
Mechanical and Infectious Complications of Central Venous Cannulation in Children: Lessons Learned From a 10-Year Experience Placing More Than 1000 Catheters

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We sought to better describe the expected incidence of mechanical and infectious complications associated with central venous cannulation of critically ill children. We undertook a retrospective analysis of a prospective data collection of 1056 consecutive percutaneous central venous catheters inserted under the supervision of an experienced surgeon. There were 245 (23%) subclavian (SC), 118 (11%) internal jugular (IJ), and 693 (66%) femoral (F) catheters placed in 289 children with an average age of 6.4 ± 5.1 years (range, 4 weeks to 18 years) admitted to a burn intensive care unit. Catheter sepsis occurred in 7.4% of SC, 7.6% of IJ, and 4.9% of F catheters (NS, $P = .25$), for an overall sepsis rate of 5.8%. The number of catheter lumens did not impact infection rate. Infection rates increased in catheters left in situ more than 10 days, increasing to 37.5% at 14 days. Acute mechanical complications occurred in three insertions (0.3%), including two (0.8%) SC, zero (0%) IJ, and one (0.1%) F catheters (NS, $P = .20$). All three were arterial cannulations that were recognized and treated successfully without surgery. There were no pneumothoraces, vascular lacerations, acute thromboses, or catheter emboli. There were six (0.6%) cases of deep venous thrombosis that occurred in cannulated sites: one (0.4%) SC, two (1.6%) IJ, and three (0.4%) F sites (NS, $P = .23$). Patient age did not influence complication rates. A total of 239 (23%) of the CVCs were placed in infants less than 24 months; 273 (26%) 2 to 5 years, 259 (25%) 6 to 10 years, and 285 (27%) >10 to 18 years. Catheter sepsis occurred in 6.7%, 5.9%, 6.2%, and 4.6%, respectively (NS, $P = .75$). There was no difference in rates of infection or mechanical complication between younger and older children. When closely supervised by an experienced surgeon, a low rate of infection (5.8%), acute mechanical complication (0.3%), and deep venous thrombosis (0.6%) accompanies central venous cannulation of critically ill children. (*J Burn Care Res* 2006;27:713-718)

Accurate data on central venous catheter (CVC) infectious and mechanical complication rates in children are scarce, particularly in children with serious burns. In a 2002 review of CVC use in burn patients, Appelgren et al¹ noted a rate of 6 infections per 1000 catheter days. Eichelberger et al,² in a 1981 review of 191 CVCs in nonburn children, noted that 5.8% of

catheters became infected. The rates of mechanical complications are likewise not well documented in children, but anecdotal reports of pneumothorax, hemothorax and hydrothorax, and cardiac tamponade demonstrate the potentially lethal nature of technical misadventures when placing CVCs in children.³ In a report of 322 pediatric CVC placements, Casado-Flores et al⁴ reported a 4% overall mechanical complication rate, with 2.8% requiring urgent surgical intervention for pneumothorax, hydrothorax, or hemothorax. In a retrospective review of 587 cannulations in infants and small children, complications occurred in 28% of the catheters with two deaths caused by cardiac tamponade.⁵ Catheter fragmentation and embolization may also occur, albeit rarely.⁶ We present the largest prospective review of central ve-

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nous catheterization results in children that has been published, to our knowledge.

METHODS

A retrospective analysis of prospectively collected data was performed of a 10-year experience with placement of 1056 consecutive CVCs in a pediatric burn unit. The data are collected as part of the hospital quality assurance program. The data analysis and publication was approved by the institutional human studies committee. The overwhelming majority of the catheters were placed in the operating room by, or under the direct supervision of, an attending surgeon. Catheters were placed under general anesthesia using strict aseptic Seldinger technique.⁷ Sonography was not used to facilitate line placement. Those few not placed in the operating room generally were inserted in the intensive care unit, in an intubated and sedated child, using sterile gowns and gloves, skin preparation, and drapes. Skin preparation was with povidone-iodine solution, and catheters were dressed with iodine ointment and a clear occlusive dressing. Antibiotic and antiseptic-bonded catheters were not used, given the absence of data to support their efficacy in this population with a known high incidence of CVC sepsis. Burn patients have frequent bacteremias associated with wound manipulations that can seed intravascular catheters,^{8,9} and catheters must often be placed near or through burn wounds. For this reason, burn programs routinely rotate catheter sites.¹⁰ Our protocol is to rotate catheters weekly to a new site.^{11,12} Catheter sepsis, or catheter-related bloodstream infection (CR-BSI) rates, were calculated per 100 catheter and 1000 catheter days, with infection defined using the Centers for Disease Control definition.^{12,13} Results were compared by χ^2 analysis and incidence density ratio, with significance defined by $P < .05$.

