

**Incidence of Complications Associated with Long Term Use of Peripherally Inserted
Central Catheters in Pediatric Cardiac Patients**

A thesis submitted to the University of Arizona College of Medicine – Phoenix in partial
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Abstract

Objective: Peripherally inserted central catheter (PICC) lines are increasingly used in neonatal and pediatric cardiac patients for long term, stable central line access and treatments. Although previous studies describe complications in the general pediatric population, this study's objective is to determine the incidence of PICC line-related complications amongst pediatric cardiac patients.

Study design: This retrospective chart review of 351 cardiac intensive care unit (ICU) patients aged between 0 days and 18 years old at a tertiary care pediatric hospital evaluated 556 PICC lines and the complications associated with their long-term use.

Results: Of the total 556 PICC lines inserted, 96.5% (n = 537) were successfully inserted with complications occurring in 31.3% (n = 168) of the successfully inserted lines. The type and incidence of complications identified in the study sample included catheter dislodgement (17.5%), migration/malposition (5.9%), thrombus (2.9%), leaking (2.4%), infection (1.3%), and catheter damage (1.1%).

Conclusions: Pediatric cardiac patients at this single institution had a much lower thrombus and infection incidence rate than previous studies have identified. The incidence of overall PICC line-associated complications in this cohort of pediatric cardiac patients (31.3%) is similar to the general population but remains high overall, thus indicating the need for further study and vigilance to limit adverse events.

Introduction

With the increased number and complexity of neonatal and pediatric congenital heart disease, surgeries, and treatments, the use of centrally placed catheters is increasing for stable postoperative central access. Central venous lines are particularly essential and useful for simultaneously continuous cardiac monitoring and intravascular central access for medications, fluid administration, parenteral nutrition, and laboratory sampling [1]. Central venous lines can include peripherally inserted central catheter (PICC) lines and catheters placed in internal jugular (IJ), femoral, subclavian, or intracardiac positions [2]. These lines are frequently used in patients requiring surgery, intensive care and those in oncological and hematological units [2].

Traditional central venous lines used include non-tunneled or tunneled central venous catheters or subcutaneous venous ports positioned in the superior vena cava after insertion via the subclavian or IJ veins [2]. Significant complications associated with traditional central venous lines include pneumothorax, arterial puncture, hemothorax, stroke, arrhythmias, nerve damage, infection, deep venous thrombosis, dislodgement, and line occlusion [2]. A newer approach that is often alternatively used in place of the traditional venous catheter is the use of PICC lines [2]. PICC lines are long flexible catheters inserted through the skin into the basilic or cephalic vein, the antecubital fossa, or the lower extremity venous system with ultrasound or fluoroscopic guidance [2]. The catheter after insertion is placed in the superior or inferior vena cava or at the cava-atrial junction for central venous circulation [2].

In many institutions, PICC lines are generally placed postoperatively in children when long-term central access is necessary [3]. Common indications for PICC placement in pediatric populations include need for inotropic support, severe infection requiring prolonged antibiotic

therapy, chemotherapy, total parenteral nutrition, and frequent blood sampling among others [4-7]. One of the benefits of PICC lines as well as other centrally placed catheters is its use for multiple types of infusions regardless of pH and osmolarity as they protect peripheral veins from irritants or vesicants such as chemotherapy, parenteral nutrition, vasopressors, and inotropes [5, 7]. Also, PICC lines seem to be safer to insert than centrally inserted central catheters [7]. Contraindications to PICC placement include burns, trauma, skin infections, and disrupted skin integrity at insertion site [5].

Due to the manner of insertion, PICC lines are thought to be associated with fewer serious complications [2]. Complications include thrombosis, leakage, PICC fracture, infection, and PICC dislodgement [4]. Other severe complications associated with PICC line use include cardiac arrhythmia and cardiac tamponade when the tip is located in the heart [6]. Existing literature studying PICC lines in pediatric cardiac patients is scant and have shown variable complication rates. The data is limited due to minimal number of studies, short-term duration of studies, and small sample sizes [3, 8-9]. There is a paucity of data assessing the morbidity associated with long term PICC line use in neonatal and pediatric cardiac patients [10]. Long term, stable central line access is a necessity when treating pediatric cardiac patients. Central line access with minimized risk of complications further results in improved efficacy and safety for these medically vulnerable patients. Given the scant number of studies assessing complications of PICC lines specifically in pediatric cardiac patients, the aim of this study is to determine the type and incidence of PICC line-related complications in pediatric cardiac patients at a large tertiary center.

