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A Practical Manual of Pediatric Cardiac Intensive Care



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Foreword
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4

CHAPTER

Central Venous Catheters in Pediatric Cardiac Patients

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Reviewed by: Aveek Jayant

INTRODUCTION

Central venous catheters (CVCs) are often placed in pediatric cardiac surgical patients to facilitate hemodynamic monitoring, to administer intravenous fluids or medications and occasionally for postoperative parenteral nutrition.[1,2] In our practice, CVCs are placed most often in the operating room (OR) under anesthesia and sometimes in the pediatric cardiac intensive care unit (PCICU) or in cardiac catheterization laboratory. CVC insertion and its maintenance in critically ill children have its own share of complications which can occur either during insertion or due to its long-term residence in a central vein.[3] With the near universal use of ultrasound in our practice the mechanical complications during catheter insertion have become rare; the infectious complications of an invasive device in the bloodstream have arguably come to the fore. This chapter intends to provide an overview of management of CVCs in pediatric cardiac surgical patients.

DEFINITION AND SITE OF CANNULATION

Central venous access is defined as placement of a catheter such that the catheter is inserted into one of the venous great vessels, namely superior vena cava (SVC), inferior vena cava (IVC), brachiocephalic vein, internal jugular vein (IJV), subclavian vein, iliac vein or common femoral vein. For the purpose of central venous pressure (CVP) monitoring, the tip of the CVC should be placed in the distal SVC, SVC/right atrium (RA) junction, or in the IVC, at or above the level of the diaphragm. These are the largest veins with the highest flow rate in the venous system. Infusion of cytotoxic, hypertonic, hypotonic, acidic or alkaline solutions in these locations minimizes the risk of venous thrombosis, drug infiltration or extravasation, and vessel perforation.

Typically for pediatric cardiac surgery, the favored sites of CVC insertion are the IJV, subclavian vein or femoral vein. Though the subclavian vein site is recommended for short-term non-tunneled CVCs to lower infection risk in adult patients, there has been no guidelines in pediatric age group.[4] The choice of site also depends upon anatomical considerations such as the presence of dextrocardia, bilateral SVC and surgical considerations such as Glenn shunt/Fontan procedure where jugular venous pressure may not reflect the true CVP. Ultrasound guided cannulation technique has become a popular aid in CVC insertion, facilitating the ease of insertion as well as limiting complications.[5]

The right IJV is the most common route for central venous access in most congenital

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heart repairs as the vein follows a straight course to the RA and is easily accessible with the landmark method.[6] Left IJV is generally avoided since it may sometimes connect to a persistent left sided superior vena cava (LSVC) draining into an unroofed coronary sinus. Additionally there is the potential risk of chylothorax due to accidental injury to the thoracic duct or venous thrombosis.[7,8] Subclavian route is not usually preferred since the catheter can get kinked during the placement of sternal retractors during cardiac surgery although intensive care groups caring for neonates are exploring the use of ultrasound-guided supraclavicular or confluence access in small neonates with high success. It is rational to avoid cannulating femoral vein as there is likelihood of thrombosis due to higher catheter-lumen ratio in small infants and to preserve venous patency for future cardiac catheterizations or interventional procedures. However in patients with univentricular physiology undergoing cavopulmonary connections, femoral site is often preferred by clinicians to minimize the incidence of SVC thrombosis. A peripherally inserted central catheter (PICC) may be considered in patients who require longer duration of central venous lines for administration of medications or for parenteral nutrition.[9]

A suggested protocol for CVC cannulation in PCICU is described here.

ARTICLES REQUIRED FOR CVC CANNULATION

- Sterile gown pack with a hand towel
- Sterile gloves
- 2.5% chlorhexidine gluconate with alcohol solution (chlorhexidine tincture)
- Linen pack
- Central line tray with a fenestrated sterile drape (Hole towel)
- CVC—4Fr double lumen/5.5Fr triple lumen
- BD Insytes™—24G, 22G
- *Surgical blade*: No. 11
- Normal saline
- 1 mL syringe with 1% lignocaine for local anesthesia
- 5 mL syringe
- *Sterile gauze pieces*: 2 cm × 2 cm
- 3-way with stopcock
- *Suture material*: 3-0 Nylon
- Sterile transparent dressing
- Pressure monitoring tubing with continuous flush system
- Transducer kit with cables
- Pressure bag
- Sterile plastic cover for ultrasound probe
- Ultrasound machine with linear probe.