RESULTS

There were 1056 consecutive CVCs placed in 289 children; 262 children were burned and had an average

burn size of $38 \pm 24\%$ (range, 1 to 97). An additional 27 children had nonburn conditions, such as toxic epidermal necrolysis, purpura fulminans, or major soft-tissue avulsions. The average age of these children was 6.4 ± 5.1 years (range, 4 weeks to 18 years). The CVCs were left in place an average of 6.3 ± 3.1 days. There were 245 (23%) subclavian (SC), 118 (11%) internal jugular (IJ), and 693 (66%) femoral (F) catheters placed. There were 113 (11%) single- (SL), 602 (57%) double- (DL), and 341 (32%) triple- (TL) lumen catheters placed.

CR-BSI rates were 7.4% for SC, 7.6% for IJ, and 4.9% for F catheters (NS, $P = .25$), for an overall CR-BSI rate of 5.8% and 9.2 per 1000 CVC days (Table 1). Infection rates were 2.7% for SL, 6.3% for DL, and 5.9% for TL catheters (NS, $P = .31$). There were no infections in 10 pulmonary artery catheters, although they were not included in this review. It is possible that the absence of a significant difference in infection rates between single and multilumen catheters is a type 2 error, based on the low number of single-lumen catheters, but no difference was seen in these data.

Acute mechanical complications occurred in three insertions (0.3%), including two (0.8%) SC, zero (0%) IJ, and one (0.1%) F catheters (NS, $P = .20$). All three acute mechanical complications were arterial cannulations that were recognized and treated successfully by catheter removal and local pressure. There were no pneumothoraces, vascular lacerations, acute thromboses, or catheter emboli. Deep venous thrombosis (DVT) was diagnosed in previously cannulated sites in six instances (0.6% of cannulations), including one (0.4%) SC cannulation, two (1.6%) IJ cannulations, and three (0.4%) F cannulations (NS, $P = .23$). These occurrences of DVT were clinically suspected on physical examination. Routine ultrasound screening was not performed.

The incidence of infectious and mechanical complications was examined by age: 239 (23%) of the CVCs were placed in infants younger than 24 months; 273 (26%) in children 2–5 years of age, 259 (25%) in children 6 to 10 years of age, and 285 (27%)

Table 1. Catheter sepsis rates

	No. CVCs	No. CVC days	Average days per CVC	No. Primary BSIs	% of CVCs infected	Rate per 1000 CVC days
IJ	118	660	5.6 ± 2.7	9	7.6*	13.6
SC	245	1799	7.3 ± 3.4	18	7.4*	10.0
F	693	4162	6.0 ± 3.0	34	4.9*	8.2
Total	1056	6621	6.3 ± 3.1	61	5.8	9.2

BSIs, bloodstream infection; CVCs, central venous catheter; F, femoral; IJ, internal jugular; SC, subclavian.

* $P = .25$ (not significant).

in children >10 to 18 years of age. CR-BSI occurred in 6.7%, 5.9%, 6.2%, and 4.6% of the groups, respectively (NS, $P = .75$; Table 2). There was no difference in rates of mechanical complication between younger and older children.

To reduce the incidence of catheter sepsis associated with the frequent occult and overt bacteremias seen in this unique patient population, our routine includes the removal and replacement of catheters weekly.^{9,14} This practice was supported by the data, with the rate of CVC infection increasing rapidly after 10 days (Figure 1). Guidewire exchange was used in 259 (25%) of the catheters. Guidewire exchange was only performed if sites were unburned and clean, if children did not appear septic, or if there were no alternative new insertion sites available because of burns or fresh grafts. They generally were performed if catheters had become occluded. There was no difference in infection rates between CVCs placed at a new site (5.8%) or by guidewire (5.8%).