Material and Methods

Study Setting and Design

This retrospective study was conducted in a tertiary, multidisciplinary pediatric cardiac intensive care unit (ICU) at Phoenix Children's Hospital. Approval, with waivers of consent and Health Insurance Portability and Accountability Act (HIPAA) authorization, was obtained from the Institutional Review Board prior to initiation of the study. The primary outcome of the study was to determine the incidence and type of complications associated with the long term use and removal of PICC lines in pediatric cardiac patients admitted to the cardiac ICU. Measured complications include thrombus, occlusion, infection, bleeding post-removal, failed removal, and catheter migration.

Study Population, Data Collection, and Statistical Analysis

The study population included patients aged 1 day to 18 years admitted to the cardiac ICU after their cardiac surgery between July 1, 2016 and June 30, 2018 that received percutaneously inserted central catheters. Patients whose cardiac surgeries were performed at other institutions, who did not have percutaneously inserted central catheters, or who were admitted to the cardiac ICU for other reasons were excluded.

Eligible patients were obtained from the institutional database. The electronic medical records of all eligible, admitted patients were reviewed retrospectively. Demographic data on the

age was recorded. Data on the type, location, and characteristics of the PICC line placed was collected and analyzed. Collected data on the characteristics of PICC lines included number of PICC lines per patient, day of placement (weekday vs. weekend), location of placement, size, location of catheter tips, and duration of line placement. Data on complications and removal of these lines were also recorded. Demographic, clinical, and PICC line data and their complications for the overall cohort of patients were described using medians and ranges for continuous variables and percentages for categorical variables.

Results

The study included 351 cardiac patients with a median age of 4.5 months (range, 0 days to 18 years old). Amongst the total of 556 PICC lines inserted in this patient population, 151 patients (43%) had 2 lines placed, 37 (10.5%) had 3 lines placed, 10 (2.8%) had 4 lines placed, and 7 patients (1.9%) had 5 or more lines placed. The majority of PICC lines (81.4%) were placed during weekdays (Monday to Friday). Of the total 556 PICC lines, 537 (96.5%) were successfully placed.

Of the 537 successfully placed PICCs, the location of the PICC line's tips were at the cavoatrial junction in 225 (41.9%), in the inferior vena cava in 214 (39.9%), superior vena cava in 62 patients (11.5%), in the right atrium in 16 (2.9%), and in other vessels in 20 patients (3.7%). In terms of location of placement, 291/556 (52.3%) were placed in the radiology department, 227/556 (40.8%) in the ICU setting, 20 (3.6%) in the catheterization laboratory, 3 (0.5%) on the inpatient floor, 2 (0.3%) in the operating room, and 13 (2.3%) in other locations. A large portion of the PICC lines placed were double lumen lines ($n = 513$, 92.2%) with the remaining 43 being single lumen. Regarding size, four catheters sizes were used: 2.6 French [Fr], 3 Fr, 4 Fr, and 5 Fr. Of them, 291 (52.3%) were 4 Fr, 163 lines (29.3%) were 2.6 Fr, 80 lines (14.4%) were 3 Fr, and 22 (3.9%) were 5 Fr. Thirty-nine of the 351 patients (11.1%) were safely discharged home with the PICC line in place to continue home therapy. The median duration of PICC line placement, defined as time from placement to removal or discharge home, was 17 days (range, 0 to 202 days).

Complications occurred in 168 of the 537 successfully placed PICC lines (31.3%). Among the 168 lines with complications, the most common complication was catheter dislodgement ($n = 94$, 55.9%), followed by migration/malposition ($n = 32$, 19%), thrombus development ($n = 16$, 9.5%), leakage ($n = 13$, 7.7%), suspected line infection ($n = 7$, 4.1%), and catheter damage ($n = 6$, 3.5%). The incidence of each complication amongst all 537 successfully placed PICC lines were 17.5% for dislodgement, 5.9% for migration/malposition, 2.9% for thrombus development, 2.4% for leaking, 1.3% for suspected infection, and 1.1% for catheter damage. Table 1 includes the number and percentage of PICC lines with complications for each category of adverse event.