CATHETER CHARACTERISTICS

Polyurethane/Teflon (Polytetraflouroethylene) catheters are preferred over polyvinyl chloride (PVC) or polyethylene catheters due to fewer infectious complications.[4]

The size of the catheter is determined by age of the patient and the size of the vein. A 4 Fr double lumen 5 cm catheter is preferred in neonates and young infants weighing <5 kg. 5.5 Fr triple lumen catheters are preferred in older children. In order to minimize the risk of bloodstream infection, it is reasonable to use a catheter with minimum number of ports or lumens essential for management of the patient.

PREINSERTION PROCEDURE

- Explain the procedure to the patient, and family as appropriate, and obtain written consent.
- Follow nil per os (NPO) instructions in nonventilated patients for procedural sedation if required.
- Ensure that coagulopathies are corrected before the procedure.

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- Assemble all the essential supplies by the bedside before the commencement of the procedure.
- Ensure that appropriate monitors are in place—ECG, SPO_2, NIBP/invasive arterial pressure, and temperature monitoring.
- Emergency resuscitation drugs and equipment (Pediatric crash cart, defibrillator, and temporary pacemaker) should be available at the bedside to manage any hemodynamic complications that might occur during the procedure.
- Bedside nurse should read the central line insertion checklist before the commencement of the insertion. A model of central line insertion bundle checklist is shown in **Figure 1**.

INSERTION CARE

- 3 minutes hand washing with chlorhexidine scrub solution should be done by the inserting physician.
- CVC should be inserted aseptically using maximal sterile barrier precautions. The bedside nurse should monitor the inserting practitioner for breach in sterile precautions. Physician must wear cap, mask, sterile gown, sterile gloves, and maintain strict aseptic technique throughout the procedure.
- Prepare skin with 2.5% chlorhexidine gluconate tincture (30 seconds scrub) before CVC insertion. Though the use of chlorhexidine gluconate for skin preparation has not been approved for neonates, several centers are using this agent without major adverse effects. (If chlorhexidine is contraindicated due to previous hypersensitivity reactions povidone-iodine solution can be used. Allow 2 minutes contact time for skin disinfection if povidone-iodine solution is used). Allow the antiseptic to dry prior to insertion.

AIMS: INSERTION BUNDLE CHECKLIST Dept. of Infection Control					
Name:				**Dr./Dept:**	
Central line insertion date:		**Date of U. Catheterization:**		**Date of intubation:**	
Inserted by:		**Inserted by:**		**Intubated by:**	
CENTRAL LINE BUNDLE CHECKLIST		**U. CATHETER BUNDLE CHECKLIST**		**INTUBATION CHECKLIST**	
☐	Hand hygiene performed before catheter insertion and manipulating the catheter	☐	Hand hygiene performed before catheter insertion	☐	Hand hygiene performed before intubation
☐	Maximal barrier precautions followed (gown, gloves, mask, etc.)	☐	Aseptic technique followed/ sterile equipment used	☐	Aseptic technique followed
☐	Chlorhexidine skin antisepsis done	☐		☐	Sterile/disinfected equipment used
☐	Optimal catheter site selection (preferrably subclavian)	☐	Proper disinfection of insertion site done	☐	Maximal barrier precautions followed (gloves, mask, cap, etc.)
☐	Catheter insertion is documented/ labeled (date, time, and personnel)	☐	Application of lubricant or anesthetic gel	☐	Oral suction done before insertion
☐	Antiseptic dressing done	☐	Catheter gently inserted	☐	ET-tube gently inserted
Comments if any:		☐	Replace if a break in asepsis occurs	☐	Used sterile suction catheter and gloves for each ET-suctioning
		☐	Proper securing of catheter in the bladder	☐	Checked cuff pressure and dislocation of ET-tube done
		☐	Catheterization is documented/ labeled (date, time, and personnel)	☐	Proper securing of ET-tube done

Fig. 1: A prototype of bundle checklist.