DISCUSSION

This is the largest reported series of pediatric CVC, to our knowledge. These data support the safety of CVC in children, provided insertions are attended by experienced personnel. Key aspects of safe cannulation can

Table 2. The incidence of infectious complications by age

	<2 yrs	2–5 yrs	6–10 yrs	>10 yrs
No. CVCs total	239	273	259	285
No. CVC days	1404	1682	1692	1843
No. Primary BSI	16	16	16	13
% CVC with Primary BSI	6.7%*	5.9%*	6.2%*	4.6%*
Primary BSI rate per 1000 CVC days	11.4	9.5	9.5	7.1
Insertion by site				
% IJ	12.1	12.5	9.3	10.9
% SC	20.5	21.6	27.0	23.5
% F	67.4	65.9	63.7	65.6
% Primary BSI by site				
IJ	3.5%	11.8%	8.3%	6.5%
SC	10.2%	8.5%	8.6%	3.0%
F	6.2%	3.9%	4.9%	4.8%

BSIs, bloodstream infection; CVCs, central venous catheter; F, femoral; IJ, internal jugular; SC, subclavian.

* $P = .75$ (not significant).

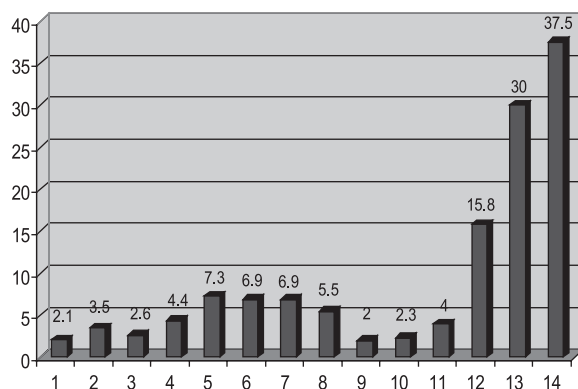


Figure 1. Catheter sepsis rate by duration of insertion.

be divided into two categories 1) general principles applicable to all insertions (Table 3) and 2) anatomic principles applicable to specific sites of insertion (Table 4).

Areas of controversy include the use of antibiotic or antiseptic catheters and CVC rotation policies. Existing data comparing standard to antibiotic or antiseptic catheters involve generally short-term catheter use in nonburn patients¹⁵ and the use of catheter colonization, rather than infection, as the study endpoint.^{16,17} Studies have shown no reduction in infection with impregnated catheters.¹⁸ Concerns have been raised over the generation of antibiotic resistance with their widespread use.¹⁹ This experience describes a policy of standard catheter use with weekly rotation.

Scheduled rotation of CVC has been a part of burn practice for many years,¹⁰ based on data suggesting that prolonged in situ catheter times lead to increased incidence of septic complications, both CVC infection as well as septic thrombophlebitis.^{12,20} It is thought that catheters are seeded by the frequent bacteremias experienced by burn patients, as well as by migration of bacteria from insertion sites near or through burn wounds.⁹ The frequency of catheter rotation varies, as does the use of guidewire exchange, with little convincing data available to determine best practice. There is one report that demonstrated a decreased infection rate with no rotation, but the numbers of catheters used was small, and the catheter infection rate exceptionally high in both groups (21% vs 14%), making the study difficult to interpret.²¹

The absence of an increased risk of infection rates in femoral catheters was surprising. It is probably related to the fact that the groin is not intertriginous in the critically ill child (as the neck often is). Further, particularly in diapered younger children, the groin often is protected from burning.

