Journal of Pediatric Oncology Nursing
1–11

DOI: 10.1177/1043454216676838
jpo.sagepub.com
SAGE

Using Practice-Based Evidence to Improve Supportive Care Practices to Reduce Central Line–Associated Bloodstream Infections in a Pediatric Oncology Unit

Lauri A. Linder, PhD, APRN, CPON[1,2], Cheryl Gerdy, MSN, RN, CPON[2], Rouett Abouzelof, MS, RN[2], and Andrew Wilson, PhD, MStat[1]

Abstract

Children with cancer are a subset of patients with central lines with distinct risk factors for infection including periods of prolonged neutropenia and compromised mucous membrane integrity. This article relates the implementation of principles of practice-based evidence to identify interventions in addition to best practice maintenance care bundles to reduce central line–associated bloodstream infections involving viridans group streptococci and coagulase-negative staphylococci on an inpatient pediatric oncology unit. Review of individual events combined with review of current clinical practice guided the development of structured protocols emphasizing routine oral care and general supportive cares. Key principles of the protocols emphasized a 1-2-3 mnemonic and included daily bathing, twice daily oral care, and out-of-bed activity 3 times daily. Poisson regression identified a significant main effect for time period for central line–associated bloodstream infection rates involving both viridans group streptococci and coagulase-negative staphylococci. Significant differences were present between the preintervention baseline and implementation of the supportive care protocols. Project outcomes demonstrate the added value of using principles of practice-based evidence to guide the development of interventions to improve clinical care when evidence-based sources are limited.

Keywords

practice-based evidence, central line–associated bloodstream infection, supportive care, outcomes

Central line–associated bloodstream infections (CLABSIs) are an important source of morbidity and mortality for hospitalized patients, resulting in prolonged hospitalization and a 12% to 25% estimated mortality risk (Srinivasan et al., 2011). The estimated cost of a CLABSI ranges from $7000 to $29 000 (Scott, 2009) and up to $70 000 for children with cancer (Wilson, Rafferty, Deeter, Comito, & Hollenbeak, 2014). In recent years, the implementation of best practice bundles for central line insertion and maintenance care have resulted in decreased CLABSI rates among adults and children, including children with cancer (Bundy et al., 2014; Centers for Disease Control and Prevention [CDC], 2016). Children with cancer are a subset of patients with central lines with distinct risk factors for infection relative to other hospitalized patients including periods of prolonged neutropenia and compromised mucous membrane integrity (Bailey, Reilly, & Rheingold, 2009). As such, interventions in addition to best practice bundles may be useful to further reduce CLABSI rates in this population. Practice-based evidence (PBE), an approach that uses real-world contexts and data, provides a valuable framework for evaluating current practice and proposing interventions to improve outcomes (Horn & Gassaway, 2007).

This article presents one institution's experience applying principles of PBE within the context of a quality improvement initiative to reduce CLABSIs in its Cancer, Blood, and Transplant Service patients. We describe our experience applying PBE related to CLABSI events to develop service-based standards for supportive cares

[1]University of Utah College of Nursing, Salt Lake City, UT, USA
[2]Primary Children's Hospital, Salt Lake City, UT, USA

Corresponding Author:
Lauri A. Linder, PhD, APRN, CPON, University of Utah College of Nursing, 10 South 2000 East, Salt Lake City, UT 84112, USA.
Email: lauri.linder@nurs.utah.edu

targeted at reducing CLABSIs resulting from organisms common to the skin and oral mucosa. We also present outcomes following implementation of these supportive care standards.

Background

Bloodstream Infections in Children With Cancer

Bloodstream infections, whether meeting criteria to be classified as CLABSIs or not, are an important source of morbidity and mortality for children with cancer. Children with hematologic malignancies are at a particularly increased risk of infection, with 50% or more experiencing an infection during the course of their treatment (Bailey et al., 2009).

Other factors contributing to the increased risk of infection include prolonged neutropenia and injury to the mucous membranes as a consequence of therapy. Gram-positive organisms including *Enterococcus* species, *Staphylococcus aureus*, viridans group streptococcus, and coagulase-negative staphylococcus predominate as organisms commonly involved in bloodstream infections (Bailey et al., 2009; Johannsen, Handrup, Lausen, Schrøder, & Halse, 2013; Kelly et al., 2011; Steinberg, Robichaux, Tejedor, Reyes, & Jacob, 2013). Gram-negative organisms including *Klebsiella* species, and *Escherichia coli* are also important causative organisms (Bailey et al., 2009; DiGiorgio et al., 2012). The increased prevalence of common gastrointestinal organisms in bloodstream infections among patients with neutropenia compared with those without neutropenia suggests gut translocation in the context of compromised mucous membranes as an important source of infection (DiGiorgio et al., 2012; Steinberg et al., 2013).

