American Journal of Infection Control 42 (2014) 1157-60

Contents lists available at ScienceDirect

American Journal of Infection Control

journal homepage: www.ajicjournal.org

Major article

Attributable costs of central line–associated bloodstream infections in a pediatric hematology/oncology population

Matthew Z. Wilson MD [a], Colleen Rafferty MD, MS [b], Deana Deeter CRNP, RN [b], Melanie A. Comito MD [b], Christopher S. Hollenbeak PhD [a,c,*]

[a] Department of Surgery, The Pennsylvania State University, College of Medicine, Hershey, PA
[b] Department of Medicine, The Pennsylvania State University, College of Medicine, Hershey, PA
[c] Department of Public Health Sciences, The Pennsylvania State University, College of Medicine, Hershey, PA

Key Words:
Children
Hospital-acquired infections
Quality improvement
Infection control

Background: Although several studies have estimated the attributable cost and length of stay (LOS) of central line–associated bloodstream infections (CLABSIs) in the pediatric intensive care unit setting, little is known about the attributable costs and LOS of CLABSIs in the vulnerable pediatric hematology/oncology population.

Methods: We studied a total of 1562 inpatient admissions for 291 pediatric hematology/oncology patients at a single tertiary care children's hospital in the mid-Atlantic region between January 2008 and May 2011. Costs were normalized to year 2011 dollars. Propensity score matching was used to estimate the effect of CLABSIs on total cost and LOS while controlling for other covariates.

Results: Sixty CLABSIs occurred during the 1562 admissions. Compared with the patients without a CLABSI, those who developed a CLABSI tended to be older (9.0 years vs 7.5 years; $P = .026$) and to have a tunneled catheter (46.7% vs 27.0%) and a peripherally inserted central catheter (20.0% vs 11.2%) as opposed to other types of catheters ($P < .0001$). Propensity score matching yielded matched groups without significant differences in patient characteristics. In the propensity score analysis, the attributable LOS of a CLABSI was 21.2 days ($P < .0001$), and the attributable cost of a CLABSI was $69,332 ($P < .0001$).

Conclusions: Among pediatric hematology/oncology patients, CLABSI was associated with an additional LOS of 21 days and increased costs of nearly $70,000. These findings may inform decisions regarding the value of investing in efforts to prevent CLABSIs in this vulnerable population.

Central venous access is an important and necessary component of treatment of hematologic malignancies in pediatric patients. Unfortunately, their use is accompanied by such complications as bloodstream infections (BSI), which carry significant morbidity and mortality.[1-4] Several strategies have been implemented in attempts to reduce the incidence of these infections, including ethanol locks, antibiotic locks, and line insertion bundles, with varying degrees of success.[5-7] Recent studies have examined multidisciplinary approaches to reducing central line–associated bloodstream infections (CLABSIs) in children, including coordination of nursing staff and physicians to use best practices (including the use of chlorhexidine skin preparations, handwashing, line access, and daily line assessment), many of which have achieved significant success.[8-13]

The attributable costs associated with CLABSIs are well established among adults in the intensive care unit (ICU) setting, where estimates range from $33,000 to $44,000, and in the surgical ICU, where estimates range from $54,000 to $75,000.[14] In the pediatric ICU, the estimated attributable cost is is $33,000-$50,000 per CLABSI[14-18]; however, very little has been written about the attributable cost of CLABSIs in pediatric patients with malignancies commonly seen in a hematology/oncology practice. By the nature of their diagnoses, these patients are at risk for an extended hospital length of stay (LOS) and resulting increased costs. The purpose of the present study was to estimate the attributable costs and LOS of CLABSIs in pediatric hematology/oncology patients from a cohort of patients treated at a large tertiary care hospital in the mid-Atlantic region.

* Address correspondence to Christopher S. Hollenbeak, PhD, Division of Outcomes Research and Quality, Department of Surgery, The Pennsylvania State University, College of Medicine, 500 University Dr, H151, Hershey, PA 17033-0850.
E-mail address: chollenbeak@psu.edu (C.S. Hollenbeak).

Conflict of interest: None to report.

0196-6553/$36.00 - Copyright © 2014 by the Association for Professionals in Infection Control and Epidemiology, Inc. Published by Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.ajic.2014.07.025

METHODS

Data

Our data were collected prospectively as part of an institutional quality improvement effort to reduce CLABSIs in the pediatric hematology/oncology population at Milton S. Hershey Medical Center, as described previously.[19] Data were obtained from the electronic medical records of all patients admitted as inpatients to the pediatric hematology/oncology service between January 1, 2008, and May 31, 2011. During this period, 291 patients had a total of 1561 admissions. A CLABSI occurred in 60 of these admissions. Information about the patients and admissions were obtained from the electronic medical records and merged with data on costs from the hospital's cost accounting database.

