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Original Article

A model for a nurse-led programme of bedside placement of peripherally inserted central catheters in neonates and infants with congenital cardiac disease

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Abstract *Background:* Neonates and infants with congenital and acquired cardiac disease often require placement of central venous lines for extended intravenous therapy. It may be advantageous to avoid the larger venous vessels of the head and neck and lower extremities in order to preserve these for future interventions and therapies. We evaluated the results of a nursing led peripherally inserted central catheter team in our congenital cardiac centre. *Materials and methods:* Bedside peripherally inserted central catheter the insertion procedures were evaluated for success, complications, and completion of therapy. *Results:* A total of 125 peripherally inserted central catheters were successfully placed in 105 patients. The mean age at the time of placement was 13.5 plus or minus 19.1 days; median age was 7 days; mean weight was 3.5 plus or minus 1.1 kilogram. Cyanotic cardiac disease accounted for 76% of the diagnoses. Central placement of these lines was successful in 78% of patients. Complications during insertions were limited to inadvertent arterial access in five (3%) infants and oxygen desaturations during sedation for the procedure in two (1%) patients. None of the infants suffered long-term compromise from arterial access; none required intubation for the desaturations. The team was able to respond to 90% of their requests within 24 hours. Median catheter dwell time was 14 days. *Conclusion:* In a population of infants with cardiac disease, a nursing staffed peripherally inserted central catheter team achieved an insertion rate of 78% with few complications and a rapid response time. Reliance on bedside insertion permits continuous critical care monitoring and may eliminate the need for fluoroscopy.

Keywords: Congenital cardiac disease; neonates and infants; nurses; peripherally inserted central catheters

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CHILDREN WITH CONGENITAL AND ACQUIRED cardiac disease often will require extended central venous access before and after surgical interventions and for the treatment of chronic cardiac failure. These populations are at substantial risk for catheter-associated blood stream infections and vessel thrombosis, as well as the inherent risks of repeated invasive procedures and exposure to sedation. The small size of these infants and their complex venous anatomy may also present technical challenges for successful placement of central venous lines. In many instances, sparing of the larger venous vessels such as the femoral and internal jugular vein is desirable. This attenuates the risk of catastrophic vessel occlusion and preserves these sites for possible future cardiac catheterisations. This is particularly important with single-ventricle patients who may undergo multiple surgeries and staged repairs. There is extensive and long-term experience with the use of peripherally inserted central catheters in neonates and infants.[1–4] Peripherally

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inserted central catheters are well-tolerated for extended periods of time and may avoid disruption and damage to the larger central venous vessels. Successful percutaneous insertion of a peripherally inserted central catheter may also eliminate the need for more invasive cut-down procedures.

Several models of peripherally inserted central catheter insertion programmes exist in paediatric centres.[5–7] These models vary from a bedside nurse programme in the neonatal intensive care unit,[6] to a "hybrid" model of nurses placing peripherally inserted central catheters in radiology with radiology support[5] or an all interventional radiology physician programme.[7] Before the implementation of bedside placement and a nurse-led peripherally inserted central catheter service at The Children's Hospital and The Heart Institute in Denver, the peripherally inserted central catheters placed in children with congenital cardiac disease were performed so by attending cardiac intensivists, neonatologists, paediatric cardiac fellows, or interventional radiologists, and performed by a variety of techniques. At present, at The Children's Hospital, the peripherally inserted central catheter team is exclusively led and staffed by dedicated registered nurses. Here, we present a 36-month review of the team's performance for peripherally inserted central catheter placement in neonates and infants in the cardiac intensive care unit.

Materials and methods

Patients and study design

After receiving institutional review board approval, a review was conducted on data gathered prospectively on the 161 consecutive peripherally inserted central catheter insertions in neonates and infants, 12 months of age and under, admitted to the cardiac intensive care unit from January, 2006 to December, 2008 for peri-operative or medical care. The cardiac intensive care unit is a 16-bed intensive care unit dedicated to the care of acutely ill neonates, infants, children, and young adults with congenital or acquired cardiac disease. The peripherally inserted central catheters placed were used for multiple types of therapy and infusates including vasoactive medications, parenteral nutrition, and long-term antibiotic therapy. All insertions were performed at the bedside by a peripherally inserted central catheter nurse, who as part of the hospital-wide peripherally inserted central catheter team is dedicated to line placement, monitoring, and care of these lines. Insertions were performed by direct visualisation, palpation, or ultrasound.