Sixty-nine of the 168 PICC lines with complications (41.1%) were removed from the patient when the complication was found. Amongst these 69 PICC lines removed due to complications, 100% ($n = 6$) of the 6 damaged PICCs, 56.3% ($n = 9$) of the 16 PICCs with thrombus, 53.8% ($n = 7$) of the 13 leaking PICCs, 46.9% ($n = 15$) of the 32 migrated/malpositioned PICCs, 31.9% ($n = 30$) of the 94 dislodged PICCs, and 28.6% ($n = 2$) of

the 7 suspected PICCs with infections were removed. Table 2 includes the number and percentage of PICC lines removed amongst each individual category of complication and amongst all 168 lines with complications.

Table 1: Total number and incidence of PICC lines with complications for each category of adverse event

Complication	No. of Complications	Incidence Amongst Lines with Complications (%)	Incidence Amongst All Lines (%)
Dislodgement	94	55.9%	17.5%
Migration/Malposition	32	19.0%	5.9%
Thrombus	16	9.5%	2.9%
Leaking	13	7.7%	2.4%
Suspected line infection	7	4.1%	1.3%
Catheter damage	6	3.5%	1.1%

Table 2: Total number and percentage of PICC lines removed amongst each individual category of complication and amongst all 168 lines with complications

Complication	No. of Lines with Complication Removed	% Lines Removed for each Complication	% Lines Removed Amongst All Lines with Complications
Dislodgement	30	31.9%	17.8%
Migration/ Malposition	15	46.9%	8.9%
Thrombus	9	56.3%	5.3%
Leaking	7	53.8%	4.1%
Suspected line infection	2	28.6%	1.1%
Catheter damage	6	100%	3.5%

Discussion

The primary finding of our study is a PICC line complication incidence of 31.3% with catheter dislodgement being the most common, followed by migration/malposition, thrombus, leaking, suspected line infection, and catheter damage (Table 1). Amongst pediatric cardiac patients specifically, existing data is limited regarding PICC use and their complications. However, previous studies of the general pediatric population have identified incidence rates of complications ranging from 29 to 41% depending on the patient population, catheter type, and indication of PICC placement [4]. Our study's complication rate of 31.3% is similar to rates identified in existing literature, which mainly included pediatric patients in all levels of care such as outpatient settings, neonates, and oncological patients. Each of these patient populations have various risk factors and therefore make extrapolating results from these studies for cardiac ICU admitted patients difficult. However, general risk factors for complications include double lumen PICCs, PICC placement in the femoral vein, younger age, and higher number of daily medication doses [4]. Previous studies suggest that PICCs used for 21 days or more in pediatric patients and 35 days or more in neonates were more likely to develop complications [4]. Conversely, Barrier et al. found that PICCs in place for shorter durations experienced a complication with the median day of first complication being 7 days. Although our study's

average duration of PICC use is 17 days, it lacks additional data regarding the timing of complication development and the frequency each PICC line was accessed, which is important to assess the significance of these risk factors in this population.

The secondary finding of our study is that our rate of thrombus development (2.9%) is lower compared to previous studies in the general pediatric population [1, 11] and studies on pediatric cardiac patients [8-9]. With regards to line venous thrombosis development in the general pediatric population, data regarding the prevalence of this complication amongst central venous catheters, including PICC lines, varies. While older studies completed in pediatric patients reported PICC-associated thrombus incidence rates ranging from 0 to 5%, a study completed in a tertiary care pediatric hospital found a thrombus incidence of 9.3% using Doppler ultrasonography with only 1 of the 20 patients presenting with clinical symptoms consistent with thrombosis [1]. Similarly, newer studies over the past decade such as a recent multicenter, prospective cohort study completed in 2020 found the overall incidence of central venous catheter-associated thrombosis to be $5.9\% \pm 0.63\%$, but specifically the incidence of PICC-associated thrombosis to be $9.0\% \pm 1.4\%$ [11]. In that particular study, the rate of thrombus development amongst patients with PICCs was significantly higher than the $2.9\% \pm 0.64\%$ thrombosis incidence rate amongst patients with tunneled catheters [11]. Another recent pediatric study completed in 2018 in children found the odds ratio (OR) of thrombus development in PICC lines to be 3.15 when compared to other non-tunneled central venous catheters inserted in the femoral, IJ, or subclavian veins [12]. Regarding studies on pediatric cardiac patients, amongst 76 pediatric univentricular patients who underwent superior cavopulmonary anastomoses, 4% of patients with upper arm PICC lines experienced thrombosis [9]. Additionally, a single-center study involving 115 neonates with congenital cardiac disease admitted to the ICU with PICC lines demonstrated an incidence of thrombosis to be 1.6% [8].

