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A Crossover Randomized Prospective Pilot Study Evaluating a Central Venous Catheter Team in Reducing Catheter-Related Bloodstream Infections in Pediatric Oncology Patients

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Abstract

Background: Treatment for most children with cancer includes the use of a central venous catheter (CVC). CVCs provide reliable venous access for delivery of chemotherapy and supportive care. This advantage is mitigated by an increased risk of bloodstream infections (BSIs). Despite the ubiquitous use of CVCs, few prospective studies have been conducted to address infection prevention strategies in pediatric oncology patients. **Design:** Prospective, crossover pilot study of a CVC team intervention versus standard care. **Setting:** Two inpatient oncology units in a metropolitan children's hospital. **Patients:** A total of 41 patients/135 admissions for the experimental unit (EU) and 41/129 admissions for the control unit (CU). **Methods:** Patients received a CVC blood draw bundle procedure by a CVC registered nurse (RN) team member (experimental intervention: EU) for 6 months and by the assigned bedside RN (standard care: CU) for 6 months. Feasibility of implementing a CVC RN team; a significant difference in CVC-related BSIs between the team intervention versus standard care and risk factors associated in the development of CVC-related BSIs were determined. **Results:** There were 7 CVC-related BSIs/1238 catheter days in the EU group (5.7/1000 catheter days) versus 3 CVC-related BSIs/1419 catheter days in the CU group (2.1/1000 catheter days; $P = .97$). Selected risk factors were not significantly associated with the development of a CVC-related BSI. **Conclusions:** A CVC team in the care of pediatric oncology patients is feasible; however, a larger cohort will be required to adequately determine the effectiveness of the team reducing CVC-related BSIs.

Keywords

central venous catheter, blood stream infection, pediatric oncology

Introduction

The majority of the 12 400 children diagnosed with cancer each year in the United States will benefit throughout their treatments from the placement of a central venous catheter (CVC) for venous access (Smith et al., 2010). However, the use of CVCs, which increases the risk of infection, has been reported predominantly in critically ill adult and pediatric patients (Aly et al., 2005; Institute for Healthcare Improvement [IHI], 2005, 2006; Jeffries et al., 2009; Krein et al., 2007; Parra et al., 2010; Pronovost et al., 2006; Shuman et al., 2010; Wall et al., 2005;). An estimated 250 000 CVC-related blood stream infections (BSIs) occur annually in U.S. hospitals, with associated mortality rates ranging between 12% to 25% (O'Grady et al., 2011). Mean CVC-related BSI rates from the National Nosocomial Infection Surveillance System range from 3.4 to 11.3 per 1000 catheter days in critically ill pediatric and neonatal patients (O'Grady et al., 2011).

Central venous catheter evidence-based practice guidelines and educational programs in pediatric patients have

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been developed (Child Health Corporation of America [CHCA], 2005; IHI, 2006; Jeffries et al., 2009; Morgan & Thomas, 2007; National Association of Children's Hospitals and Related Institutions [NACHRI], 2008). Trends in reduction of CVC-related BSIs have been identified with the implementation of CVC practice guidelines and education programs (Brungs & Render, 2006; East & Jacoby, 2005; Horvath et al., 2009; IHI, 2005; Kline, 2005; Marschall et al., 2008; Render et al., 2006; Yilmaz, Caylan, Aydin, Topbas, & Koksal, 2007). Several investigators have reported specific risk factors (age, CVC type, diagnosis, treatment regimen) thought to be related to an increased incidence of CVC BSIs in children with cancer (Abbas et al., 2004; Fratino et al., 2005; Mirro et al., 1989). Currently, there are no published studies regarding the efficacy of a CVC registered nurse (RN) team for reduction of CVC-related BSIs in pediatric oncology patients.

This report describes the results of a 12 month randomized crossover single-site pilot study testing the use of a CVC RN team compared with standard care for the reduction of CVC-related BSIs in pediatric oncology patients at an urban, tertiary-care pediatric hospital. The primary aims of this pilot study were to evaluate (*a*) the feasibility of implementing a CVC RN team and (*b*) its effectiveness in reducing CVC-related BSIs compared with standard care. The secondary aim was to examine risk factors related to the development of CVC-related BSIs.

