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Central Line-Associated Bloodstream Infection Risk Factors in a Pediatric Population

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Abstract

Background: Central venous line (CVL) placement in children is often necessary for treatment and may be complicated by central line-associated bloodstream infection (CLABSI). We hypothesize that line type and clinical and demographic factors at line placement impact CLABSI rates.

Methods: This is a single-institution case-control study of pediatric patients (≤18 years old) admitted between January 1, 2015, and December 31, 2019. Case patients had a documented CLABSI. Control patients had a CVL placed during the study period and were matched by sex and age in a 2:1 ratio. Bivariate and multivariate logistic regression analysis was performed.

Results: We identified 78 patients with a CLABSI and 140 patients without a CLABSI. After controlling for pertinent covariates, patients undergoing tunneled or non-tunneled CVL had higher odds of CLABSI than those undergoing PICC (OR 2.51, CI 1.12-5.64 and OR 3.88, CI 1.06-14.20 respectively), and patients undergoing port placement had decreased odds of CLABSI compared to PICC (OR .05, CI 0.01-.51). There were lower odds of CLABSI when lines were placed for intravenous medications compared to those placed for solid tumor malignancy (OR .15, CI .03-.79). Race and age were not statistically significant risk factors.

Discussion: Central lines placed for medication administration compared to solid tumors, PICC compared to tunneled and non-tunneled central lines, and ports compared to PICC were associated with lower odds of CLABSI. Future improvement efforts should focus on PICC and port placement in appropriate patients to decrease CLABSI rates.

Keywords

CLABSI, pediatric surgery, pediatric central line

Key Takeaways

- There is a difference in CLABSI rates depending on line type and key clinical factors.
- Line selection in the setting of primary diagnosis leading to central access need has the potential to improve CLABSI rates in a pediatric population.
- For short-term access, PICCs are preferred over non-tunneled or tunneled central lines and for long term not requiring daily access, ports are preferred.

Introduction

Central venous line (CVL) placement in children is necessary for a multitude of diagnoses, including cancer, infection, and malnutrition. Previous studies have estimated that 5 million pediatric CVLs are placed yearly.[1] However, CVL placement can be associated with infectious complications. These central line-associated bloodstream infections (CLABSIs) are a significant cause of increased morbidity and mortality.[2–4] Central line-associated bloodstream infections are among the most costly hospital-acquired infections.[5]

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There are 4 main types of CVLs, and each can be used depending on the treatment and duration needed.[6] These include completely implantable CVLs with a subcutaneous access port that can be used intermittently, also known as a "port." Tunneled CVLs have an exposed hub and can be utilized when frequent or daily access is required. Both ports and tunneled CVLs can be used for long-term access. Non-tunneled CVLs can be used temporarily, as can peripherally inserted central catheters (PICCs). However, there is little consensus on the definition of temporary and long term; additionally, the effect size of line selection on CLABSI rates is unknown.

Decreasing CLABSI rates is an active area of quality improvement and research efforts.[3] Implementation of CLABSI-prevention bundles have been shown to effectively decrease CLABSI rates.[7,8] These bundles vary from institution but typically consist of maximum sterile barrier precautions during insertion, properly cleaning the skin with chlorhexidine, application of sterile dressings, regular maintenance of lines with aseptic technique while in place, and promptly removing the line when no longer clinically indicated.[9] While bundles have proven effective for reducing the risk of CLABSI, there are little data on CLABSI rates based on CVL type, clinical indication, and patient factors to assist with targeted improvement efforts.

We hypothesize that pre-operative clinical factors, line site, and type of CVL are associated with CLABSI rates.

Methods

Data Collection

This study was reviewed and approved by the University of North Carolina (UNC) Institutional Review Board (IRB# 20-0569). This was a retrospective single-institution case-control study conducted at UNC Children's Hospital from January 1, 2015, to December 31, 2019. Patients were included in the study if they were ≤18 years old and had a central line placed at our institution during the study period. Hospital epidemiology database were queried for case patients (positive CLABSI) during the study period. The Carolina Data Warehouse for Health at UNC was queried for CPT codes for central line placement during the study period, and then we generated a list of matched controls in a 2:1 ratio by sex and age.