Children receiving cytarabine-based therapy are at increased risk of infection from viridans group streptococcus which is responsible for about 30% of infections in children with hematologic malignancies. Other key risk factors for bloodstream infection involving viridans group streptococcus include profound neutropenia, poor dental health, and a prior history of viridans group streptococcal infection (Bailey et al., 2009; Johannsen et al., 2013).

Coagulase-negative staphylococci predominate as the leading cause of bloodstream infections in hospitalized patients in the United States (Wisplinghoff et al., 2004) and are also an important source of infection in children with cancer. These common commensal skin organisms account for up to 50% of bloodstream infections in children with cancer (Bailey et al., 2009).

Practice-Based Evidence

PBE is a research methodology that uses data from routine clinical practice to determine interventions or practices that are effective and efficient in routine care (Horn & Gassaway, 2007). Studies that are based on practice are useful when the evidence to guide the practice has not been well established and in situations where a randomized clinical trial may not be feasible. As such, PBE emphasizes a broader incorporation of the patient experience and allows for patient heterogeneity with attention to detailed description of patient characteristics. Patient characteristics can be further stratified based on illness severity to help discern which intervention(s) work for which group of patient. PBE also does not require blinding with regard to the intervention. PBE relies on local knowledge and the engagement of participating clinicians. Outcomes of interest most often relate to effectiveness, rather than efficacy, and association, rather than assigned causality.

PBE studies often involve multiple sites and the organization of robust patient data into comprehensive databases to support analyses (Horn & Gassaway, 2007). PBE studies have been used to implement practice changes associated with decreased pressure ulcers in long-term care facilities (Horn et al., 2010) and to identify variations in patient outcomes associated with different treatments following traumatic brain injury (Horn et al., 2015). Data from PBE studies can be incorporated within rapid learning systems to support real-time clinical decision making (Finlayson, Levy, Reddy, & Rubin, 2016).

Principles of PBE may be implemented in institution-based quality improvement initiatives. Because children with cancer face additional risk factors for CLABSIs relative to other hospitalized children, using PBE to guide a more rigorous description of patient and clinical characteristics has the potential to guide the development of more focused interventions to reduce CLABSIs.

Project Implementation

Project Setting

The project setting was a 32-bed inpatient unit in the Intermountain West serving children with immune compromised conditions. Although the unit primarily serves children with cancer and those undergoing hematopoietic stem cell transplantation, it also serves children with nonmalignant hematologic conditions and those who have received liver or kidney transplants. The unit has approximately 1350 admissions each year and approximately 6000 central line days each year. The hospital's Cancer, Blood, and Transplant Service provides care to approximately 190 newly diagnosed patients with cancer each year.

Review of Baseline Data

The unit's efforts to reduce CLABSIs began in late 2010 with a retrospective review of CLABSI events occurring between

2006 and 2010. Institutional review board approval, including a waiver of consent, was granted to perform retrospective chart reviews to better understand clinical characteristics of patients who had developed CLABSIs. Each event had been identified by the institution's infection preventionist as meeting criteria to be classified as a CLABSI using CDC definitions. The number of inpatient central line days was identified by the hospital based on its central line data base which track central lines from the time of placement to the time of removal. During this 5-year period, the unit had a total of 156 CLABSIs, and annual CLABSI rates ranged from 3.56 to 6.31/1000 line days. CLABSIs most frequently occurred in patients with hematologic malignancies (73%; n = 114), patients with neutropenia (74%; n = 116), and patients with multilumen tunneled central venous catheters (68%; n = 106). Viridans group streptococci (23%; n = 36) and coagulase-negative staphylococci (17%; n = 26) were the organisms most frequently involved in CLABSIs (Linder, 2011).