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- The patient should be monitored for airway and hemodynamic compromise during the procedure.
- Ultrasound guidance is recommended if equipment is available to reduce the number of cannulation attempts and prevent mechanical complications.
- After insertion, location of the tip of the catheter should be confirmed from the waveform and pressure recording.
- All catheters should be sutured in place with 3-0 Nylon to prevent migration and inadvertent removal. The catheter tip location should be verified immediately after insertion with the help of a chest X-ray.
- Use sterile transparent dressing to cover the insertion site. The transparent dressing permits visual inspection of the exit site and minimizes the need for frequent dressing changes. However if, the insertion site is oozing/bleeding, gauze and tape dressing can be used till this resolves.
- Do not use any topical antibiotic at the insertion site.
- The date and time of catheter placement should be documented on the top of the dressing.

CVC MONITORING SYSTEM AND TRANSDUCER SETUP

- Prepare the continuous flush system with the transducer and make sure the system is devoid of air bubbles. Normal saline is used as continuous flush for CVCs.
- Attach the transducer cables to the monitor.
- Connect the catheter to the monitoring system once the catheter tip is located in the SVC-RA junction.
- Level the transducer at the phlebostatic axis (i.e., 4th intercostal space in the mid axillary line). Transducer is typically taped to the patient bed.
- Zero—calibrate the transducer (choose the appropriate scale to get the best waveform and set appropriate alarm limits).
- Obtain the pressure reading, and document on the flow sheet.
- Label date, and time on the pressure bag and tubing.
- In case of patients returning from OR, transducer and tubing with flush system will be provided from the OR.

NORMAL CVP WAVEFORM

The normal CVP waveform is depicted in **Figure 2**.

CVC COMPLICATIONS

Monitor the patient for probable complications of central venous catheterization[10] during and after the insertion.

Immediate

- *Inadvertent arterial puncture with hematoma formation*: Accidental arterial puncture is a frequent complication following CVC insertion.[11] Ultrasound-guided techniques are generally preferred to minimize this complication and to ensure high success rates.[12] In the event of a hematoma, local compression of the site with gauze dressing will usually control the bleeding, and limit hematoma formation. The bedside nurse should also monitor the neck, arm or shoulder area for any swelling which may appear after the insertion.
- *Pneumothorax*: This is a potential complication which can occur after subclavian vein cannulation. This can be identified clinically by low oxygen saturations, reduced air entry/breath sounds in the ipsilateral hemithorax, increased air leak from chest drains, and occasionally subcutaneous emphysema. In a nonventilated patient, there may be a sudden onset tachypnea, and

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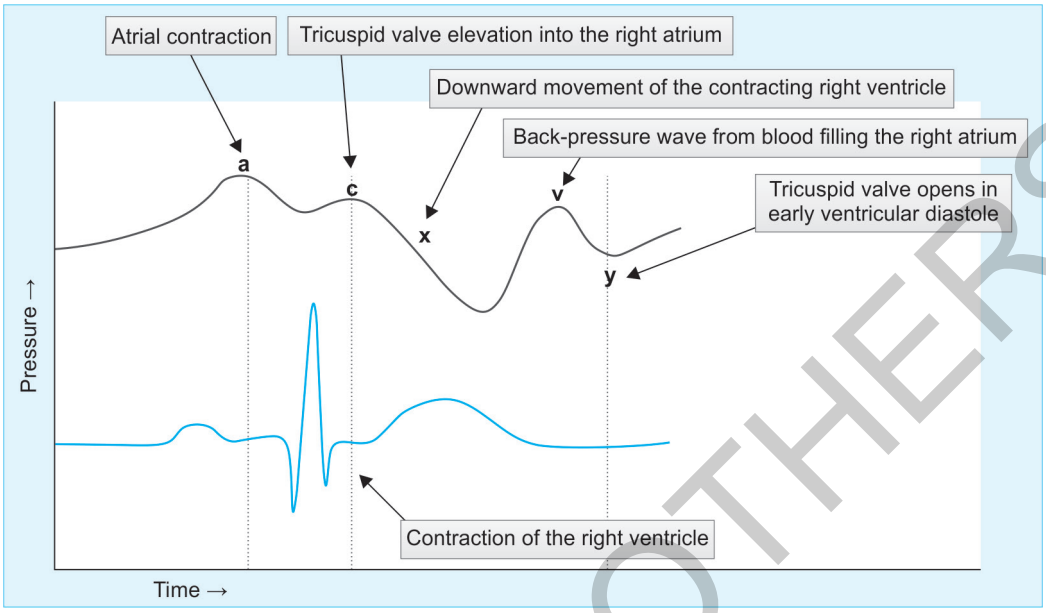


Fig. 2: Normal central venous pressure waveform.
Source: www.derangedphysiology.com

desaturation. A tension pneumothorax can also cause hemodynamic instability. It is reasonable to obtain a chest X-ray after central line insertion in the ICU to confirm the position of the catheter tip, and to rule out pneumothorax.