Table 3. General insertion principles applicable to all catheter sites

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- The operator should be knowledgeable of the anatomy, indications for line placement, complications and their management, and have adequate individual experience and/or supervision. The family should be properly counseled.
 - The operator should be physically comfortable. The child should be comfortable if not under anesthesia. Anesthesia often is justified to facilitate safe cannulation of young children, especially subclavian cannulation.
 - Determine in advance the depth of insertion and choose an appropriate catheter length. It is ideal if the line can be fully inserted because such lines are more secure.
 - Know how long your needle is so you can have an idea of how much guidewire must be introduced before the guidewire enters the vein.
 - Widely prep and drape the field. Prep and drape common alternate sites simultaneously.
 - It is ideal not to attempt contralateral upper body sites, especially subclavian sites, after failure, to avoid bilateral pneumothoraces.
 - Equipment should be placed on a sterile field so it is within easy reach in the sequence it will be needed. Fumbling for a guidewire located inside an equipment tray placed behind the operator while trying to stabilize a needle in a central vein is best avoided.
 - Very carefully pick the skin puncture site, using palpation, a Doppler probe, or an ultrasound (in decreasing order of general utility).
 - With a #11 blade, puncture the skin at the insertion site to eliminate skin friction on the needle interfering with needle control.
 - Make sure the needle is attached loosely to the syringe so it can be removed without moving the needle. A small amount of saline or heparin flush solution in the syringe will facilitate subsequent needle clearance.
 - Align the needle bevel with the syringe numbers so you know the orientation of the bevel at all times.
 - Hold the needle hub with the thumb, index, and middle finger of the nondominant hand while resting the ulnar two digits of the hand on the patient. Hold the syringe with the thumb, index, and long fingers of the dominant hand while gently aspirating with the ring and small fingers. This syringe-needle holding arrangement allows for maximum control.
 - Most central veins are not round but relatively flat in cross-sectional diameter, especially in hypovolemic patients. Rapid insertion often results in transfixion of the vein without a telltale return of blood into the syringe. Insert and withdraw slowly.
 - If seemingly unsuccessful with entering the vein on first insertion, you may have transfixed it. Therefore, remove the needle *slowly* while maintaining gentle aspiration. It is quite common to successfully enter central veins while removing the needle.
 - When you have free aspiration and injection of blood, maintain eye contact with the needle insertion site while gently removing the syringe and placing the guidewire insertion sleeve into the hub of the needle. Gently advance the guidewire through the needle. If the guidewire does not *easily* pass, *stop*. Many people have unconsciously pushed the needle deeper, transfixing the vein. With the guidewire withdrawn into the needle, withdraw the needle 1 mm and *gently* reintroduce the guidewire. If it does not *easily* pass, remove the guidewire, place it down where it can be easily reached, replace the syringe and reverify that you are in the vein lumen by free aspiration and easy injection of blood. Then reintroduce the guidewire and try again.
 - Always introduce the curved end of the guidewire first. Only rarely should the straight end be used. Even in very small children, the curved end of the guidewire should pass. Using the straight end risks perforation.
 - Once the guidewire is in past the end of the needle, insert it gently to a degree that there is a proper amount of external guidewire to accept the entire length of the catheter.
 - Remove the needle and place the dilator on the guidewire. *Gently* and *slowly* advance the dilator. If you rapidly or forcefully try to pass the dilator, it is possible to buckle the wire-dilator, damaging the vessels and/or deforming the wire.
 - Do not persist beyond reason at the primary site. Abandoning a primary site and moving to a secondary site is sometimes necessary and demonstrates good judgment.
 - If a line is essential, for example a patient on vasopressors through an existing line, avoid guidewire exchange.
 - Pneumothoraces frequently are too small to be seen on the initial chest X-ray. If insertion was difficult, a repeat film some hours later is advisable.
 - Be wary of becoming entangled with intravenous filters if excessive guidewire is passed in their presence. This risk is a particular common with right femoral insertions.
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In most experienced burn units, catheter rotation frequency varies from every 48 hours to every 7 days. We have experienced a septic catheter rate of approximately 6% when changing catheter sites every 7 days and generally avoid guidewire exchange.^{13,22} This practice is supported by the increased rate of infection noted in those catheters left in situ longer than this.