Method

After institutional review board approvals, on 2 inpatient oncology units (Unit A and Unit B), a randomized crossover trial of a CVC RN team versus standard care was initiated. To support causal inference while controlling for treatment diffusion and crossover, randomization at the unit level was used. The study was conducted in two 6-month phases. During Phase I, the units were randomized to serve as either the experimental unit (EU) in which all patients received a CVC RN team intervention or as the control unit (CU) in which all patients received standard care for 6 months. During Phase II, all patients admitted to each unit received the opposite intervention for the next 6 months. The experimental intervention included daily application of the CVC blood draw bundle procedure (proper hand hygiene, use of clean gloves, gather appropriate supplies, alcohol 20 second scrub/10 second dry, stopcock method for blood discard, specimen and normal saline flush, maintain sterility, and proper disposal and handling) according to institutional policy and national standards performed by a CVC RN team member (CHCA, 2005; IHI, 2006; NACHRI, 2008; O'Grady et al., 2011). Standard CVC care included daily performance of the same procedure by the assigned bedside RN. The numbers of CVC-related BSIs were reported as the number of infections per 1000 catheter days. The relationship of selected risk factors (gender, age, CVC types, patient acuity, lengths of stay (LOS), number of infection free days, reasons for admissions, and number of blood draws) potentially associated with BSI rates were also determined.

Subjects

The study subjects included pediatric oncology patients with a CVC. Subjects met all of the following eligibility criteria: (*a*) a diagnosis of cancer with a CVC; (*b*) age 2 to 16 years; and (*c*) admitted with a new oncology diagnosis, routine chemotherapy/radiation therapy treatment, or a noninfectious surgical or radiological procedure. Patients were excluded if they were (*a*) <2 or >16 years old, (*b*) admitted with a defined infection, (*c*) under evaluation for a probable infection, and/or (*d*) receiving active end-of-life care.

Instruments

Gender, diagnosis, age, date of admissions, LOS, CVC types, and reasons for admissions were abstracted from medical records onto a general demographic data form. A patient status form including data on patient acuity and BSI was completed during each admission. Patient acuity was measured by the Optilink Healthcare Management patient acuity system (The Advisory Board Company, Washington, D.C.) used at the pediatric hospital. The Optilink electronic management tool collected real-time and reasons for definition of acuity recorded daily by the charge nurses. The principal investigator (PI) verified that the patient acuity recorded by the RNs on the daily patient status form was congruent with the Optilink data. Individual patient data regarding BSIs were abstracted from the monthly laboratory-confirmed BSI report generated by the hospital senior infection control coordinator. A CVC-related BSI was defined as a BSI occurring in study patients who had an indwelling CVC for at least 48 hours prior to the onset of the BSI.

A CVC blood draw bundle procedural checklist was used to record the number of blood draws performed and to document adherence to CVC evidence-based blood draw bundle procedures. The CVC RN team and/or bedside RN were required to complete this checklist for each blood draw procedure performed. Reliability of treatment and measures was ensured by providing staff education, confirming CVC care competencies, and establishing validity and reliability of the checklist prior to study implementation.

Procedures

The PI provided education regarding the study to both units prior to patient enrollment. The PI met with the

parent/primary caregiver of each patient to explain the research study and obtain informed consent. For the EU, the consent process included permission for the CVC RN team to perform the blood draw procedures. In both units, which are spatially separated, identical nurse staffing patterns were employed according to institutional policy and California nurse/patient ratio requirements. Tunneled and non-tunneled CVCs were available for placement in pediatric oncology patients on both units. The decision regarding what types of CVC were placed in patients, however, was determined jointly by the primary physician and family.

All RNs on the study units had identical training, education, and competencies regarding institutional CVC procedures. Additionally, the 10 member RN team for the EU regularly participated as CVC skills lab instructors and members of the unit-based CVC task force. The PI directly observed the team members' performance on the EU and the bedside RNs on the CU for a total of 120 observations.