- *Arrhythmias*: Transient atrial or ventricular arrhythmias can occur during the passage of guidewire during central line insertion. This can be minimized by limiting the depth of guidewire insertion. ECG waveform should be carefully monitored for the occurrence of arrhythmias.
- *Air embolism*: This can occur when there is a negative pressure in the venous system or due to accidental flushing of air bubbles into the catheter. Paradoxical air embolism can occur if the patient has a patent foramen ovale or an intracardiac shunt. Entry of air bubbles into the coronary system can produce ST elevation in ECG waveform, tachycardia, and hemodynamic instability. Air embolism into the cerebral circulation can be one of potential causes for postoperative stroke or seizures after congenital heart surgery.
- *Hemothorax*: Injury to a major blood vessel or RA/right ventricle (RV) perforation with nonflexible guidewires can rarely occur leading to bleeding, and hemothorax. It is usually identified by hemodynamic instability or increased bleeding from the intercostal drains.

Late Complications

Infectious Complications

- A *localized infection* at the catheter site can manifest as redness, swelling or oozing from the site. Patient may sometimes develop fever or tachycardia and the bedside nurse should vigilantly monitor for these clinical signs.
- *Central Line Associated Bloodstream Infection (CLABSI)*: This is an important cause of morbidity in critically ill children in pediatric intensive care units.[13] A CLABSI is a primary bloodstream infection (BSI)

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in a patient who had a central line within 48 hours of the development of the BSI and is not related to an infection at another site.[14] This is not the same as catheter related BSI, which is a clinical definition that is used when diagnosing and treating patients, and requires specific laboratory testing that identifies catheter as the source of infection. Common causative organisms include gram positive organisms such as *Staphylococcus aureus, Coagulase-negative staphylococci (CoNS), Enterococcus, etc. and gram negative organisms such as Klebsiella pneumoniae, Escherichia coli and Pseudomonas aeruginosa*. A more specific diagnosis of catheter related bloodstream infection (CRBSI) follows from either demonstrating earlier time to positivity or colony count >10^5 colony forming units per mL from two specimens: one from the catheter and another from a peripheral venous site.

- *Occlusion*: Resistance to flow of infusion when attempting to flush a catheter may indicate occlusion. Aspiration with syringe may demonstrate inability to draw blood samples from the catheter. This can happen due to thrombosis or inadvertent kinking of the catheter. It can rarely be caused by precipitation of any medications or solution incompatibilities. Thrombosis is one of the dreaded complications after pediatric cardiac surgery. Neonates, patients with low oxygen saturation (<85%), use of deep hypothermic circulatory arrest, longer cumulative times of central lines, previous thrombosis, heart transplantation, and use of extracorporeal membrane oxygenation (ECMO) has been associated with postoperative thrombosis after pediatric cardiac surgery.[15] Thrombosis can be decreased by using a continuous flush system that ensures the patency of the catheter. Several centers prophylactically use a continuous heparin drip to prevent venous thrombosis in neonates and small infants with indwelling CVCs though there is no strong evidence in favor of heparin flushes when compared to normal saline for periodic flushing of the catheter. Precipitation occluding the catheter can also be limited to a large extent by taking care not to allow mixing of medications or solutions with known incompatibilities (e.g., calcium and bicarbonate). A collective team effort to remove CVC at the earliest possible window, seems to be the best strategy to prevent significant venous thrombosis.

CVC INSERTION SITE CARE AND DRESSING POLICY[16]

Transparent dressings are preferred as it offers visibility of the catheter insertion site while monitoring for signs of infection or bleeding. Transparent dressings should be changed every 7 days or sooner if it becomes loose or soiled. If gauze is used under the dressing, then the sterile dressings should be changed every 48 hours or sooner if it is soiled or loose. Assess and change gauze dressing as needed. Change to transparent dressing as soon as possible.

