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Predictors of Nonelective Removal of Peripherally Inserted Central Catheters in Infants

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Abstract

Background: Nonelective removal of peripherally inserted central catheters (PICCs) due to complications continues to be a major concern in neonatal intensive care units (NICUs) around the world. Nonelective removal results in interruption of intravenous therapy, added costs, stress, and negative impacts on infant's health. Identification of predictors of complications that lead to nonelective removal of PICCs would allow for the initiation of preventive strategies to improve the quality of care. **Aim:** To identify predictors of nonelective removal of PICCs in neonates. **Methods:** A prospective cohort study with a sample of 524 PICC lines inserted in 436 neonates admitted to a tertiary-level NICU of a Brazilian hospital. Data were collected on all neonates between August 31, 2010, and August 30, 2012. Neonates were monitored daily from insertion of the catheter until its removal. Bivariate analysis and a logistic regression were conducted in order to identify predictors of nonelective removal. **Results:** A diagnosis of a transitory metabolic disorder (hypoglycemia; disorders of calcium, magnesium, sodium, or potassium; or dehydration), previous PICC line insertion, insertion of dual-lumen polyurethane PICC, noncentral tip position, and multiple intravenous solutions in a single-lumen silicone PICC were predictors of nonelective removal of PICC lines. **Conclusion:** The avoidance of repeated PICC insertions, noncentral tip position, and placement of single-lumen silicone PICCs for administration of four or more intravenous solutions is suggested. Interventions should be explored that facilitate PICC insertion success and correct tip placement.

Keywords

central venous catheterization, risk factors, infant, newborn, neonatal intensive care, nursing

Increasing survival rates for preterm and high-risk neonates hospitalized in neonatal intensive care units (NICUs) worldwide increased the need for a better understanding of contributors to reliable vascular access for infusion of medications, fluids, and nutrition. In 1973, Shah and Shah (2008) first described the successful placement of a peripherally inserted central catheters (PICCs) in neonates. Currently, the use of PICCs is an integral part of routine practice in NICUs around the world (Sharpe, 2008).

Despite the benefits of lower sepsis rates and easier insertion when compared to surgically inserted central venous catheters in high-risk neonates, PICCs are associated with complications that lead to nonelective removal of the catheter (LeFlore & Engle, 2007). A nonelective removal of a PICC occurs when there is a complication that limits the functionality of the catheter or threatens the infant's life. These complications include infectious, thrombotic, and mechanical problems (Pettit & Wyckoff, 2007). Nonelective removal of PICCs can potentially result in interruptions of intravenous therapy, added costs, and negative impacts on the infants' health. It thus represents a major concern for nurses worldwide. Identifying the predictors of nonelective removal of PICCs in neonates can clarify nursing interventions necessary to prolong the life of the PICC line until the need for intravenous therapy has passed.

Previous studies have identified predictors of complications of PICCs in neonates such as an insertion at lower extremities (Hoang et al., 2008) or at femoral sites (Hsu et al., 2010), insertion procedures requiring 60 min or more (Tsai & Chu, 2011), duration of use longer than 30 days (Chu, Cheng, Law, & Tso,

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2007), and a noncentral tip position (Jain, Deshpande, & Shah, 2013). However, the roles of potential factors such as the clinical characteristics of the infant, material and number of lumens of the catheter, intravenous therapy that indicated the insertion, antiseptic solution adopted, and previous PICC insertion have not been studied in the neonatal population. The lack of clarity about which factors are most associated with the nonelective removal of PICCs underscores the need for additional research.

The frequent use of PICC lines requires evidence to inform best practices. Identifying factors associated with the nonelective removal of PICCs could help nurses to make decisions regarding the selection of the catheter, insertion technique, and routine care while taking into consideration the clinical conditions of the infant, the infusion therapy prescribed, and the characteristics of the catheter such as the material, number of lumens, and tip position. Such knowledge would support nurses' efforts to implement preventive measures and improve the quality of care, thereby decreasing the incidence of nonelective removal of PICCs. In the present study, we aimed to identify predictors of nonelective removal of PICCs in neonates.