A database and spreadsheet was developed and maintained by the primary investigators and data collection was initiated at the time of insertion and completed once the catheter was removed. Variables collected prospectively included patient characteristics, underlying cardiac diagnoses, indication for catheter placement, procedural specifics including vein used, catheter characteristics, and other insertion-related complications. Ongoing catheter monitoring and removal information was also collected.

Educational requirements for registered nurses before peripherally inserted central catheter clinical training included didactic and practical components for insertion and care and management of the catheters by a qualified instructor as approved and recommended by the Association of Vascular Access.[8] Successful insertions were performed by the nurse with the preceptor present, until competency was achieved as agreed upon by both clinicians.

Description of the catheter placement

All procedures were performed bedside in the cardiac intensive care unit with the necessary cardiopulmonary monitoring. Sedation was provided as necessary by the attending physician or the bedside nurse following the American Society of Anesthesia Guidelines. The decision to use sedation and the choice of sedation was at the discretion of the cardiac intensive care physician. At the time of peripherally inserted central catheter placement, the nurse and the physician devised a sedation plan for each patient. If propofol was used, the physician was present to titrate the infusion to affect. When intermittent sedation was used, this was given at the discretion of the peripherally inserted central catheter nurse and the bedside nurse.

The veins were located primarily by palpation or visualisation. Ultrasound was provided by a SonoSite 180^{TM} with a 38-millimetre linear probe of 5–10 megahertz (SonoSite, Bothell, Washington, United States of America) was available for part of this study period. A majority of catheter placements were performed in the upper extremity although a few lower extremity insertions were attempted. After the location and quality of veins were assessed and a site chosen, the non-intubated infant was swaddled and an estimation of catheter length was determined by following the pathway of the vein from insertion site to one finger-breadth above the nipple line. Infants requiring mechanical ventilation were not swaddled. The extremity was prepared and draped in a sterile fashion and maximal sterile barrier precautions[9] were followed. A modified Seldinger technique[10–13] was used in all of the procedures. The vein was accessed using 22- or 24-gauge peripheral intravenous catheters. A guide wire of 0.014 or 0.018 inch was then advanced through the cannula into the vein but advanced no further than the proximal portion of the extremity. The site was then anaesthetised

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subcutaneously with a small amount of 1% lidocaine solution without epinephrine buffered with sodium bicarbonate ratio of 10:1. The catheter was then trimmed by using a Trimming Tool^{TM14} (Becton Davis, Franklin Lakes, NJ, USA) according to the previously taken measurement. By using a two-piece peel away 5-centimetre dilator, the vein was dilated just enough to ensure that the larger portion of the dilator was indwelling. The inner portion of the sheath dilator was removed and the catheter advanced. Techniques used to facilitate placement included slow advancement, retracting the stylet 0.5–1 centimetre into the body of the catheter or using a "float-in" flushing technique with a syringe of normal saline. If resistance was encountered during advancement, the extremity and/or patient's head was repositioned. Ultrasound in some instances was used to scan the ipsilateral internal jugular region to check whether or not the catheter was malpositioned.

Portable X-ray was obtained bedside to confirm peripherally inserted central catheter placement. The peripherally inserted central catheter nurse was responsible for repositioning the catheter if necessary. Central access was defined as the catheter tip residing in the superior caval vein, cavoatrial junction, or inferior caval vein. Dressing changes were performed by the peripherally inserted central catheter team, time permitting, otherwise this was performed by the primary bedside nurse. The peripherally inserted central catheter nurses were also available for occlusion management or other problems related to site care. The endpoint for tracking catheter outcomes was upon catheter removal or discharge date if the patient was discharged or transferred with the catheter in place for the purpose of the study.

Results

A total of 161 procedures were attempted with successful catheter placement in 125 cases, in a total of 105 patients, for an overall success rate of 78% (125 of 161). Demographic data (Table 1) are based on the first insertion in cases of multiple insertions. The median age at the time of peripherally inserted central catheter placement was 7 days with a mean age of 37 days, range: 1–265 days. In all, 74% of the 105 patients were neonates, defined as greater than or equal to 28 days of age. The median weight at time of insertion was 3.3 kilograms with a mean weight of 3.5 plus or minus 1.1 kilograms with a range from 1.8 to 7.6 kilograms. Cyanotic cardiac lesions accounted for 76% of the patient's diagnoses. The most common diagnosis was hypoplastic left cardiac syndrome found in 29% of patients, followed by the transposition of the great arteries in 13% of patients.

Table 1. Patient characteristics.