CVC DRESSING CHANGE

Articles: Sterile transparent dressing, alcohol swabs, chlorhexidine solution, sterile gauze pieces, dressing tray, sterile gloves.

- Two nurses are required to change the dressing. One person stabilizes the patient and limits movement, while the other changes the dressing.
- Perform hand hygiene and wear clean gloves.
- Remove the old dressing and the tape, while securing the catheter.
- Observe the insertion site for signs of infection, redness, swelling, discharge and skin damage.

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- Remove gloves, perform hand hygiene, and wear sterile gloves.
- Clean the catheter site with chlorhexidine solution. The strokes should be from the center to outer aspect or in a circular fashion from insertion site outwards.
- Clean the catheter if soiled from insertion site to hub, being careful not to dislodge the catheter.
- Allow the cleansing solution to dry completely.
- Apply sterile transparent dressing.
- Observe the CVP waveform for optimal position.

CVC MONITORING AND MAINTENANCE[16]

Monitoring Guidelines

- Central venous lines should be continuously monitored for waveform, and pressure.
- Appropriate alarm limits should be set.
- Transducers are to be taped to the bed, and leveled at the phlebostatic axis.
- A continuous flush system with pressure infuser to be used at 300 mm Hg.
- Zero calibrate the transducers at least once a shift and with position changes.
- If using multilumen catheters, designate each lumen for a specific infusion or purpose. Use the distal lumen for CVP monitoring and blood sampling. Inotropes should be infused through a dedicated lumen. All infusions should be labeled at the proximal and distal ends of the extension lines.
- Use minimum number of three ways required for administering drugs or infusions through the central lines to decrease infectious complications.
- An injection port should be connected at the proximal access port for administering stat drugs which need to be given through the central line.
- CVC access ports should not be kept open. It should be closed with sterile end caps or needleless connectors.
- Monitor the system continuously for presence of air bubbles. Ensure that all air bubbles are removed after accessing the catheter or changing the IV tubing.
- Monitor the system for any backflow of blood into the extension lines. If noted to have any backflow, look for any loose connections or emptying of the continuous flush solution bag. The lines should then be flushed free of any traces of blood.
- Flush the catheters using push-pause technique to increase turbulence and more effectively clear the lumen. Ensure that all air bubbles are displaced from the lumens after accessing the catheter.
- All connections must be luer locked, to minimize catheter or tubing disconnection.

Catheter Maintenance

One of the key quality improvement interventions that has successfully brought down CLABSI have been the use of central line bundle checklists.[17] This refers to the systematic use of a group of evidence-based practices to prevent central line associated BSIs by all members of the health care team by the utilization of a prevention bundle checklist. Typically the bundle checklist action items should be monitored while maintaining the catheter in PCICU. A prototype of a composite bundle checklist for preventing hospital acquired infections that is utilized at our center is provided as **Figure 3**. In patients with CVC in PCICU ensure the following points:

- Follow the central line bundle checklist for maintenance of the catheter.
- The duration for which the catheter is maintained in the postoperative period, is dictated by the clinical need and assessed daily during multidisciplinary rounds.

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Pt. Name:				MRD No.					Dr./Dept				ICU									
CENTRAL LINE BUNDLE FOLLOW-UP	**CENTRAL LINE REMOVED ON:**												**DONE BY:**									
	DAY 1			**DAY 2**			**DAY 3**			**DAY 4**			**DAY 5**			**DAY 6**			**DAY 7**		
	Shift 1	**Shift 2**	**Shift 3**	**Shift 1**	**Shift 2**	**Shift 3**	**Shift 1**	**Shift 2**	**Shift 3**	**Shift 1**	**Shift 2**	**Shift 3**	**Shift 1**	**Shift 2**	**Shift 3**	**Shift 1**	**Shift 2**	**Shift 3**	**Shift 1**	**Shift 2**	**Shift 3**
Hand hygiene performed before and after manipulating the catheter																					
Hub cleaning done before accessing the catheter																					
Daily review of catheter insertion site																					
U. CATHETER BUNDLE FOLLOW-UP	**FOLEY'S CATHETER REMOVED ON:**												**DONE BY:**									
Proper fixing of catheter on thigh																					
Urobag not touching the floor																					
Urine flow should remain unobstructed																					
Perform routine hygienic metal care																					
Hand washing done after catheter/urobag manipulation																					
Maintaining closed drainage system																					
Uro bag emptied every 6 hours																					
Proper disinfection of sample collection site																					
Urine aspirated for culture using sterile needle and syringe																					
Specimen transported to lab within 2 hours of collection																					
Sterility maintained throughout the procedure																					
Hand washing done after removal of gloves																					
VENTILATOR BUNDLE FOLLOW-UP	**DATE OF EXTUBATION:**												**DONE BY:**									
Head elevation (30-45ºC)																					
Antiseptic oral care																					
Daily sedation vacation																					
PUD prophylaxis																					
DVT prophylaxis																					
Assessment of readiness to extubate																					
Instructions: If "Yes" place "√" or "x" if " No"/Please write comment (if any) in the respective box.																					