Method and Material

Design

We utilized a prospective cohort study design to identify predictors of nonelective removal of PICCs in hospitalized neonates. Neonates were enrolled following PICC placement and monitored daily until catheter removal. The hospital ethics committee approved the study (#238/2010).

Participants

We recruited a convenience sample of neonates born at the hospital, admitted to the NICU, and submitted to a successful insertion of a single-lumen silicone 1.9-French or dual-lumen polyurethane 2.0-French PICC. Based on our previous study (Costa, Bueno, Alves, & Kimura, 2013) conducted in the same NICU in which we reported a nonelective removal rate of 37.7%, the convenience sample of 524 PICC lines in the present study was adequate to detect an odds ratio of 1.45 for a dichotomized variable equally stratified with 80% of power and 5% of significance level. We followed neonates from the insertion until the removal of the PICC. If a single infant had successive PICCs placed during the hospitalization, he or she contributed more than once in the data analysis. We excluded neonates if there was no reason for PICC removal provided in the medical chart, if they required a surgically placed central venous catheter, or if they were transferred to another institution or died with the PICC still in place.

Data Collection

We collected data from the medical records of the neonates between August 31, 2010, and August 30, 2012. Before including neonates in the study, we obtained informed consent from the parents. Demographic data to describe the sample included infant's weight at the time of catheter insertion, postmenstrual age, postnatal age, gender, and medical diagnoses according to International Classification of Diseases, Tenth Revision.

For each PICC inserted, we collected data about the previous number of PICC lines used by the infant, catheter dwell time of the current PICC line, reason for removal, any complication resulting in nonelective catheter removal, and a variety of factors with the potential to influence nonelective PICC removal. Data collected to evaluate these factors included the number of venipuncture attempts needed to insert each catheter, antiseptic solution used, site of insertion (vein, extremity, and hemisphere of insertion), catheter tip position (central or noncentral), anatomical tip position (axillary, brachiocephalic, jugular, subclavian, superior or inferior vena cava, iliac, or saphenous vein), type of catheter (1.9-French single-lumen silicone or 2.0-French dual-lumen polyurethane), number of distinct intravenous solutions prescribed on the date of catheter insertion, and type(s) of intravenous solution.

The outcome of interest was the "reason for removal of the PICC line." Elective removal occurred when a PICC was no longer required (e.g., end of therapy). Nonelective removal was defined as removal of a PICC due to one of several complications including occlusion, catheter-associated bloodstream infection, external rupture, accidental dislodgment (inadvertent partial or complete removal of the catheter), tip migration, extremity edema, infiltration, extravasation, thrombosis, or phlebitis. If we needed additional information to confirm the reason for PICC removal, we contacted the nurse responsible for care at the time of the removal.

Setting

Data were collected from a 60-bed tertiary-level NICU of a large private maternity hospital in São Paulo, Brazil. The majority of the neonates in this unit are admitted with prematurity, respiratory distress, and congenital diseases. Nurses at the unit are required to participate in a 20-hr training program that consists of didactic and practical development of clinical skills for PICC insertion, maintenance, and removal. At the end of the program, each nurse must answer 70% of the exam questions correctly to achieve a passing score.

In the NICU, the attending neonatologist determined the need for PICC insertion based upon the intravenous therapy prescribed and the clinical condition of the neonate. All PICCs were placed at the bedside under strict sterile conditions by two staff nurses skilled in PICC insertion, maintenance, and removal. The catheter tip location was assessed by a nurse and a physician on a chest radiograph to confirm appropriate placement. The thoracic vertebral bodies and the carina were used as anatomical landmarks to determine the anatomic location of the catheter tip. Catheters were dressed with a sterile transparent semipermeable membrane and surgical strips.

Maintenance care of each PICC included the use of gloves and alcohol swab to access the line, flushing with saline solution using a 10-ml syringe before and after each drug infusion or every 6 hr, and the infusion of saline solution at 0.5 ml/hr when the catheter was being used for intermittent medication. All procedures related to the PICC were performed by the nursing staff. Decisions about PICC removal were made by nurses and the attending neonatologist according to the neonate's clinical condition, type of intravenous therapy, and functionality of the PICC.