Implementing Best Practice Bundles

Reducing CLABSIs in pediatric hematology/oncology patients was established as a 2011 goal by the multihospital system to which the children's hospital belongs. Efforts to support the unit in achieving this goal included dedicated hospital resources, including support from the hospital's System Improvement department to assist unit leaders in establishing a structured plan to achieve the goal (Gerdy & Linder, 2012a). The unit formed a project team including clinical leadership, a clinical educator, staff nurse champions, and a project consultant. This team collaborated with other key stakeholders within the hospital while implementing the project. The hospital also participated in Children's Hospital Association's (CHA) Hematology/Oncology Collaborative between 2011 and 2013 which included implementation of best practice maintenance care bundles (Bundy et al., 2014; O'Grady et al., 2011). Institutional review board approval, including a waiver of consent, was obtained to allow data reporting to CHA as well as ongoing in-depth review of individual CLABSI cases.

Formal staff education regarding CHA's best practice central line maintenance care bundles was implemented in a series of four modules during the first half of 2011 (Gerdy & Linder, 2012b). Education included computer-based modules and unit-based bulletin boards emphasizing bundle components. Nursing staff also completed skills competency checklists addressing key psychomotor skills associated with the bundles.

Using Practice-Based Evidence to Identify Additional Areas for Improvement

The project team met on a regular basis to discuss the overall progress of the project and to identify ongoing areas for improvement. The unit's CLABSI rate decreased relative to the preintervention period (2.78/1000 line days in 2011 and 3.83/1000 line days in 2012) with patients experiencing a total of 44 CLABSIs. Although best practice guidelines for reducing CLABSIs have been established (O'Grady et al., 2011) and are incorporated in the CHA best practice bundles, they are general in scope and do not fully address the additional risk factors associated with cancer treatment. The team sought additional specific interventions to refine central line care and further reduce these infections. Principles of PBE, specifically attention to patient characteristics, and the use of local knowledge provided a framework for our team to explore evidence within our own practice and to propose additional interventions.

Sources of Practice-Based Evidence

Each CLABSI event was reviewed in detail. Key sources of evidence extracted from each review during 2011-2012 included adherence to best practice bundle components, characteristics of patients who developed CLABSIs, the organisms involved in CLABSI events, and the clinical care environment in which CLABSIs were occurring. Specific attention was given to the 72 hours prior to the time of the positive blood culture as this was the time frame during which the organism was most likely to have been introduced into the bloodstream.

Adherence to Best Practice Bundles. As part of the unit's participation in the CHA quality improvement initiative, team members conducted weekly in-person audits with unit staff to address adherence with bundle components. These audits indicated greater than 90% adherence. Areas for improvement identified through review of CLABSI events included attention to timely replacement of loose dressings rather than reinforcing them.

Patient Characteristics. Of the 44 CLABSIs occurring during 2011-2012, 82% (n = 36) occurred in patients with leukemia. Of these 36 events, 20 occurred in patients with acute myelogenous leukemia. Seventy-five percent (n = 33) of CLABSIs occurred in patients who were neutropenic at the time of the event, a time when skin and mucous membranes were at increased vulnerability to injury and the ability to heal was compromised. Nearly one third of CLABSIs (n = 14) occurred in patients with documented oral mucositis or thrush. One fourth of CLABSIs (n = 11) occurred in patients with a documented compromise in skin integrity.

Organism Characteristics. Viridans group streptococci and coagulase-negative staphylococci remained the predominant organisms involved in CLABSI events. Although the occurrence of these events had decreased from the preintervention baseline, the percentage of CLABSI events involving these organisms was relatively unchanged. Twenty-three percent of events (n = 10) involved viridans group streptococci, and 14% (n = 6) of events involved coagulase-negative staphylococcus.

We also examined organism characteristics based on admitting service. No patients admitted to the hematopoietic stem cell transplant (HSCT) service experienced CLABSIs involving viridans group streptococci. CLABSIs involving coagulase-negative staphylococci were split evenly between oncology service patients and HSCT service patients.

Clinical Care Environment. Examination of the clinical care environment included attention to routine care practices, including basic supportive cares. Our team noted that while HSCT service patients had a structured, formalized process for routine oral care and daily bathing, this same process was not in place for oncology service patients. Feedback from nursing staff indicated that these basic cares were often passively delegated to parents rather than staff taking an active role to see that they were completed. Staff also related that some patients and parents resisted basic cares and did not wish to push the child to complete them if he or she was not feeling well. Staff also reported limited efforts on the part of staff and families to actively promote routine out-of-bed activity.