N = 105		
Sex		
Female	42	40%
Male	63	60%
Age		
0–8 days	78	74%
29–365 days	27	26%
Mean: 13.5 days (+/−19.1; range: 1–288 days)		
Median: 7 days		
Weight		
Mean: 3.5 kg (+/−1.1)		
Median: 3.3 kg (range: 1.8–7.6 kg)		
Most common diagnoses		
Hypoplastic left cardiac syndrome	30	29%
Transposition of the great vessels	14	13%
Tetralogy of Fallot	8	8%
Cyanotic	80	76%
Non-cyanotic	25	24%

Table 2 outlines procedural information for the 161 total procedures attempted. The basilic and cephalic veins were the most commonly accessed veins. An ultrasound was used for visualisation in 23% of the cases. A SonoSite S-ICU^{TM} (SonoSite, Bothell, Washington, United States of America) using a 25-millimetre linear probe of 6–13 megahertz) was implemented in October, 2008. With this newer technology used in the last 3 months of the study, the rate for successful peripherally inserted central catheter insertion increased to 90%. Patients received intravenous sedation during 57% of the procedures, and a titrated continuous propofol infusion was used in 3% of the procedure for five patients. A total of 38% patients with 61 procedures did not require any sedation and were managed with comfort measures including swaddling and a sucrose-dipped pacifier. Central placement was achieved in 75% of the insertions. About 29 malpositioned catheters in jugular veins, contralateral subclavian veins or right atrium required manipulation to achieve successful central placement.

The mean number of attempts needed for successful placement was 2.4 plus or minus 1.3. Procedural complications included inadvertent arterial access in five patients, that is, 3% of the total procedures attempted. One of these neonates experienced a transient arterial compromise after arterial access. He was taken for exploration and underwent a sympathectomy, but found to have an intact brachial artery. He has since fully recovered with no neurovascular or functional sequelae. Of note, all the inadvertent arterial punctures occurred before the adoption of ultrasound use. The other procedural complications noted were documented in

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Table 2. Procedural and catheter information.

Attempted insertions (N = 161)		
Successful placement	125	78%
Sedation		
Intravenous sedation	91	57%
Oral medications	4	2%
Propofol/general anaesthesia	5	3%
None (concentrated glucose)	61	38%
Technique used		
Palpation	120	76%
Ultrasound	36	23%
Number of attempts per patient		
Mean	2.4 (±1.3)	
Complications of the procedure		
Arterial access	5	3%
Transient desaturation	2	1%
Successful insertions (N = 125)		
Veins used		
Basilic (includes median cubital)	60	48%
Brachial	5	4%
Cephalic	60	48%
X-ray results		
Central		
SCV/cavo–atrial junction	95	76%
Non-central	30	24%
Subclavian	13	
Axillary	9	
Brachiocephalic	5	
Other	3	
Catheters used		
L-Cath® (dual lumen) 2.6 Fr	75	60%
L-Cath® (dual lumen) 3.5 Fr	3	2%
FirstPICC® 2.8 Fr SL	42	34%
PerQCath® 3.0 fr SL	5	4%
Catheter dwell (0–71 days)	Mean 16.6 days (± 11.1) Median 14 days	

SCV, superior caval vein

Table 3. Catheter performance and reasons for removal.

	N	%
Successful placement	125	
Successful completion		
End of therapy	78	62
Transfer or discharge home	5	4
Expired	7	6
Total completion	90	72
Reasons for early catheter removal	35	
Catheter occlusion	7	5.6
Broken/leaking catheter	6	4.8
Dislodgment	5	4.0
Unable to reposition	5	4.0
Bacteremia	4	3.2
Catheter-associated bloodstream infections (per 1000 line days): 1.9		
Leaking at the site	3	2.4
Edematous extremity	1	<1
Reason not known	4	3.2

two non-intubated patients who experienced desaturations related to hypoventilation with the administration of sedation. These patients required transient non-invasive support but did not decompensate further and did not require intubation. Catheters remained in place for up to 71 days, with a mean dwell time of 17 days and a median time of 30 days. The peripherally inserted central catheter team was able to provide same day insertion service in 60% of the referrals and another 30% of the insertions were performed within 24 hours of the referral. The remaining peripherally inserted central catheter lines were placed within 3 days after the referral was received.