Data Analysis

We performed statistical analyses using the Software R, Version 3.01. We report descriptive analysis and median values along with the 25th and 75th percentile. We used bivariate analysis to test the potential predictors of nonelective removal. Specifically, for categorical variables, we used a χ^2 test or Fisher exact test, and for continuous variables, we used the Mann–Whitney U test. For all statistical analyses, we used $p \leq .05$ as a cutoff of statistical significance. We also estimated the relative risk for nonelective removal of the catheter, according to the exposure variable of interest, with a 95% confidence interval (CI).

We performed a logistic regression that included all significant variables ($p \leq .05$) from the bivariate analyses. Additionally, we initially included catheter dwell time and parenteral nutrition in the model because prior research indicated that they could be risk factors for nonelective removal of a PICC (Jumani, Advani, Reich, Gosey, & Milstone, 2013). We entered variables in the multivariable model adopting a stepwise forward modeling technique. Only variables predictive of nonelective removal of the PICC line were included in the final model. We explored an interaction between number of intravenous solutions and type of PICC (silicone single lumen vs. polyurethane dual lumen) by including interaction terms explicitly in the full model and by evaluating a graph of the model estimating nonelective removal rates across number of intravenous solutions for a given type of PICC line.

Results

There were 17,341 births in the hospital and 1,482 admissions to the NICU during study data collection period. Of the neonates admitted to the NICU during this period, 460 (31%) had 550 PICCs inserted and were evaluated for inclusion in the cohort. We excluded 26 of these neonates from the study: 24 because the infant either died or was transferred to another hospital with the PICC still functional and 2 due to lack of information about reasons for PICC removal. The final sample consisted of 524 PICC lines inserted in 436 neonates with a total of 6,200 catheter-days.

The majority of PICCs were inserted in male neonates (55.2%). The most common diagnosis was prematurity (82.6%), followed by respiratory distress syndrome or transient tachypnea of the newborn (68.3%). Most of the catheters were dual-lumen polyurethane PICCs (53.8%) and were centrally located (85.5%). The PICCs were inserted for administration of antibiotics (76.3%), parenteral nutrition (66.8%), and general intravenous access (36.3%). Other baseline characteristics are shown in Table 1.

Table 1. Demographic Characteristics of the Participating Neonates ($n = 436$) With PICCs ($n = 524$) and Characteristics of the PICC Insertions.

Characteristic	Value
Demographic	
Weight (g), median (IQR)	1,600 g (1,175–2,485)
Postmenstrual age (weeks), median (IQR)	33.5 weeks (30.7–36.4)
Postnatal age (days), median (IQR)	4.0 days (2–7)
PICC insertion	
No. of venipuncture attempts, median (IQR)	2.0 (1–4)
No. of intravenous solutions that indicated PICC insertion, median (IQR)	3.0 (2–4)
PICC dwell time (days), median (IQR)	9.0 (6–16)
Previous PICC line insertion, no, *n* (%)	419 (80)
Vein of insertion, *n* (%)	
Axillary	147 (28.4)
Basilic	97 (18.8)
Cephalic	70 (13.5)
Saphenous	61 (11.8)
External jugular	46 (8.9)
Median cubital	42 (8.1)
Dorsal venous arch (hands)	20 (4)
Temporal	11 (2.1)
Dorsal venous arch (feet)	8 (1.5)
Popliteal	8 (1.5)
Posterior auricular	7 (1.4)
Site of insertion, *n* (%)	
Upper extremities	373 (72.6)
Lower extremities	80 (15.6)
Neck	43 (8.4)
Scalp	18 (3.4)
Right	333 (64.8)
Left	181 (35.2%)

Note. IQR = interquartile range; PICCs = peripherally inserted central catheters.

Most PICCs (329, 62.8%) were removed electively on completion of therapy, but 195 (37.2%) were removed because of complications. The overall incidence of nonelective removals was 31.5 per 1,000 catheter-days (see Table 2). Reasons for nonelective PICC removal are listed in Table 2. The average dwell time for all PICCs was 11.8 days (range 1–70 days), with a median of 9 days. The bivariate analysis examined the neonates' baseline characteristics, procedures, intravenous therapy characteristics, and PICC dwell times for their ability to predict nonelective removal of PICC lines (see Table 3). Most variables in this analysis were dichotomized in order to facilitate the applicability of the predictors in clinical practice: for example, a postmenstrual age $\leq$ or >32 weeks. Number of venipuncture attempts, number of intravenous solutions, and PICC dwell time were left as continuous variables.