Summary

As a result of the ongoing review of these sources of practice-based data, the team elected to pursue interventions targeted at improving basic supportive cares as a strategy to reduce CLABSIs, specifically those resulting from viridans group streptococci and coagulase-negative staphylococci. Although basic supportive care expectations were addressed in the hospital's collaborative practice guidelines, they were not brought together in a way that engaged staff and families to facilitate completion of cares on a routine basis.

Developing Service-Based Supportive Care Protocols

The team's goal in developing supportive care protocols was to formalize expectations in a structured manner. Interventions set forth in the protocols incorporated best practices based on review of the literature. These protocols included current standards for any pediatric patient as well as considerations for children with cancer. The result was two supportive care protocols that would be applicable in both the inpatient and ambulatory care setting: one addressing oral care and the second addressing more general supportive cares. Both documents emphasized routine care processes rather than the endorsement of products.

Table 1. Key Components of Oral Care Protocol.

For all patients

- Brush teeth at least twice daily using a soft toothbrush and fluoride toothpaste.
- Use moistened sponges or gauze for babies.
- Daily flossing, discontinue if flossing results in pain or bleeding.
- Rinse mouth with saline or water after brushing and flossing.
- Lip balm or water-soluble gel to keep lips moist.
- Ensure adequate hydration.

For patients with mucositis, continue the above along with the following:

- Substitute moistened sponges for tooth brushing if pain or bleeding occurs.
- Administer analgesics as needed to promote comfort with oral care and relieve pain associated with mucositis.

Oral Care Protocol

Table 1 presents key components of this protocol which center around at least twice daily toothbrushing as recommended by the American Dental Association (ADA) as well as Children's Cancer and Leukaemia Group/ Paediatric Oncology Nurses Forum's Mouth Care Group (ADA, 2016; Glenny et al., 2010). The oral care protocol also included the Oncology Nursing Society's Putting Evidence into Practice (PEP) team's summary that addressed interventions for the management of oral mucositis (Harris, Eilers, Harriman, Cashavelly, & Maxwell, 2008). The protocol includes routine oral hygiene for any pediatric oncology patient as well as modified interventions for the patient with oral mucositis. The protocol also includes attention to keeping the lips moist to avoid peeling or cracking.

The goal of ensuring routine oral hygiene was to reduce the load of common commensal organisms, specifically viridans group streptococci, to create a clean environment. Because mucosal injury can be present, even in the absence of clinically evident mucositis (Sonis, 2009), minimizing the oral bacterial load through routine hygiene may help prevent translocation of organisms across mucous membranes. Maintaining a clean oral environment during periods of prolonged neutropenia with or without clinically evident mucositis can further support tissue healing as immune function recovers.

General Supportive Cares Protocol

The general supportive cares protocol emphasized daily bathing, skin care, and out-of-bed activity. The overall goal of this protocol was to promote skin integrity and to minimize the load of common commensal organisms, specifically coagulase-negative staphylococci on the

Table 2. Key Components of General Supportive Cares Protocol.

- Daily bath or shower with a mild, nondrying soap
- Daily linen change
- Initiate barrier creams on admission for diapered patients receiving chemotherapy
- Promote regular bowel movements
- Out-of-bed activity at least 3 times daily, in addition to ambulation to the bathroom

skin. Key components of this protocol are summarized in Table 2.

The protocol emphasizes daily bathing with soap and water. Because the unit's PBE suggested that routine bathing practices among oncology service patients were limited, the team elected to begin with an emphasis on soap-and-water bathing rather than introduce chlorhexidine baths. The protocol also includes a preventive approach to diaper dermatitis for infants and other diapered patients by initiating barrier creams on admission.

Out-of-bed activity at least 3 times daily is emphasized in the protocol as a strategy for promoting skin integrity and to avoid other hazards of immobility. Out-of-bed activity may be adapted as necessary for nonambulatory patients (eg, holding babies) and those who are severely ill (eg, sitting in a chair or extra steps in the room after getting up to the bathroom).

Out-of-bed activity was also viewed as a strategy to promote gastrointestinal health. As part of our team's review of our PBE, we identified at least one CLABSI event in which constipation may have been contributed to compromised lower gastrointestinal tract mucosa leading to the CLABSI event. Although CLABSIs involving organisms common to the lower gastrointestinal tract are more difficult to prevent in patients with neutropenia, avoiding constipation through out-of-bed activity as well as pharmacological interventions may prevent some of these CLABSIs. Likewise, managing diarrhea may help avoid CLABSIs occurring as a consequence of injured gastrointestinal mucosa and compromised perianal skin integrity.