Data were then confirmed and supplemented with manual chart review for demographic and clinical predictors of CLABSI based on literature review. Factors included in the database creation included age, sex, race, ethnicity, BMI, weight for children less than 2 years old, primary diagnosis leading to line placement, type of line, anatomic location of line, line procedure location, line duration with days until infection and total central venous access device (CVAD) days, temperature within 24 hours of line placement (defined as >38.5°C), multiple lines in place, blood work within 1 week prior to line placement (absolute neutrophil count, platelet, and hemoglobin), and line thrombosis requiring TPA administration. Primary diagnosis was divided into 4 categories: solid tumor malignancy, hematologic malignancy, parenteral nutrition, and administration of IV medications (Table 1). Standard institutional central line care protocol, including central line insertion checklist with all inclusive central line kit, maximum sterile barrier precautions, appropriate skin prep, use of US guidance, scrubbing the hub when accessing, assessing dressings and IV tubing at least once per shift, sterile dressing changes, sterile caps on unattached lines, antibiotic locks for dialysis lines, daily CHG treatment in high-risk areas (ICUs, Stepdown Units, Oncology) on patients >3 months of age, and daily evaluation of central line necessity, was assumed.

Statistical Analysis

Differences in demographic and clinical covariates by CLABSI status were assessed using descriptive statistics. Statistical comparisons of differences were generated using Wald chi-square tests for categorical variables and differences in means were generated using student's *t* test. Demographic and clinical factors were also examined during multivariate logistic regression analysis. Akaike information criterion (AIC) and likelihood ratio tests (LRTs) were used to determine which covariates should be included in the final model. The final model included primary diagnosis (categorized as solid tumor, AML/ALL, malnutrition, or other IV antibiotics and/or medications), race (categorized as white, black or others), age (continuous), and line type (categorized as PICC, tunneled, non-tunneled, or port). Statistical significance was set at a *P*-value of <.05. All analyses were performed using SAS software version 9.4 (SAS Inc., Cary, NC, USA).

Results

During the study period, we identified 218 total patients with 78 patients having a documented CLABSI and 140 patients without CLABSI. The mean number of days to infection was 41.38 with a standard deviation of 124.96. There were 22, 55, 16, and 125 patients who underwent port, tunneled CVL, non-tunneled CVL, and PICC placement, respectively. Differences were seen in in patient age (μ (SD) = 3.67 (6.05)) (μ (SD) = 3.25 (5.67)) and line duration (μ (SD) = 60.77 (124.68)) (μ (SD) = 74.40 (172.91)), for CLABSI and non-CLABSI, respectively (*P*-value <.01). Categorical clinical factors of primary diagnosis and line type were also shown to have statistical significance (Table 2).

Table 1. Primary Diagnosis Groups.

Solid tumor malignancy	Hematologic malignancy	Parenteral nutrition	IV medication
Neuroblastoma, retinoblastoma, medulloblastoma, rhabdomyosarcoma, metastatic rhabdoid tumor, round cell sarcoma, embryonal tumor with multilayered rosettes, melanoma, ependymoma, carcinoma unknown primary, soft tissue sarcoma	Acute myeloid leukemia (AML), myeloid sarcoma, acute lymphocytic leukemia (ALL), T-cell lymphoblastic lymphoma, B-cell lymphoblastic lymphoma, large-cell lymphoma, Hodgkin's lymphoma	Hypoxic-ischemic encephalopathy, multiple congenital abnormalities, congenital cardiac disease, congenital diaphragmatic hernia, tracheal esophageal fistula, prematurity, necrotizing enterocolitis, failure to thrive, protein losing enteropathy, small bowel obstruction, pyloric stenosis, biliary atresia, malrotation, gastroschisis, omphalocele, intestinal atresia, imperforate anus, Hirschsprung's disease, trauma, multisystem organ failure	Varying clinical scenarios comprised primarily of patients with medications requiring central access and also included IV antibiotics, poor IV access, dialysis, need for blood exchange transfusion

When controlling for pertinent covariates (age, race, line type, and primary diagnosis), we found patients undergoing tunneled and non-tunneled CVLs had higher odds of CLABSI than those undergoing PICC (OR 2.51, CI 1.12-5.64 and OR 3.88, CI 1.06-14.20), patients undergoing port placement had decreased odds of CLABSI compared to PICC (OR .052, CI 0.01-.51), and there were lower odds of CLABSI when lines were placed for IV medications compared to those placed for solid tumor malignancy (OR .15 (.03-.79)) (see Table 3). References were selected based on clinical reasoning. No other clinical or demographic factors were associated with an increased odds of CLABSI. A complete list of pathogens identified is shown in Supplementary Table 1.