Table 2. Reasons for Nonelective Removal of PICCs.

Reason	Definition	Incidence per 1,000 Catheter-days
Catheter-associated bloodstream infection	A laboratory-confirmed bloodstream infection where a PICC line was in use during the 48-hr period before development of the infection	11.5
Catheter occlusion	Inability to flush the catheter with saline solution using a 10 ml syringe	5.0
Catheter dislodgment	Inadvertent partial or complete removal of the catheter from the neonate's body	4.4
Catheter rupture	Rupture of the external segment of the catheter	4.0
Extravasation	Escape of potentially injurious solutions from the walls of the vein causing skin redness, edema, and discoloration	1.8
Extremity edema	Mild to severe edema in the area surrounding the catheter insertion site or in the extremity associated with the catheter	1.6
Phlebitis	Inflammatory reaction in the vein associated with the placement and dwell time of a catheter, identified by erythema or palpable venous cord at the vein	1.5
Tip migration	Spontaneous movement of the tip of the catheter at any time while in situ, leading to a peripheral location as identified by radiograph	1.1
Infiltration	Escape of a solution from the walls of the vein causing skin redness, edema, and discoloration	0.3
Cardiac tamponade	Infusion of intravenous solution directly contacting the myocardium	0.2
Thrombosis	Mild to severe edema in extremity associated with the catheter followed by a blood clot visualized with ultrasound	0.2
Total		31.5

Note. PICCs = peripherally inserted central catheters.

Neonates weighing ≤1,500 g at the time of PICC insertion, who were >7 days old or who had a postmenstrual age ≤32 weeks, were at an increased risk for complications leading to PICC removal. Medical diagnoses of sepsis due to necrotizing enterocolitis, urinary tract infection, or nosocomial infection; congenital malformations of the circulatory system (malformations of cardiac septa; malformations of pulmonary, tricuspid, aortic, and mitral valves; or congenital malformation of great arteries); transitory metabolic disorders (hypoglycemia, disorders of calcium or magnesium metabolism, dehydration, and disturbances of sodium or potassium balance); and shock were also associated with nonelective removal of the catheter. Having at least one previous PICC line insertion also increased the incidence of nonelective removal significantly, as did having use of antibiotics as an indication for PICC insertion.

The use of dual-lumen polyurethane PICC, a noncentral tip position, multiple intravenous solutions, and an average number of more than three intravenous solutions also predicted significantly greater risks for nonelective removal. An interaction between the type of catheter and the number of intravenous solutions revealed a flat linear risk for nonelective removal when dual-lumen polyurethane catheters were used. However, for single-lumen silicone PICCs, the risk for nonelective removal increased substantially when four or more intravenous solutions were infused (see Figure 1).

We included in the logistic regression all variables that were statistically significant in the bivariate analysis (weight ≤ 1500 g, postmenstrual age ≤ 32 weeks, postnatal age > 7 days, diagnoses of sepsis, congenital malformations of circulatory system, transitory metabolic disorders and shock, use of dual-lumen polyurethane PICC, previous PICC insertion, noncentral tip position, and catheter indication for antibiotics) and two variables indicated as predictive in the literature (catheter dwell time and parenteral nutrition). The final model consisted of previous PICC line insertion, diagnosis of transitory metabolic disorder, number of intravenous solutions, dual-lumen polyurethane PICC, noncentral tip position, and number of intravenous solutions for dual-lumen PICC because they maintained their prognostic significance (Table 4). We examined the accuracy of the final model by calculating the area under the receiver–operating curve (AUC = 0.73, 95% CI: [0.70, 0.76]).

Discussion

Identifying risk factors of PICC complications will allow neonatal nurses to implement targeted interventions to prevent PICC-related complications and to detect complications early in order to minimize associated morbidities. The predictors of nonelective removal that we found in this study were diagnosis of transitory metabolic disturbance, previous catheter insertion, use of dual-lumen polyurethane catheters, multiple intravenous solutions in a single-lumen silicone PICC, and a noncentral tip position. The average indwelling duration of almost 12 days in the present study was comparable or slightly inferior to other studies conducted in NICUs that reported a mean dwell time of 12 (Gomes & Nascimento, 2013) and 13.5 days (Wrightson, 2013).