Variables

CLABSIs were defined using National Healthcare Safety Network criteria.[20] Specifically, a CLABSI was classified as a laboratory-confirmed bloodstream infection when a central line or umbilical catheter was in place for >2 calendar days from the date of the event, the infection was not present on admission, and there was no other source of infection documented. CLABSIs were identified using an electronic surveillance system (Carefusion, San Diego, CA), and all cases were confirmed by an infection control specialist with access to patient records and laboratory data.

Variables controlled for in multivariate analyses included demographic data, including age (classified as 0-4, 5-9, 10-14, and 15-18 years), sex, type of central venous catheter (CVC; eg, subcutaneous port, tunneled catheter, peripherally inserted central catheter, other lines, such as triple-lumen CVCs), total number of line-days (defined as days on which a CVC was present), and the number of times the CVC was accessed by hospital personnel other than those on the pediatric hematology/oncology ward. Also included were the number of blood cultures performed, the number of blood cultures that yielded identifiable microorganisms, and the total number of excessive blood cultures, defined as blood cultures not associated with admission, documented fever, or leukocytosis or more than 2 negative follow-up cultures for candidemias or bacteremias caused by gram-negative organisms, *Staphylococcus aureus*, *Bacillus* spp, or vancomycin-resistant enterococci, or more than 1 negative follow-up culture for a culture positive with other organisms.

Outcome variables included total LOS and total cost of admission. These data were obtained from the hospital's cost accounting database (McKesson, San Francisco, CA). Costs from the cost accounting system are estimated using a cost-to-charges ratio. Our analysis used fully loaded operating costs, which included both fixed and variable costs as well as overhead costs; thus, here cost represents total costs to the hospital in terms of all resources used.

Statistical analysis

The statistical analysis was designed to estimate the attributable costs and LOS per admission for CLABSIs among pediatric hematology/oncology patients. Summary statistics were computed for the cohort and stratified by the incidence of CLABSIs. Patient demographic data were compared using the Student t test for continuous variables and the χ^2 test for categorical variables.

Propensity score matching was used to estimate the costs and LOS attributable to CLABSIs.[21] This method was used because patients who develop a CLABSI may differ in terms of characteristics and risk factors, and those risk factors also may be associated with costs and LOS. Propensity score matching deals with this covariate imbalance by matching CLABSI admissions to a comparison cohort with a similar distribution of characteristics and risk factors. Our propensity score model first fit a model of CLABSI risk using logistic regression. From this model, the predicted probability of developing CLABSI was estimated for all patients. Next, CLABSI admissions were matched 1:1 without replacement to admissions without CLABSI using a nearest-neighbor approach with a caliper restriction. The primary metric for the propensity score analysis was the average effect of treatment on the treated (ATT), the difference between the outcome (costs and LOS) for CLABSI admissions and their matched comparison group. To deal with the uncertainty induced by both the selection process and the data, a bootstrapping algorithm was used to compute 95% confidence intervals (CIs) around the ATT. Inferences for the ATT are based on 1000 bootstrap replicates. All statistical analyses were performed using Stata version 12.1 (StataCorp, College Station, TX) and the psmatch2 routines.[22] Statistical significance for all analyses was defined as a P value <.05.

Table 1
Characteristics of admissions with and without a CLABSI (n = 1562)

Variable	CLABSI (n = 60)	Non-CLABSI (n = 1502)	P value
Age, y			
Mean	7.5	9.0	.026
Median	6.0	7.5	
IQR	10.0	11.0	
Age distribution, %			
<5 y	43.3	31.96	
5-9 y	23.3	23.04	
10-14 y	13.3	17.91	
15+ y	20.0	27.10	
Sex, %			.4355
Male	70.0	65.11	
Female	30.0	34.89	
CVC type, %			<.0001
Port	28.3	60.05	
Tunneled	46.7	26.96	
Peripherally inserted central catheter	20.0	11.19	
Other	5.0	1.80	
Diagnosis, %			<.0001
Acute lymphoblastic leukemia	25.0	24.97	
Neuroblastoma	10.0	10.32	
Acute myelogenous leukemia	21.7	6.46	
Osteosarcoma	0.0	9.05	
Ewing sarcoma	0.0	5.93	
Other	43.3	43.3	
Line-days	34.2	7.7	<.0001
Blood cultures	22.2	2.8	<.0001
Excessive blood cultures	3.2	0.2	<.0001
Procedures	2.8	0.6	<.0001
LOS, d	37.4	7.5	<.0001
Costs, US$	105,895	18,870	<.0001

RESULTS

The 291 patients had a total of 1562 admissions during the study period. Characteristics of these patient admissions are presented in Table 1. Sixty of the 1562 admission involved a CLABSI during its course. Patients who developed a CLABSI were older on average (7.5 years vs 9.0 years; $P = .052$). Overall, there were more males in the study cohort, but the difference in sex distribution between the CLABSI and non-CLABSI groups was not statistically significant. The distribution of diagnoses differed ($P < .0001$) between the 2 groups; the rate of CLABSI was markedly lower in admissions of patients with acute myelogenous leukemia (6.5% vs 21.7%). The distribution of CVC type was also significantly different in the 2 groups. The CLABSI group had a higher proportion of tunneled catheters and