Fig. 3: A prototype of maintenance bundle checklist.

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- The catheter should be promptly removed as soon as it is not essential for patient care.
- The catheter site should be monitored regularly for any evidence of infection and leaking.
- If the catheter is suspected as a source of infection, it should be promptly removed.

Accessing the Catheter for Injection

- Minimize the number of manipulations, and entries into the catheter. Combine the tasks to decrease the risk of contamination.
- Perform hand hygiene using antiseptic soap and water or chlorhexidine hand rub before and after handling the catheters and IV system.
- Wear sterile gloves.
- The injection port should be wiped with chlorhexidine swab for 15 seconds. Attach the medication syringe or IV tubing to the port, taking care not to introduce air bubbles, and infuse the medication. After the medication is infused, remove air bubbles if any, and flush the catheter with normal saline by pulling the fast flush valve of the transducer.
- Flush and discard volumes may be less for fluid sensitive patients (<3 kg), and more for patients with larger catheters, but should be at least three times the catheter lumens' priming volume.
- Perform hand hygiene after accessing the catheter.

Blood Drawing

- Perform hand hygiene and wear clean gloves.
- Turn off all infusions briefly and clamp lumens not used for blood sampling before drawing blood.
- Draw the sample from the largest or the most distal lumen if possible.
- Place a 2 × 2 cm gauze piece under the sampling port.
- Clean the sampling port and aspirate 5 mL blood from the larger lumen. Then withdraw the amount of blood required for laboratories and inject into appropriate vacuette®. Reinfuse the initially aspirated 5 mL blood after drawing the samples for laboratories without any air bubbles.
- Flush the catheter and hub with normal saline and restart previously stopped infusions.
- If no medication is to be given, close with a fresh stopper/injection port.

REMOVAL OF CENTRAL LINE IN THE ICU

Articles: Suture removal set, sterile gloves, hand rub, alcohol swabs, chlorhexidine solution, No. 11 surgical blade, gauze pieces, and adhesive tape.

- Central lines should be removed when no longer essential, and early deintensification should be encouraged to minimize colonization and occurrence of catheter related BSI.
- The decision to remove the CVC should be taken based on the hemodynamic status of the child, requirement of inotropic supports, need for frequent sampling of blood and need for parenteral nutrition.
- Obtain confirmation from ICU physician.
- Two staff nurses are required, one to stabilize the patient, and another to remove the line.
- Stop infusions, and close the T-connector or three-way.
- Perform hand hygiene, and wear clean gloves.
- Remove the dressing.
- Skin preparation should be done with chlorhexidine solution.
- Stabilize the catheter, and remove sutures using the No. 11 surgical blade.
- Withdraw the catheter slowly.

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- Apply manual pressure with gauze for at least 5 minutes, until bleeding is controlled.
- If bleeding is controlled, apply occlusive dressing to prevent air embolism through skin tract. Otherwise apply pressure for 5 minutes followed by pressure dressing and close monitoring.
- Inspect the catheter and make sure it is intact.
- Remove gloves.
- Perform hand hygiene.
- Document on flow sheet the date of removal, condition of catheter, and any associated complications during removal.

SUMMARY

Central venous pressure monitoring and use of CVCs are routine practices in postoperative period after congenital heart surgery. CVC can be associated with complications during insertion, and maintenance. Institution of care bundles helps to improve standard of care, and minimizes catheter-related complications. Prolonged duration of an indwelling CVC increases morbidity, and the team should collectively decide on catheter removal at the earliest.

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