Similar to previous studies (Corzine & Willett, 2010; Jain et al., 2013), our findings suggest that noncentral PICCs are twice as likely to have complications necessitating removal than centrally placed catheters. Therefore, neonatal intensive care nurses should prevent noncentral tip positions by accurately measuring the length of catheter to be inserted and assuring a complete insertion of the premeasured length. They

Table 3. Potential Predictors of Nonelective Removal of PICCs.

	Nonelective Removal					
	No ($n = 329$)		Yes ($n = 195$)			
Predictor	*n*	%	*n*	%	*p* Value	*OR* [CI]
Demographics of the neonates						
Weight[a]					.014	1.57 [1.07, 2.28]
≤1,500 g	134	41.2	100	52.4		
>1,500 g	191	58.8	91	47.6		
Postmenstrual age					.005	1.68 [1.14, 2.46]
≤32 Weeks	105	31.9	86	44.1		
>32 Weeks	224	68.8	109	55.9		
Postnatal age					<.001	3.98 [2.62, 6.05]
≤7 Days	281	85.4	116	59.5		
>7 Days	48	14.6	79	40.5		
Medical diagnosis[a,b]						
Prematurity					.46	0.84 [0.51, 1.37]
Yes	274	83.3	158	81		
No	55	16.7	37	19		
Respiratory distress syndrome[a]					.54	0.88 [0.59, 1.32}
Yes	225	69.2	130	66.6		
No	100	30.8	65	33.3		
Sepsis[a]					.01	1.69 [1.1, 2.66]
Yes	55	16.9	50	25.6		
No	270	83.1	145	74.4		
Congenital malformations of circulatory system[a]					<.001	2.33 [1.4, 3.9]
Yes	36	11.1	44	22.6		
No	289	88.9	151	77.4		
Gastrointestinal disorder[a]					.42	1.22 [0.72, 2.05]
Yes	45	13.8	32	16.4		
No	280	86.2	163	83.6		
Transitory metabolic disorders[a]					<.001	3.17 [1.56, 6.62]
Yes	15	4.6	26	13.3		
No	310	95.4	169	86.7		
Shock[a]					.01	3.82 [1.2, 14.2]
Yes	5	1.5	11	5.6		
No	320	98.5	184	94.4		
PICC insertion						
Previous PICC line insertion					<.001	3.61 [2.26, 5.79]
Yes	40	12.2	65	33.3		
No	289	87.8	130	66.7		
Antiseptic solution[a]					.5	
Chlorhexidine alcohol + chlorhexidine gluconate	160	95.8	280	96.9		Reference
Chlorhexidine gluconate (2%)	3	1.8	6	2.1		0.87 [0.13, 4.16]
Chlorhexidine alcohol (0.5%)	4	2.4	3	1.0		2.33 [0.38, 16.09]
2.0-French dual-lumen polyurethane PICC[a]					.007	1.9 [1.3, 2.8]
Yes	159	49.2	119	61.3		
No	164	50.8	65	38.7		
Noncentral tip position[a]					.01	1.9 [1.1, 3.2]
Yes	37	11.5	37	19.7		
No	284	88.5	151	80.3		
Indication for PICC insertion						
Antibiotics					.009	1.8 [1.1, 2.7]
Yes	239	72.6	161	82.6		
No	90	27.4	34	17.4		
Parenteral nutrition					.19	1.3 [0.8, 1.8]
Yes	213	64.7	137	70.3		
No	116	35.3	58	29.7		

(continued)

Table 3. (continued)

	Nonelective Removal					
	No ($n = 329$)		Yes ($n = 195$)			
Predictor	*n*	%	*n*	%	*p* Value	*OR* [CI]
General intravenous access					.3	0.8 [0.6, 1.2]
Yes	125	38	65	33.3		
No	204	62	130	66.7		
Continuous variables	Median	Q1–Q3	Median	Q1–Q3		
Number of venipuncture attempts	2	1–4	2	1–4	.61	
Number of intravenous solutions	3	2–4	3	2–4.5	<.001	
PICC dwell time	9	6–15	10	4–17	.749	

Note. *OR* = odds ratio; CI = confidence interval; PICCs = peripherally inserted central catheters.
[a]Missing data. [b]There was overlap across many medical diagnoses.