Statistical Analysis

A priori, estimates from historical hospital data regarding patients meeting eligibility requirements indicated that approximately 140 admissions per month would be available for analysis. These admissions were projected to represent a total of 11 200 catheter days, or approximately 7 catheter days per admission. Power computations were based on a one-sided test with 10% ($P = .10$) type I error, and 80% power to detect a halving of the estimated BSI incidence rate of 5/1000 catheter days, using a two-sample log rank test with an underlying exponential failure process, and assuming equal distribution between units (EU and CU).

Comparison of patient and admission characteristics by unit was conducted by two-sided Fisher's exact test for categorical variables and t test or Wilcoxon rank sum test for continuous variables. Monthly rates of CVC-related BSIs per 1000 catheter days were calculated by unit. For analysis, each admission was considered an independent analytic case. Multiple admissions for the same patient were assigned the same study identification number and distinguished by admission date. The primary endpoint, the incidence rate of BSIs, was estimated for each unit by dividing the number of new infections by the total number of catheter days on the unit and reported as BSIs per 1000 days with 95% confidence intervals. A one-sided Fisher's exact test was performed to determine whether the CVC RN team (EU) resulted in a significant reduction over standard care (CU). A 50% reduction is believed to indicate a clinically important change by the IHI in CVC-related BSIs compared with standard care (CU; IHI, 2005; Rubinstein et al., 2005).

Table 1. Patient Characteristics by Unit

Characteristic	CU; n (%)	EU; n (%)	P
No. of patients	41	41	NA
Gender			
Male	25 (61.0)	22 (53.7)	
Female	16 (39.0)	19 (46.3)	.66
Diagnosis			NA
ALL	10 (24.4)	7 (17.1)	
AML	6 (14.6)	6 (14.6)	
NHL	5 (12.2)	2 (4.9)	
ATRT	1 (2.4)	2 (4.9)	
EP	1 (2.4)	0	
EWS	2 (4.9)	1 (2.4)	
MB/PNET	3 (7.3)	4 (9.8)	
NBL	6 (14.6)	9 (22.0)	
Osteosarcoma	3 (7.3)	6 (14.6)	
Other solid tumor	3 (7.3)	2 (4.9)	
Rhabdomyosarcoma	1 (2.4)	2 (4.9)	
Age in years; mean ± SD	8.9 ± 4.8	8.8 ± 3.9	.92

Abbreviations: CU, control unit; EU, experimental unit; ALL, acute lymphocytic leukemia; AML, acute myelogenous leukemia; NHL, non-Hodgkin lymphoma; ATRT, atypical teratoid rhabdoid tumor; EP, ependymoma; EWS, Ewing's sarcoma; MB/PNET, medulloblastoma/primitive neuroectodermal tumor; NBL, neuroblastoma; NA, not applicable.

Poisson regression was used to evaluate selected risk factors for association with developing a BSI, after adjusting for location (Unit A and Unit B) and type of unit (CU vs EU).

Results

In the 12-month study period, there were a total of 82 patients/264 admissions with a total of 2657 catheter days and 1933 blood draws. There were 41 patients/129 admissions on the CU and 41 patients/135 admissions on the EU. The patient characteristics by unit are illustrated in Table 1. No differences were noted between the units in patient gender distribution or age. A summary of patient admission characteristics by unit are displayed in Table 2. There was a significant increase in the number of blood draws per catheter days (0.91 ± 0.66; $P = .0081$ vs 0.68 + 0.34; $P = .0081$) on the EU compared with the CU. Most important, there was a significant difference in the CVC types used on the units, with a significantly greater percent of tunneled versus non-tunneled CVCs on the EU compared with the CU (EU, 66.7% vs 33.3%; CU, 47.3% vs 52%; $P = .0018$), respectively.