Acute mechanical complications are perhaps the most feared aspect of central cannulation of young children, with many of these complications, some being lethal, requiring urgent surgical intervention. Most reports describe a rate of acute mechanical complications requiring urgent surgical intervention of between 2.5% and 4%.^{4-7,13,23-27} In children, bed-

Table 4. Insertion principles specific to anatomic catheter location

Subclavian insertion

- A small vertical roll should be placed vertically between the shoulder blades to gently extend the neck. Hyperextension is not useful.
- The head should be turned 30 degrees to the contralateral side and the child placed into Trendelenburg position with the arms at the side.
- A wide skin prep ideally includes the ipsilateral internal jugular site.
- Routine landmarks are used for insertion, but the skin should be pierced at least 2 cm from the clavicle to allow a straight trajectory of the needle to the vein without deforming the soft tissues. If this is not done, the guidewire may subsequently assume a difficult undulating route as it passes beneath the clavicle.
- The clavicle should be gently touched by the needle tip to be certain of needle tip location, especially if the child is edematous.
- Advance the needle slowly with gentle suction on the syringe.
- When free flow of blood is obtained, pass the guidewire gently. If there is any resistance, remove the wire, replace the syringe, and manipulate the needle until you again have free flow of blood. Usually the needle tip has been advanced too far into and through the vein.
- Watch the cardiac monitor for ectopy. Back the wire out if there is excessive ectopy. The presence of ectopy implies venous placement into the central circulation.
- In small children, a finger placed on the base of the neck will often allow one to feel a guidewire advancing cephalad into the internal jugular vein. It may also direct the wire centrally.
- It is important to dilate the clavipectoral fascia slowly and gently. It is not necessary to pass the dilator deeply, and doing so may risk injury to the central venous structures if the dilator is forced to take a hard curve or be otherwise misdirected.

Internal jugular insertion

- Position the child with a small roll placed vertically between the shoulder blades. Extremes of position will flatten the vein and may make cannulation more difficult.
- Extending both the neck and the head independently while the head is gently turned to the side contralateral to the insertion will place the mandible down, so as to interfere less with the needle and attached syringe.
- The child should be placed in moderate Trendelenburg position to distend the central venous system and to decrease the risk of air embolism.
- The ideal position for the operator is standing at the child's head, on the side opposite to the side of insertion, so as to have a straight needle and guidewire trajectory.
- Insertion can be done in two general positions. A low insertion can be done at the cephalad apex of the triangle formed by the two heads of the sternocleidomastoid muscle. The needle is directed toward the ipsilateral nipple. A higher insertion, at the level of the cricoid, may be associated with a lesser risk of pneumothorax. This insertion is done by first palpating the cricoid ring, then sliding the fingers laterally until the carotid artery is clearly palpated. The internal jugular vein is just lateral to this point.
- The vein is flat and superficial. It is commonly transfixated on initial insertion. Insert and withdraw slowly, being careful not to pull the needle tip out of the vein while removing the syringe and inserting the guidewire.
- Ectopy supplies useful information, but should not be allowed to be excessive.

Femoral insertion principles

- The femoral vessels take a relatively sharp posterior direction into the pelvis as they cross beneath the inguinal ligament. Therefore, insertion is more effective, and safer, if they are cannulated below the ligament, where their course is flat in relation to the operator.
- Especially in hypovolemic patients, the femoral vein is quite flat in anteroposterior dimension, and is commonly transfixated at initial insertion. Slowly withdrawing the needle after initial ineffective venipuncture often will result in successful cannulation.

side ultrasound has not been found to be reliably useful to facilitate cannulation or to decrease mechanical complications.^{24,28} The direct involvement of an experienced operator is likely to be an important factor in reduction of mechanical complications.³

Although the study is a retrospective analysis of a prospective data collection, documentation of an acute mechanical complication rate of 0.3%, supports the contention that the incidence of mechanical com-

plications can be markedly lowered by careful attention to detail, with adequate supervision of all catheter insertions. Further, this low rate of mechanical complications is not affected by the age or size of the child. In conclusion, catheter sepsis rates can be kept acceptably low in pediatric burn patients, and a very low rate of mechanical complications is possible at all sites and in all age groups when insertions are routinely attended by an experienced operator.

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