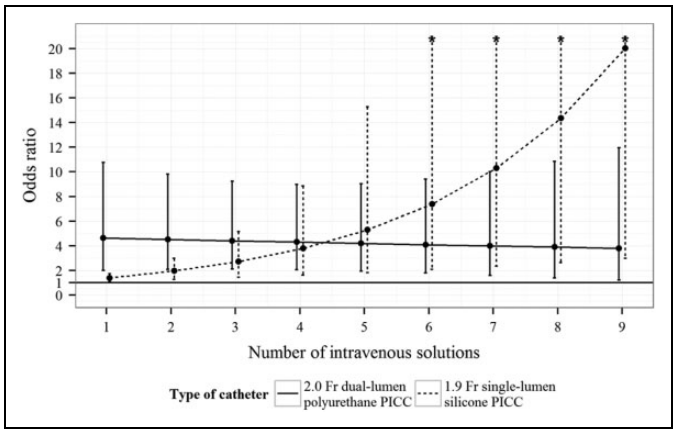

Figure 1. Nonelective removal of peripherally inserted central catheter according to the type of catheter and the number of intravenous solutions that indicated catheter insertion.

Table 4. Multivariate Analysis of the Risk Factors for Nonelective Removal of PICCs.

Risk Factor	*OR* (95% CI)	*p* Value	β Regression Coefficient
Previous PICC line insertion	3.2 [2.0, 5.15]	<.01	1.16
Diagnosis of transitory metabolic disorders	3.1 [1.5, 6.4]	<.01	1.13
Number of intravenous solutions	1.4 [1.1, 1.7]	<.01	0.33
Dual-lumen polyurethane PICC	4.7 [1.8, 12.3]	<.01	1.56
Noncentral tip position	1.9 [1.1, 3.2]	.02	0.63
Number of intravenous solutions for dual-lumen polyurethane PICC	0.7 [0.5, 0.9]	.01	−0.36

Note. *OR* = odds ratio; CI = confidence interval; PICCs = peripherally inserted central catheters.

should also frequently monitor initial signs of extravasation and infiltration such as skin redness, edema, and discoloration in neonates with noncentral PICCs.

Our study identified new predictors of nonelective removal of PICC lines not previously studied in neonates. Dual-lumen polyurethane PICCs were 4 times more likely to be removed when compared to single-lumen silicone PICCs with the administration of only one intravenous solution. A study that evaluated more than 4,000 PICC insertions in adults found that PICCs with fewer lumens reduced complications and costs (O'Brien, Paquet, Lindsay, & Valenti, 2013). However, in that study, when more than four infusates were needed, single-lumen silicone PICCs had higher rates of nonelective removal. A prospective study conducted with 38 adult patients who had 4-French single-lumen PICCs placed for the infusion of long-term antibiotics found that complication rates of PICCs used for a single infusate were lower when compared to catheters used for various infusates (Chu et al., 2007).

Considering the material of the catheter, a randomized controlled trial conducted with 26 adult patients reported no differences among silicone with distal side slits and polyurethane open-end-tip PICCs (Miyagaki et al., 2012). Data are not available to compare the number of lumens by catheter material. However, given the available data, we would suggest using a single-lumen silicone catheter for up to four types of infusates and a double-lumen polyurethane catheter when more than four infusates are required.

Additionally, we found that neonates with transitory metabolic disturbances had 3 times the risk for PICC complications than those without a metabolic disturbance. This finding may be related to the neonate's severity of illness because the more severe, the more likely that additional intravenous fluid, electrolyte, and nutrition will be required.

As with the findings of previous studies (Yang et al., 2012), having a previous PICC line insertion was significantly associated with the nonelective removal of the catheter in the present study. Unfortunately, a frequent challenge during subsequent PICC insertions is the appearance of an occluded or stenotic venous system and associated collateral vessels where the previous PICC resided, commonly in the region of the axillary or subclavian vein (Yang et al., 2012). Our findings reinforce the importance of avoiding catheter-related complications by minimizing the need for more than one PICC during the infant's hospitalization.