Discussion

We found that after controlling for pertinent covariates, tunneled and non-tunneled CVLs have higher odds of CLABSI than PICCs, ports have lower odds of CLABSI than PICCs, and lines placed for IV medication administration are safer with lower odds of CLABSI than when placed for solid tumors. The results of this study show that there is a difference in CLABSI rates depending on line type and key clinical factors, and we also demonstrate the effect size of line selection. Line selection in the setting of primary diagnosis leading to central access need has the potential to improve CLABSI rates in a pediatric population, and to guide patient and parental counseling about risks associated with needed procedures.

The use of PICCs has been increasing over the past several decades,[10–12] and there are many benefits of PICC placement in children including easier placement and reduced need for general anesthesia.[13] Previous data regarding the safety of PICC lines raised concerns about their safety profile;[14,15] however, there have been many studies and a recent systematic review that have shown PICCs to be a safe option for central access in the pediatric population.[13,16,17] In our participants, we found a decreased odds of CLABSIs in PICCs compared to both tunneled and non-tunneled CVLs. Our incidence rate of CLABSI with PICC placement was 30.4%, and this is slightly higher than the average reported incidence in Bahoush et al[16] of 16.4% to 28.8%. Our finding has clinical implications when surgeons are making line selection decisions for short term and intermediate central access. Given PICC's lower odds of CLABSI compared to both tunneled and non-tunneled CVLs, they should be used preferentially for patients not requiring long-term access (additional studies are still needed to define long vs intermediate vs short term).

Our study showed that ports have lower odds of CLABSI compared to PICCs, regardless of primary diagnosis. This is fitting with other studies that have shown lower rates of CLABSIs in patients with port access.[6,18,19] Some institutions place PICCs at the time of diagnosis of malignancy with a plan to transition to port placement after induction chemotherapy, but our data do not support this practice, and randomized trials examining this practice are needed. Additionally, we did not find a difference in the rates of CLABSI in neutropenic patients with ports. A recent study by Elgarten et al[20] found no difference in CLABSI rates by CVL type in neutropenic patients. Hence, our data support the selection of port as the preferred long-term central access in pediatric patients that do not require daily access. This is in agreement with prior studies suggesting preferential selection of port for central line access in patients with malignancy and

Table 2. Patient Demographic and Clinical Characteristics.

	Overall (n = 218)	CLABSI, n (%) = 78 (35.78)	No CLABSI, n (%) = 140 (64.22)	*P*-value
Age, mean (SD)	3.40 (5.80)	3.67 (6.05)	3.25 (5.67)	<.001
Gender, n (%)				.77
Male	123 (56.4)	43 (55.1)	80 (57.1)	
Female	95 (43.6)	35 (44.9)	60 (42.9)	
Race, n (%)				.22
White	95 (45.9)	32 (42.1)	63 (48.1)	
Black/African American	64 (30.9)	29 (38.2)	35 (26.7)	
Others	48 (23.2)	15 (19.7)	33 (25.2)	
Ethnicity, n (%)				.67
Non-Hispanic	172 (83.9)	64 (85.3)	108 (83.1)	
Hispanic	33 (16.1)	11 (14.7)	22 (16.9)	
Primary diagnosis, n (%)				.02
Solid tumor	15 (6.4)	6 (7.7)	9 (6.4)	
AML/ALL	31 (12.1)	14 (18.0)	17 (12.1)	
Malnutrition	124 (56.9)	50 (64.1)	74 (52.9)	
Others	48 (22.0)	8 (10.3)	40 (28.6)	
Line type, n (%)				<.001
Port	22 (10.1)	1 (1.3)	21 (15.0)	
Tunneled	55 (25.2)	31 (39.7)	24 (17.1)	
Non-tunneled	16 (7.3)	8 (10.3)	8 (5.7)	
PICC	125 (57.3)	38 (48.7)	87 (62.1)	
Line location, n (%)				.40
IJ	29 (13.4)	9 (11.8)	20 (14.3)	
Subclavian	45 (20.8)	21 (27.6)	24 (17.1)	
Femoral	12 (5.6)	6 (7.9)	6 (4.3)	
Upper extremity	96 (44.4)	29 (38.2)	67 (47.9)	
Lower extremity	21 (9.7)	7 (9.2)	14 (10.0)	
Head	13 (6.0)	4 (5.3)	9 (6.4)	
Line placement, n (%)				.09
OR	65 (29.8)	30 (38.5)	35 (25.0)	
VIR	34 (15.6)	10 (12.3)	24 (17.1)	
Bedside	118 (54.1)	37 (47.4)	81 (57.9)	
Others	1 (.5)	1 (1.3)	0 (.0)	
Line duration, mean (SD)				<.001
Days until infection	41.38 (124.96)	41.38 (124.96)	n/a	<.01
CVL total days	69.52 (157.19)	60.77 (124.68)	74.40 (172.91)	<.001