Table 3 outlines catheter performance for the 125 successfully placed catheters. Successful treatment included completion of therapy, home discharge, and transfer to another facility, or expiration with the catheter in place. This was achieved in 72% of the time (90 catheters). This left a total of 35 instances in which early catheter removal was required. The most frequent complications were catheter occlusions in seven (6%) of patients, six (5%) broken or leaking catheters, and five (4%) unplanned catheter removals. Four patients developed catheter-associated bloodstream infections with *Staphylococcus* species, none were identified as *Staphylococcus aureus*. The infection rate was 1.9 incidences per 1000 line days. This was below the hospital's internal target rate for catheter-associated bloodstream infections for intensive care patients.

A total of 36 of the 161 peripherally inserted central catheter insertion attempts were unsuccessful. The most common reasons as cited by the peripherally inserted central catheter nurses were difficulty with advancing guide wires and/or dilators in 16 instances, or difficulty in accessing the vein in 11 instances.

Discussion

This study describes the adoption and performance of a nursing led, bedside placement peripherally inserted central catheter team in a population of critically ill neonates and infants with congenital and acquired cardiac disease. The neonate and infant with either congenital or acquired cardiac disease may present particular challenges to successful placement and maintenance of central venous lines. The peripherally inserted central catheter team in our cardiac intensive care unit experienced few complications as well as a low incidence of catheter-associated bloodstream infections. The team was also able to respond to referrals in a rapid and efficient manner. All the insertions were performed at the bedside in the cardiac intensive care unit. This permitted patients to remain under close monitoring and reduced the inherent risks of transporting a critically ill patient to the radiology suite.

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Continuing evaluation should show an improvement as the nurses gain experience.

The peripherally inserted central catheter team depended primarily on palpation techniques to achieve successful placement. The SonoSite 180™ was available for vein visualisation for the majority of the study, but found to be more useful on larger infants because of the size of the probe and the resolution of the image. Our success rate increased dramatically with the introduction of the SonoSite S-ICU™ late in the study used for vein visualisation. A majority of our patients suffered from cyanotic cardiac disease and were prostaglandin dependent. They, therefore, often required placement of peripherally inserted central catheters within the first few hours and days of life. This acuity as well as their weight at the time of insertion may speak to the challenges of placing peripherally inserted central catheters in these patients. In fact, as shown by the high number of neonates with hypoplastic left cardiac syndrome, these may be considered among the most tenuous of patients in the cardiac intensive care unit.

Organisations such as the Association for Vascular Access,[15] Infusion Nursing Society,[16] and Society of Interventional Radiology[17] have released position statements or guidelines stating that the distal third of the superior caval vein or the cavoatrial junction are the recommended tip locations for central lines. The national association of neonatal nurses guidelines for practice[18] states that catheter tips should reside in the superior caval vein and this could also be included for the inferior caval vein. Centrally placed tips are associated with lower rates of complications such as thrombosis, catheter occlusion, and leaking at the catheter insertion site.[19–21] From the author's experience it was not always possible to obtain central access in neonates and infants through the bedside techniques of palpation, visualisation, and ultrasound guidance. However, the ability to obtain central placement at the bedside compared favourably in our model to others who collected initial X-ray location data.[22,23] One quarter of the peripherally inserted central catheters placed did not meet the previously mentioned criteria for central venous location. This must be considered a limitation of bedside peripherally inserted central catheter placement. Ultimately these devices were not removed and were successfully utilised after the therapy or infusates were adjusted accordingly.[24]

Other models for peripherally inserted central catheter placement in paediatrics have utilised interventional radiologists and fluoroscopy,[7] bedside registered nurses in a neonatal intensive care unit,[6] and a hybrid model of registered nurses placing peripherally inserted central catheters with the support of radiology.[5] These models provide a similar success rate for placement as well few complications. In the author's opinion, an important benefit of bedside placement is maintaining critical care monitoring in a safe environment of an often fragile or unstable patient. Related to this, another benefit of our bedside insertion model is eliminating transportation of a potentially unstable patient out of the cardiac intensive care unit. Finally, this bedside model also avoids the cost of fluoroscopy that other models may incur. Of course, in the absence of a direct comparison of cost, it is difficult to say which of these models is financially preferable. Future research should include a cost analysis of different models.

A limitation of this study is that it is reflective of the experience of a single centre. There was no analysis of data before the implementation of an exclusive bedside nursing led peripherally inserted central catheter insertion model; thus it is not possible to state that the dedicated bedside insertion team led by nurses is necessarily better than other models. It also remains to be seen if with the increased use of bedside ultrasound to assist insertion, whether the incidence of complications such as inadvertent arterial puncture can be further reduced.