Over the 12-month study period, the 10 member CVC RN team successfully performed all blood draw procedures on the EU. During the 40 random observations of the CVC team's performance, the PI observed 100%

Table 2. Admission Characteristics by Unit

Characteristic	CU	EU	*P*
No. of admissions	129	135	NA
	Median (Range)	Median (Range)	
No. of admissions/patient	3 (1-10)	3 (1-11)	.66
	Mean ± SD	Mean ± SD	
LOS (days)	11.0 ± 12.8	9.2 ± 11.2	.4601
Infection-free days	10.9 ± 12.8	8.6 ± 10.4	.3560
Patient acuity (low = 1, medium = 2, high = 3)	1.82 ± 0.31	1.88 ± 0.40	.4357
Blood draws (n)	7.9 ± 10.1	7.8 ± 10.8	.6488
Blood draws/CVC days (n)	0.68 ± 0.34	0.91 ± 0.66	.0081
	n (%)	n (%)	
CVC type			
Tunneled catheters			
Hickman DL	0	20 (14.8)	
Hickman SL	0	2 (1.5)	
Port	41 (31.8)	47 (34.8)	
Apheresis	20 (15.5)	21 (15.6)	
Non-tunneled catheters			
PICC DL	24 (18.6)	26 (19.3)	
PICC SL	44 (34.1)	19 (14.1)	
Tunneled vs Non-tunneled	47.3% vs 52.7%	66.7 % vs 33.3%	.0018
Reason for admission			
Chemo	112 (88.2)	127 (96.2)	
New diagnosis	11 (8.7)	2 (1.5)	
Procedure	3 (2.4)	2 (1.5)	
Surgery	1 (0.8)	1 (0.7)	
No information	2	3	
Chemo vs non chemo	88.2% vs 11.9%	96.2% vs 3.7%	.0192

Abbreviations: CU, control unit; EU, experimental unit; LOS, length of stay; NA, not applicable; CVC, central venous catheter; PICC, peripherally inserted central catheter; DL, double lumen; SL, single lumen; Chemo, chemotherapy.

procedural adherence to the evidence-based and unit guidelines. In 80 random observations of the RN staff on the CU, adherence was 83.6%. The mean time for completion of the procedure did not differ between the 2 units.

Rates of BSI in the CU and EU were 2.1/1000 and 5.7/1000 catheter days; $P = .97$, respectively. There were a total of 10 CVC-related BSIs: 3 on the CU and 7 on the EU (Figure 1). The selected risk factors in the 10 patients that developed BSIs are depicted in Table 3. The CVC RN team intervention (EU) did not significantly reduce the BSI rate compared with the bedside RN (CU; Table 4).

The summary of associations between BSI rate/1000 catheter days and selected potential risk factors adjusted for location and type of unit during the study are presented in Table 5. Multivariate analysis of risk factors did not reveal any significant associations with occurrence of a BSI with the possible exception of CVC type. Having a peripherally inserted central catheter (PICC) CVC increased the incidence rate 7-fold ($P = .054$) over having a non-PICC CVC.

Discussion

This is the first CVC RN team intervention trial for CVC-related BSI reduction in pediatric oncology patients to be reported. The concept of implementing a CVC RN team on a pediatric oncology unit was deemed feasible, and the team adhered to all policies and procedures 100% of the time. In the 15 months preceding the study, the institutional incidence of CVC-related BSIs for all patients admitted to Unit A and Unit B ranged between 0 to 5.2 and 0 to 3.9 per 1000 catheter days, respectively. Overall, the 12-month study demonstrated no evidence of reduction in the rate of CVC-related BSIs in the EU compared with the CU (Table 4). However, there were no CVC-related BSIs in either unit in the final 3-month study period. Ten months post study period, there are sustained