Despite the technological advances in the fields of neonatal and pediatric care, health care–related infections continue to be a global challenge due to the variability of diagnostic and therapeutic procedures (Gomes & Nascimento, 2013). In the present study, we found that, after nonelective removal of a PICC line for any cause (incidence of 31.5/1,000 catheter-days), a catheter-associated bloodstream infection was the most common complication for these neonates (incidence rate of 11.5/1,000 catheter-days), followed by occlusion (5/1,000 catheter-days) and accidental dislodgment (4.4/1,000 catheter-days). Previous studies conducted with neonates (de Brito, de Brito, Abdallah, & Gontijo Filho, 2010; Hsu et al., 2010) have reported lower rates for these complications of PICCs.

Considering these findings, we suggest that changes in nursing practice could be beneficial for improving the quality of care and reducing the incidence of nonelective removal of catheters. The use of standardized, evidence-based care practice checklists, bundling care practices, and a dedicated PICC team are associated with reduced central-line-associated bloodstream infections. Implementing a PICC team with a limited number of highly trained individuals, with a standardized, consistent insertion and dressing-change technique with frequent opportunity to maintain their skill levels, is preferable to having a large number of individuals with limited experience and potentially variable techniques inserting PICCs. Use of a PICC team would make it more practical to ensure appropriate continuing education. Educational programs focused on insertion technique and maintenance care have the potential to impact PICC outcomes (Butler-O'Hara & Stevens, 2012; Corzine & Willett, 2010).

The success of quality improvement initiatives to reduce catheter-associated bloodstream infection in NICUs also depends on increasing compliance with the best line-care bundles. One study that evaluated a new maintenance bundle element reported a decrease of 71% in the infection rate in NICUs (Fisher et al., 2013).

Mechanical complications such as catheter occlusion and accidental dislodgment are also preventable. Prophylactic use of heparin for PICCs allows a greater number of neonates to complete therapy by reducing occlusion. Evidence supports the use of heparin in PICCs for neonatal subjects within a 0.5 UI/kg/hr dose (Shah & Shah, 2008). Procedures initiated for prevention of accidental dislodgment, breakage, and infection should include aspects related to the dressing technique. Several priorities should be taken into account when providing a protective skin barrier to the friable skin of extremely low-birth-weight neonates (Gomes & Nascimento, 2013): Most importantly, nurses should avoid excessive manipulation of the catheter, including during dressing changes, except when the dressing is significantly soiled or loose or the catheter becomes exposed (O'Grady et al., 2011). However, evidence is still needed to develop the best clinical dressing practice for the neonatal patient.

Conclusion

In this study, we reported new predictors of nonelective removal of PICC lines in neonates. In order to provide quality PICC care, nurses must have an understanding of evidence-based recommendations to prevent catheter-related complications.

While the single private hospital setting of this study limits the generalizability of the findings, the number of PICC lines ($n = 524$) studied and congruence of findings with other research is promising. Vascular access is a real challenge in neonates, and PICCs are a useful alternative in this population. Data analysis supported the identification of new predictors of nonelective removal of PICC lines in neonates. However, future studies assessing other risk factors related to maintenance care, such as dressing materials, infusion rate of intravenous solutions, and use of technologies such as ultrasound to monitor complications, should be encouraged in order to improve the accuracy of the prognostic model.

Author Contribution

P. Costa contributed to conception and design; contributed to acquisition, analysis, and interpretation; drafted the manuscript; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. A. F. Kimura contributed to conception and design; contributed to analysis and interpretation; drafted the manuscript; critically revised manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. D. H. Brandon contributed to conception and design; contributed to analysis and interpretation; drafted the manuscript; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy. L. P. Damiani contributed to design; contributed to analysis and interpretation; drafted the manuscript; critically revised the manuscript; gave final approval; and agrees to be accountable for all aspects of work ensuring integrity and accuracy.

Authors' Note

The authors declare that all research materials related to the article can be accessed by contacting the corresponding author.

Declaration of Conflicting Interests

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