Protocol Implementation

Protocol implementation included strategies to engage clinical team members as well as patients and families. The protocols were drafted and refined during the third and fourth quarter of 2012 with feedback from multidisciplinary team members. The key principles of the protocols: daily bathing, twice daily oral care, and out-of-bed activity 3 times daily were introduced using a 1-2-3 mnemonic to foster staff and patient/family engagement. Formal implementation began in January 2013.

Staff Engagement. Staff engagement was directed toward both registered nurses and patient care technicians. Efforts included the use of unit-based bulletin boards and education via the monthly staff newsletter. Education emphasized the scientific rationale driving the interventions and the relationship to CLABSI prevention. Staff were also coached on strategies to foster more active patient/family engagement such as, "When would you like to take your bath today?" rather than "Do you want to take a bath today?" Audits addressing adherence to best practice bundles also incorporated discussion of the 1-2-3 supportive cares to support staff engagement and address barriers to implementation. Project team members also met with patient care technicians during a routine staff meeting to discuss the 1-2-3 supportive cares not just as tasks but as components of CLABSI prevention.

As CLABSI events occur, the registered nurses caring for the patient in the 72 hours prior to the time of the positive culture meet with clinical leadership team members to review the case and factors that may have contributed to the CLABSI. During these reviews, adherence to 1-2-3 supportive care is addressed along with any barriers to adherence.

Patient/Family Engagement. Engaging patients and families is a key component of CLABSI-reduction initiatives (Wilson Deeter, Rafferty, Comito, & Hollenbeak, 2014). Unit-based bulletin boards in public areas of the unit emphasized the components of the 1-2-3 supportive cares (Figure 1). Dry erase communication boards placed in patient rooms to support patient/family engagement and communication with providers were designed to include the 1-2-3 supportive cares (Figure 2). They also include check boxes to serve as a visual reminder of daily expectations.

Teaching the 1-2-3 supportive cares has been included as part of routine education for families whose children have been newly diagnosed with cancer. Unit-based rounds involving clinical leadership also serve to reinforce this teaching as well as the rationale for the 1-2-3 cares.

Project Outcomes

Data Organization and Analysis

All CLABSI events were confirmed by an institution-based infection preventionist using definitions established by the CDC. The unit's number of central line days was identified by through a query of the institution's central line database that tracks central lines from the time of initial placement to the time of removal.

Data were organized into the three time periods: (1) preintervention (2006-2010), (2) bundle implementation

Figure 1. Unit bulletin board introducing 1-2-3 supportive care initiative.

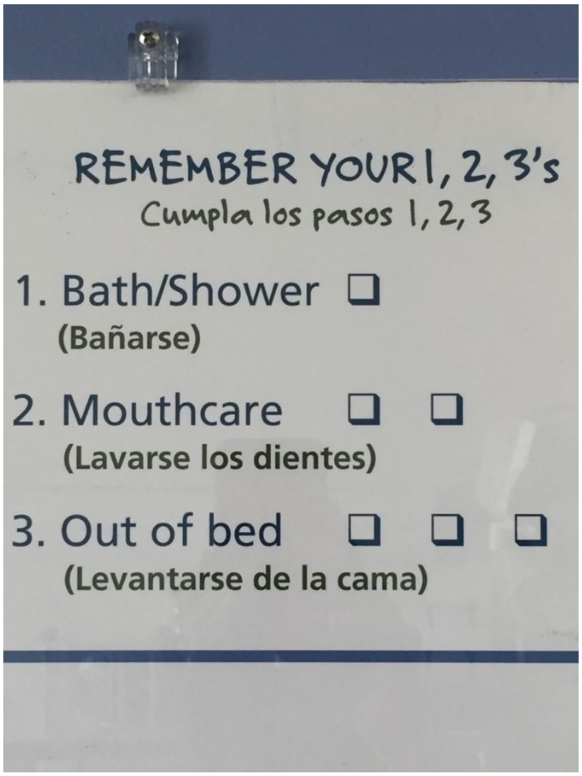

Figure 2. Section of dry erase communication board in patient room with checkboxes for completing 1-2-3 supportive cares.

(2011-2012), and (3) bundles plus 1-2-3 supportive cares (2013-2015) to support comparisons across each intervention phase. Figure 3 presents the frequency of events involving viridans group streptococci and coagulase-negative staphylococci during each year of the overall 10-year period.

