommended unreservedly. Two types of antimicrobial-impregnated CVCs are widely available: chlorhexidine/silver sulphadiazine and rifampicin/minocycline. Few head-to-head trials between the two types exist. Almost all of the available trials were carried out in adults. The chlorhexidine/silver sulphadiazine CVCs have been shown to be cost-effective if the institutional rate of CRBSI is > 2%.²⁶ In a major review of 37 trials,²⁷ the effectiveness of silver-coated or impregnated catheters vs. rifampicin/minocycline was questioned. This may have been influenced by use of the first-generation catheter which had an extraluminal coating only. The second-generation catheter has intraluminal impregnation as well. There is some suggestion of a possible impact on antibiotic resistance in vitro. However, as yet, no serious adverse events have been reported.²⁸ The antibiotic in the catheter is slowly eluted and effective levels remain for 4-6 days, the time during which colonisation rates are highest. No studies that compared infections rates between heparin-bonded and antibiotic-impregnated catheters exist. Antibiotic-impregnated catheters are recommended if > 5 days dwell time is anticipated;^{3,20} in high-risk patients. e.g. those with burns and neutropenia;^{20,28} in units where CRBSI > 3.3/1 000 catheter days;²⁰ and in patients in whom sepsis poses a particular risk, e.g. a prosthetic heart valve in situ.²⁸ Antibiotic-impregnated catheters should not be used as an excuse to take short cuts on adequate asepsis in relation to the insertion and maintenance of the CVC.

Antibiotic flushing of lumens decreases colonisation, but increases microbial drug resistance. Antibiotic locking of lumens with vancomycin reduces colonisation, but is associated with a significant rate of development of vancomycin-resistant enterococcus (VRE).³ Heparin infusions have been shown to decrease rates of mechanical complications and possibly CRBSI, but it is uncertain whether the latter effect is because of a decrease in thrombus formation, or because of the antimicrobial preservatives that are found in heparin.²⁹

Intravenous antibiotic prophylaxis that is given at the time of insertion does not reliably protect against the development of CVC-related infection and may increase resistance.²⁰

Low birthweight infants who are given vancomycin cover for line insertion showed improvements in morbidity, but not mortality, and demonstrated an increased incidence of VRE infections.³⁰

Although in-line antimicrobial filters may decrease the risk of infection from contaminated infusate, they block easily, increasing line manipulation and the risk of infection.²⁹ Thus, they are not recommended. The number of lumens in a CVC does not increase the risk of CVC-related infection.³¹

Several sizeable prospective paediatric studies have found no association between the site of insertion and the risk of CVC-related infection.^{7,23,32} Guidelines produced by the Society for Critical Care Medicine of the USA recognise this.²⁹ While the national evidence-based guidelines for preventing healthcare-associated infections in NHS hospitals in England²⁰ recommend the use of the subclavian vein in adults, they avoid making any specific recommendations for paediatric patients. Staff who are responsible for the insertion and maintenance of CVCs should be trained and educated in the insertion and care of these devices. Audits should be performed regularly to check compliance with recommendations.^{20,29}

Ultrasound use

Use of ultrasound to prelocate vessels or guide access is well established with regard to the internal jugular vein. It is also gaining favour for use in femoral vein access. Ultrasound-guided subclavian vein access in children was first described in 2007.³³ The technique is growing in popularity and safety.³⁴ A 2009 meta-analysis of five studies that compared landmark vs. ultrasound prelocation/guided techniques in children found no advantage in terms of

success rate, speed or reduction of complications with the use of ultrasound. A subgroup analysis suggests that less experienced practitioners may have more success when using ultrasound.³⁵ However, the study was criticised for including papers in which ultrasound was used only for prelocation, as well as for including a study where a single operator with very limited ultrasound experience, but vast landmark experience, may have skewed the results. It has been suggested that exclusion of this single paper would have led to quite different results in the meta-analysis and have possibly indicated an advantage of ultrasound over the landmark technique.³⁶ While it is not true to say that ultrasound-guided vascular access is the standard of care yet, if future studies show improved accuracy and decreased rates of failed attempts at access, it may be found that ultrasound-guided access reduces the risks of complications that are associated with vessel wall damage (thrombus formation, and indirectly, infection).

Site of insertion

A major decision to be made when inserting a CVC is which vein to cannulate. A practitioner may favour a particular site. Table III considers the advantages and disadvantages of each of the three commonly cannulated veins. Cannulation of the subclavian vein carries the highest risk of complications. Many difficulties relate to inexperienced technique. Repeated passes are more likely to be associated with puncture of other structures (pleura and arteries) and damage to the vein, precipitating thrombosis. Newer techniques that involve supraclavicular ultrasound-guided access of the subclavian vein³⁴ may result in improved accuracy and safety when cannulating this vein.

Table III: Advantages and disadvantages of cannulation sites

Subclavian vein	
Advantages	Disadvantages
<ul style="list-style-type: none"> Fewer infections, but only conclusive in adult literature. Paediatric literature disagrees.^{7,23,24,32} Good for mobile patients. 	<ul style="list-style-type: none"> Highest rate of acute complications per site (haemothorax and pneumothorax). High incidence of misplacement, especially with right-sided cannulation.³⁷ Thrombosis.^{6,8} Cannot easily apply pressure in the case of arterial cannulation, thus is not suitable for patients with bleeding risk.
Internal jugular vein	
Advantages	Disadvantages
<ul style="list-style-type: none"> Consistently less thrombosis than other sites.^{6,8} Fewer incidents of misplacement than those relating to the subclavian vein (more direct line to the right atrium). Can easily apply pressure in the case of arterial puncture. 	<ul style="list-style-type: none"> Pneumothorax. Thoracic duct or brachial plexus injury.
Femoral vein	
Advantages	Disadvantages
<ul style="list-style-type: none"> Easy access and predictable anatomy. Can easily apply pressure in the case of arterial puncture. No cardiac or thoracic complications. Away from the airway, useful in an emergency when airway management is underway. 	<ul style="list-style-type: none"> Thrombosis^{6,8} incidence is equal to that of the subclavian vein, especially high risk associated with dehydration and hyperosmolarity.³⁸⁻⁴⁰ Septic arthritis (rare).⁴¹

Conclusion

The decisions that are made when inserting a CVC in a child can significantly impact on the development of potentially devastating complications. The practitioner inserting a CVC should keep abreast of advances in technology and techniques, and carefully consider the presented evidence to support decisions. Staff who are responsible for the maintenance of a CVC should be assisted with regular training and updates on care. Audits of practice must be undertaken to assess the effects of the introduced interventions with the aim of decreasing complication rates.

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