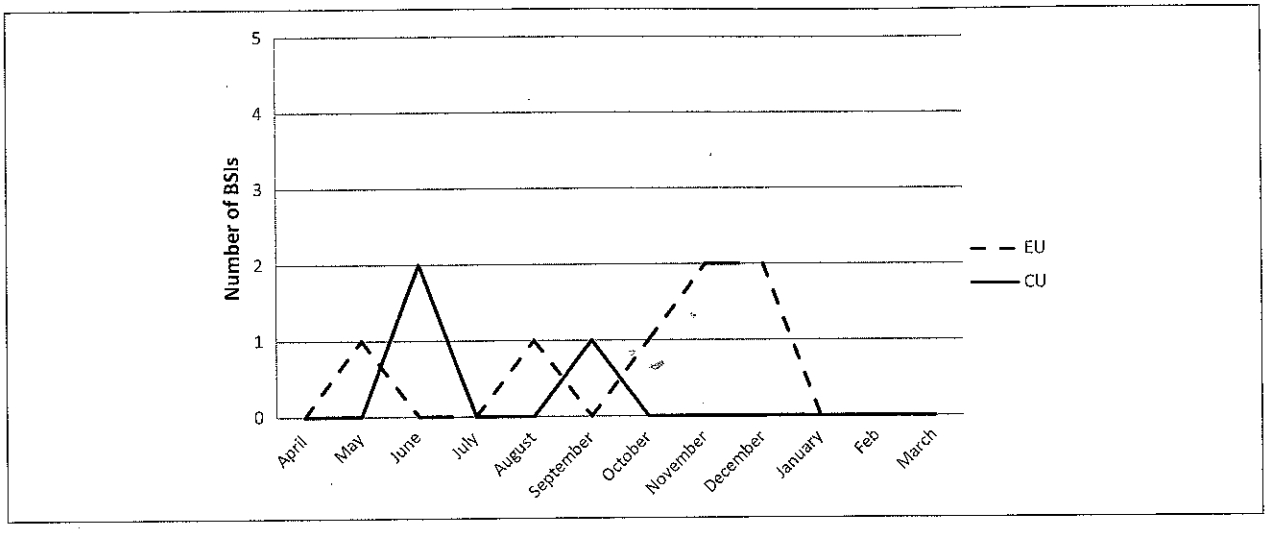

Figure 1. Central venous catheter–related bloodstream infections (BSIs): Experimental unit (EU) and control unit (CU), April 1, 2010 to March 31, 2011

Table 3. Risk Characteristics of Patients With a CVC-Related BSI

Unit	Gender	Diagnosis	Age (Years)	CVC Type	Patient Acuity	LOS Days	Reason for Admission	Blood Draws (n)
CU	Female	AML	16	PICC DL	High	14	Chemo	13
CU	Male	AML	16	PICC DL	High	22	Chemo	11
CU	Male	AML	15	PICC DL	High	16	Chemo	7
EU	Female	MB	8	PICC DL	High	34	Chemo	95
EU	Male	ATRT	4	Apheresis	High	52	Chemo	47
EU	Male	AML	15	PICC DL	High	18	Chemo	17
EU	Female	AML	14	PICC DL	Medium	4	Chemo	6
EU	Male	AML	7	PICC SL	High	17	Chemo	15
EU	Male	AML	4	PICC DL	High	29	Chemo	38
EU	Female	AML	13	PICC DL	High	21	Chemo	15

Abbreviations: LOS, length of stay; CVC, central venous catheter; BSI, blood stream infection; PICC, peripherally inserted central catheter; DL, double lumen; AML, acute myelogenous leukemia; MB, medulloblastoma; ATRT, atypical teratoid rhabdoid tumor; Chemo, chemotherapy; CU, control unit; EU, experimental unit.

Table 4. CVC BSI Data by Unit (April 1, 2010 to March 31, 2011)

Variable	Control	Experimental	*P*
Total catheter days	1419	1238	NA
No. of BSIs	3	7	NA
Rate of BSI/1000 catheter days	2.1/1000	5.7/1000	.97
95% CI	(0.4/1000, 6.2/1000)	(2.3/1000, 11.6/1000)	

Abbreviations: CVC, central venous catheter; BSI, bloodstream infection; NA, no applicable; 95% CI, 95% confidence interval.

rates ranging between 0 to 2.0/1000 catheter days in both units. The current single-site pilot study accrued 76% less total catheter days than planned. The historical admission estimates for subject eligibility included all patients admitted to the 2 oncology units as compared with the selected and finite group of pediatric oncology patients enrolled in the pilot study, which led to lower power than anticipated. Future studies, including larger

Table 5. Selected Risk Factors for CVC BSI Rate/1000 Catheter Days Unit A and Unit B (April 1, 2010 to March 31, 2011)