Abbreviations: AML = acute myeloid leukemia; ALL = acute lymphocytic leukemia; PICC = peripherally inserted central catheter; IJ = internal jugular; OR = operating room; VIR = vascular and interventional radiology; CVL = central venous line.

stem cell transplantation, even in the presence of neutropenia.[19–21]

Our finding of decreased odds of CLABSI in children requiring line placement for medication administration compared to those with solid tumor malignancy is consistent with the published literature and supports the validity of findings and the generalizability of our approach. While primary diagnosis is not a modifiable risk factor, our data support the development of diagnosis-specific CLABSI bundles as a future improvement project for high-risk groups.[22]

Our study has limitations. First, the retrospective nature of this study makes causality difficult to confirm. Our line type groups were not equally distributed with significantly more in the PICC group and few in the port group; this likely reflects clinical practice with PICCs being one of the most common central lines in pediatric inpatients.[23] We did not control for the presence of pre-existing antibiotics within the line type groups. The study uses administrative data to assign patients to either case or control study groups; this can be associated with misclassification or other biases. We believe that in this case, this misclassification was ameliorated by supplemental manual chart review and correction of errors; however, patients who have CLABSIs at an outside institution or who were not included in our

Table 3. Risk Factors Associated With Pediatric (≤18 years) CLABSIs.

Risk factor	Crude OR (95% CI)	*P*-value	Adjusted OR (95% CI)	*P*-value
Primary diagnosis				
Solid tumor	1. (ref)		1. (ref)	
AML/ALL	1.235 (.35-4.32)	.74	1.170 (.21-6.67)	.86
Malnutrition	1.014 (.34-3.03)	.98	.993 (.20-4.88)	.99
Other IV antibiotics/other medications	.300 (.08-1.08)	.07	**.148 (.03-.79)**	**.02**
Type of line				
PICC	1. (ref)		1. (ref)	
Tunneled	**2.957 (1.54-5.69)**	**.00**	**2.512 (1.12-5.64)**	**.03**
Non-tunneled	2.289 (.80-6.55)	.12	**3.883 (1.06-14.20)**	**.04**
Port	**.109 (.01-.84)**	**.03**	**.052 (.01-.51)**	**.01**
Race				
White	1. (ref)		1. (ref)	
Black/African American	1.631 (.85-3.13)	.14	1.747 (.86-3.57)	.13
Others	.895 (.43-1.88)	.77	1.326 (.54-3.25)	.54
Age	1.013 (.97-1.06)	.61	1.068 (.98-1.16)	.13

Abbreviations: OR = odds ratio; AML = acute myeloid leukemia; ALL = acute lymphocytic leukemia; IV = intravenous; PICC = peripherally inserted central catheter.
Bolded items reflect findings with significance of $p < 0.05$.

administrative databases at selection may potentially bias our results.

In conclusion, our study supports PICC utilization compared to tunneled and non-tunneled CVLs in patients with short-term need for central venous access. In patients with long-term CVL needs who do not require daily access, port is preferred, regardless of diagnosis or neutropenia. Patients requiring CVL placement for chemotherapy have a higher odds of CLABSI than those needing CVL for medication administration and should be a focus of future improvement efforts. Finally, we highlight that the timing and placement of CVL in pediatric patients should be an individualized decision based on patient needs and clinical factors.

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Supplemental Material

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