Conclusion

A nursing led peripherally inserted central catheter team can provide safe and efficient peripherally inserted central catheter insertions in the critically ill neonate and infant with congenital and acquired cardiac disease. More experience is needed to determine the degree of improvement that may occur with the use of the upgraded portable ultrasound; however, it is possible to build a successful programme of bedside peripherally inserted central catheter insertion lead by dedicated and trained nurses in a congenital cardiac centre.

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References

1. Trotter CW. A national survey of percutaneous central venous catheters practices in the neonates. Neonatal Netw 1998; 17: 31–38.
2. Rudin C, Nars PW. A comparative study of two different percutaneous venous catheters in newborn infants. Eur J Pediatr 1990; 150: 119–124.

3. Durand M, Ramanathan R, Martinelli B, Tolentino M. Prospective evaluation of percutaneous central venous silastic catheters in newborn infants with birthweights of 510 to 3950 grams. Pediatrics 1986; 78: 245–250.
4. Dolcourt JL, Bose CL. Percutaneous insertion of silastic central venous catheters in newborn infants. Pediatrics 1982; 10: 484–486.
5. Gamulka B, Mendoza C, Connolly B. Evaluation of a unique, nurse-inserted, peripherally inserted central catheter program. Pediatrics 2005; 115: 1602–1606.
6. Linck DA, Donze A, Hamvas A. Neonatal peripherally inserted central catheter team. Evolution and outcomes of a bedside-nurse-designed program. Adv Neonatal Care 2007; 7: 22–29.
7. Tan L, Hess B, Diaz LK, et al. Survey of the use of peripherally inserted central venous catheters in neonates with critical congenital cardiac disease. Cardiol Young 2007; 17: 196–201.
8. Manly L, Williams A. The NAVAN PICC course approval program is new and improved. J Vasc Access 2000; Spring: 34–35.
9. Centers for Disease Control and Prevention. Guidelines for the prevention of intravascular catheter-related infections. MMWR Recomm Rep 2002; 51: 1–29.
10. Pettit J. Technological advances for PICC placement and management. Adv Neonatal Care 2007; 7: 122–131.
11. Frey AM. Peripherally inserted central catheters in neonates & children: modified seldinger (Microintroducer) technique. J Vasc Access 2002; 7: 9–16.
12. Sansivero GE. Use of imaging and microintroducer technology. J Vasc Access Dev 2001; 6: 7–13.
13. Royer T. Nurse-driven interventional technology. J Infus Nurs 2001; 5: 326–331.
14. Pettit J. Trimming of peripherally inserted central catheters: the end result. J Assoc Vasc Access 2006; 11: 209–214.
15. National Association of Vascular Access Networks. NAVAN position statement. J Vasc Access 1998; 3: 8–10.
16. Infusion Nursing Society. Infusion nursing society standards of practice. J Infus Nursing 2006; 29: S1–S92.
17. Lewis CA, Allen TE, Burke DR, et al. Quality improvement guidelines for central venous access. J Vasc Interv Radiol 2003; 14: S231–S235.
18. Pettit J, Wyckoff MM. Peripherally inserted central catheters: guidelines for practice. Natl Assn Neonatal Nurses 2001; document 1221: 1–42.
19. Racadio JM, Doellman DA, Johnson ND, Bean JA, Jacobs BR. Pediatric peripherally inserted central catheters: complications rates related to catheter tip position. Pediatrics 2001; 107: E28.
20. Kearns P, Coleman S, Werner J. Complications of long arm catheters: a randomized trial of central vs peripheral tip location. J Parenter Enteral Nutr 1996; 2: 20–24.
21. James L, Bledsoe L, Hadaway LC. A retrospective look at tip location and complications of peripherally inserted central catheter lines. J Intraven Nurs 1993; 16: 104–109.
22. Fricke BL, Racadio JM, Duckworth T, Donnelly LF, Tamer RM, Johnson ND. Placement of peripherally inserted central catheters without fluoroscopy in children: initial catheter tip position. Radiology 2005; 234: 887–892.
23. Chaturvedi A, Bithal PK, Dash H, Chauhan RS, Mohanty B. Catheter malplacement during central venous cannulation through arm veins in pediatric patients. J Neurosurg Anesthesiol 2003; 15: 170–175.
24. Thiagarajan RR, Bratton SL, Gettmann T, Ramamoorthy C. Efficacy of peripherally inserted central venous catheters placed in noncentral veins. Arch Pediatr Adolesc Med 1998; 152: 436–439.