	Unit A		Unit B			
Risk Factor	CU	EU	CU	EU	IRR (95% CI)	*P*
Gender						
Female	2.46	9.26	0.0	2.70	1.0	
Male	4.05	8.82	0.0	3.22	1.13 (0.32, 4.02)	.85
Age (years)						
≤8	0.0	12.35	0.0	5.76	1.0	
>8	4.62	7.61	0.0	0.0	0.75 (0.21, 2.75)	.67
CVC type						
Non PICC	0.0	0.0	0.0	1.83	1.0	
PICC	3.57	12.14	0.0	7.30	7.05 (0.71, 70.13)	.05
Average acuity						
≤2	3.68	9.09	0.0	2.12	1.0	
>2	0.0	0.0	0.0	4.74	1.08 (0.11, 10.42)	.95
Length of stay (days)						
≤7	0.0	10.31	0.0	0.0	1.0	
>7	3.78	7.29	0.0	7.22	3.15 (0.35, 28.36)	.25
Infection-free days						
≤7	0.0	19.42	0.0	0.0	1.0	
>7	3.82	7.41	0.0	8.26	1.51 (0.28, 8.12)	.62
Reason for admission						
Other	0.0	0.0	0.0	0.0	N/A	NA
Chemo	4.01	10.94	0.0	3.20		
No. of blood draws						
≤5	0.0	13.33	0.0	0.0	1.0	
>5	4.21	8.42	0.0	5.46	2.55 (0.31, 21.35)	.33

Abbreviations: CU, control unit; EU, experimental unit; CVC, central venous catheter; BSI, bloodstream infection; IRR, incidence rate ratio; 95% CI, 95% confidence interval; PICC, peripherally inserted central catheter; Chemo, chemotherapy; NA, not applicable.

sample sizes in a multisite trial using power computations based on a one-sided test with 10% ($P = .10$) type I error, and 80% power to detect a halving of this pilot study BSI incidence rate requires 24 000 catheter days. Therefore, a larger trial will be necessary to determine whether a CVC RN team will be effective in significantly reducing CVC-related BSIs.

Several factors may have accounted for these results. First, targeted CVC nursing education and use of CVC bundle care may have heightened staff awareness of the problem, resulting in a positive "bystander effect" on the bedside nurses on the CU. Second, ongoing and active participation in this research effort by all nurses may have contributed to the overall final improved clinical outcome. Importantly, implementation of a CVC bundle blood draw checklist, an approach highly recommended by professional organizations (CHCA, 2005; NACHRI, 2008) may have served as an unanticipated intervention on the CU and in the final study period. The likelihood of this possibility is supported by previous reports of the advantages of checklists (CHCA, 2005; IHI, 2005, 2006; NACHRI, 2008).

Other investigators in adult acute care facilities have studied the effect of specialty intravenous (IV) teams on IV complications, quality of care, and hospital costs (Brunelle, 2003; Larson & Hargiss, 1984; Meier, Fredrickson, Catney, & Nettleman 1998; Mellema & Poniatowski, 1985; Tomford & Hershey, 1985; Tomford, Hershey, McLaren, Proter, & Cohen, 1984;). These studies reported that the overall benefits of a specialty IV team included reductions in BSI and phlebitis rates, hospital costs, bedside RN workload, and hospital LOS. In a randomized trial of 60 pediatric patients with CVCs, Nelson, Kien, Mohr, Frank, and Davis (1986) reported a significant reduction in CVC-related BSI rates with a team of RN experts performing CVC care compared with non-RN experts. In a neonatal intensive care intervention study, Taylor et al. (2011) reported that catheter related infection was reduced by nearly half in extremely low birth weight infants after implementation of a dedicated neonatal PICC team.

In this study, 8 of the 10 patients who developed BSIs were diagnosed with acute myelogeous leukemia. In a nonrandomized study of pediatric oncology patients with 418 CVCs, Fratino et al. (2005) reported higher BSI rates in those with hematological disease versus those with solid tumors. Although the LOS was not associated with increased risk of developing infection ($P = .25$), 9 of the 10 study patients who developed a BSI had LOS more than 7 days. Although these results further support earlier findings that children with hematological malignancies and/or those with increased LOS and CVCs may be at greater risk for CVC-related BSIs, a larger cohort will be required to determine if these are independent risk factors.