The variation in thrombosis rates can be attributed to their insertion site [11]. PICC lines are placed into smaller caliber vasculature in the forearm, antecubital fossa, or lower extremity and occupy a significant portion of the vessel lumen [11]. Conversely, other types of lines such as tunneled catheters are inserted into larger central veins and have shorter intravascular courses from the site of insertion [11]. Furthermore, intraluminal catheter occlusions mostly occur in smaller catheters, such as PICC lines, due to increased flow resistance and blood stasis [5]. Longer infusions of medications, low flow states, and inadequate catheter flushing can result in the retrograde backing of stagnant blood and increase the risk of catheter occlusion [6]. Risk factors for the incidence of thrombosis in children after cardiac surgery seem to be cardiopulmonary bypass and blood product transfusions, which increase patients' hypercoagulable state [9]. Along those lines, double-lumen PICCs compared to single-lumen PICCs were associated with higher risk of thrombosis with an odds ratio (OR) of 2.77 due to their occupation of most of the vessel lumen [13]. Prior history of thrombosis and a diagnosis of leukemia are also significant risk factors for thrombus development in patients with central venous catheters [11]. Other risk factors studied include repeated PICC insertions in the same arm [13] and more distal catheter tip placement versus proximal placement in the right atrium and superior vena [5]. Of note, previous studies, mostly completed in ICUs, amongst oncological patients, amongst infants, or in single-institution settings also contribute to the variable thrombosis rates [1, 11].

In fact, due to the increasing perceived incidence of PICC line occlusion and thrombosis, Giangregorio et al. evaluated the use of heparin in pediatric heart failure patients awaiting cardiac surgery and requiring continuous inotropic support [6]. The study suggested that patients receiving low dose heparin with their inotropic infusions had a longer period of catheter patency and did not require anti-thrombotics to restore patency [6]. Although this finding was not statistically significant, the study revealed clinically significant results as in pediatric cardiac patients, especially those receiving inotropic support, it is essential that central venous access and line patency is maintained to prevent treatment cessation and subsequent hemodynamic instability [6]. This finding goes along with some recent studies that have associated PICC lines not heparin coated with a higher incidence of thrombosis compared to other central venous catheters and intracardiac lines [3, 11-12].

The tertiary finding of our study is that the rate of line infection (1.3%) is lower in our subset of pediatric cardiac patients when compared to previous studies. In a 2017 single-institution study involving pediatric patients undergoing cardiac surgery, patients with PICC lines had an incidence of line infection of 10% [3]. Within the general pediatric population, the 2020 multicenter CIRCLE study found a much higher infection incidence of $22\% \pm 2.8\%$ in patients with PICC lines compared to other tunneled lines [11]. Noonan et al. also described an increased likelihood of developing catheter infections in children with PICC lines compared to other non-tunneled central venous catheters inserted in the femoral, IJ, or subclavian veins (OR 3.15) [12]. The source of the higher incidence of infections with PICC lines may be due to the site of insertion in the arm, which is often difficult to keep clean and dry [11]. However, a novel access technique using real-time ultrasound-guided distal superficial femoral vein cannulation of PICC lines has proven to have a high success rate with a PICC-associated infection rate of 4.6 per 1000 line-days in 31 critically ill infants with cardiac disease [14]. The discrepancies amongst studies may be due to our institution's larger study population and institutional guidelines or practices.

Our study has a few limitations. As our study was a retrospective database review of a single-center experience with a limited sample, we were not able to evaluate risk factors for complications. Additionally, our data represents a subpopulation of pediatric cardiac patients so it cannot be extrapolated to the general pediatric population. Finally, the absence of standardized PICC care placement and maintenance may be an important confounder. Future studies should expand to include a larger cohort of pediatric cardiac patients and assess risk factors for each complication.

Conclusion

Our study revealed an incidence of PICC line-related complications of 31.3% with catheter dislodgement being the most frequent. We also found a lower rate of thrombus and line infection in our cohort of pediatric cardiac patients when compared to previous studies. Data from this study indicates the need for increased vigilance and monitoring of PICC lines due to their variably high complication rate, especially amongst critically ill, pediatric cardiac patient population.

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