This is one of the first studies to investigate patient acuity in the context of CVC-related BSIs in the pediatric oncology population. Although patient acuity levels were not significantly associated with risk of developing a BSI ($P = .95$), 9 of the 10 study patients who developed a BSI were coded as high acuity. Patient acuity is recognized as an important quality and safety indicator because as patient acuity rises, more nursing resources are needed to provide care (Van Slyck & Johnson, 2001). It is likely that the small number of observed BSIs and the limited distribution of acuity may have reduced the power of our CVC RN intervention to detect this relationship.

The current study patients who developed BSIs all had external CVCs. Nine of the ten infections were in patients with external non-tunneled peripherally inserted catheters, which may also be associated with increase infection risk as compared with tunneled catheters (Maki, Kluger, & Crnich, 2006). There are inconclusive reports that suggest that tunneled externalized double lumen catheters are significantly associated with increased rates of BSIs (Kline, 2005; Mirro et al., 1989). In a prospective study of 286 CVCs in 264 pediatric oncology patients,

Mirro et al. (1989) demonstrated a trend toward lower rates of BSIs with implanted ports compared with external CVCs. Abbas et al. (2004) reported no significant difference in BSIs in children with cancer with 199 external CVCs compared with 87 implanted ports. Further studies with a larger cohort will be required to determine whether CVC type is a significant risk factor in the development of CVC-related BSIs in pediatric oncology patients.

Each CVC blood draw procedure increases a patient's vulnerability for risk of BSI. In this study, there was not a significant association for risk of BSI for patients who had ≤5 versus >5 blood draws per 1000 catheter days ($P = .33$; Table 5). However, all the patients who developed a BSI during their admission had greater than five blood draws (Table 3). These findings suggest that frequent CVC blood draw procedures may increase the risk of BSIs. Thus, to reduce CVC-related BSIs, it may be important to limit the number of blood draws by batching specimen collections whenever possible.

Limitations

There were several limitations to our study. Generalizability of the study results from a single institution may not hold true for all pediatric oncology patients. Additionally, the historical data which included all patients admitted to our two oncology units were used for estimation of sample size. However, fewer eligible pediatric oncology patients were available during the study period, which yielded a lower power than anticipated. This insufficiently powered study may have incorrectly concluded that the relationship between the team intervention and rate of BSIs was not significant.

Heterogeneity of the patients on the 2 units may have limited the effectiveness of the CVC RN team intervention because patients on the EU and CU had various diagnoses and treatment regimens, which could have influenced their risk of BSI. To minimize this risk, patients were enrolled if they were admitted for routine chemotherapy and were excluded if a preexisting infection was suspected. Other heterogeneities of the patients on the two units included variables such as number of admissions, CVC type or patient acuity; they were not equally stratified on both units. Finally, an additional limitation may have included the possibility of experimenter expectancies if RNs perceived the investigator's desired responses ("Hawthorne effect"). To control for this limitation, the investigator included in the staff education a discussion of the importance of documenting behaviors accurately, with emphasis on the anonymity of data collection.

Conclusion

In summary, these preliminary results demonstrated the feasibility of implementing a CVC RN team for CVC blood draw procedures in pediatric oncology patients. The results of this pilot study from both units suggest in part that essential CVC BSI prevention interventions should include targeted CVC nursing education, ongoing and active staff nurse participation in CVC BSI prevention research and implementation of a CVC care bundle checklist. Additionally, it would seem valuable to implement nurse staffing models that allow adequate staffing levels and opportunities for education to ensure optimal performance of patient care procedures. Furthermore, a larger cohort in a multisite study will be required in the future to determine the effectiveness of a CVC RN team intervention in reducing BSIs and to determine if the previously mentioned risk factors are significantly associated with the development of CVC-related BSIs in pediatric oncology patients.

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Authors' Note

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