Overall CLABSI rates per 1000 central line days and 95% confidence intervals were calculated for each time period. CLABSI rates and 95% confidence intervals for events involving viridans group streptococci and coagulase-negative staphylococci were also calculated to examine the impact of the central line bundles and supportive care protocols on these target organisms. These data are summarized in Table 3.

Comparison of CLABSI Rates by Time Period

Poisson regression using R (R Foundation for Statistical Computing, 2016) was used to evaluate for the effect of time period on CLABSI rates involving viridians group streptococci and coagulase-negative staphylococci. Because CLABSIs are relatively rare events, using Poisson regression was appropriate to model these data. Post hoc Tukey pairwise comparisons evaluated differences among each of the three time periods.

Viridans Group Streptococci. Figure 4 presents a plot illustrating changes in CLABSI rates involving viridans group streptococci across the 3 time periods. A significant main effect for time period was present ($\beta = -0.45$; $P = .01$), indicating that a significant change in CLABSI rate was present based on time period.

Post hoc Tukey pairwise comparisons identified significant differences only between the preintervention period (2006-2010) and the bundle plus supportive care protocols period (2013-2015; $z = -2.365$; $P = .045$). These results emphasize the added benefit of interventions targeted at minimizing the risk of pathogens entering the bloodstream from sources other than the central venous catheter.

Coagulase-Negative Staphylococci. As with viridans group streptococci, a significant main effect for time period was present for CLABSI rates involving coagulase-negative staphylococci ($\beta = -0.59$; $P = .01$). Figure 5 presents a plot illustrating changes in CLABSI rates involving coagulase-negative staphylococci across the 3 time periods.

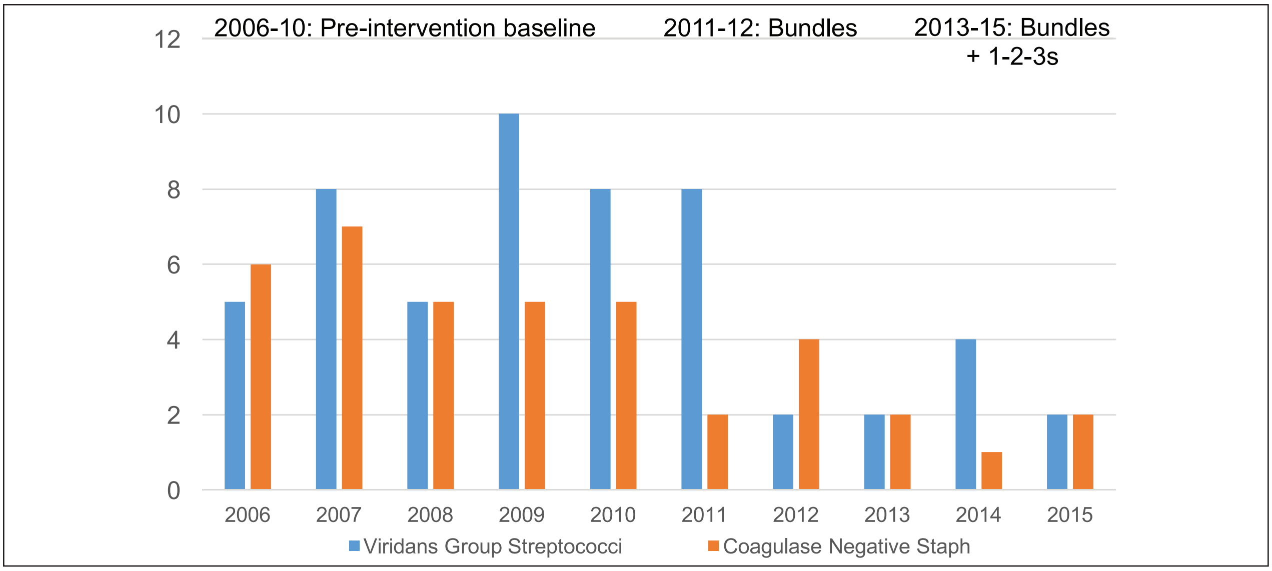

Figure 3. Central line–associated bloodstream infection (CLABSI) events involving viridans group streptococci and coagulase-negative staphylococci.

Table 3. Comparison of CLABSI Events and Rates: Preintervention, Following Implementation of Best Practice Bundles, and Following Addition of 1-2-3 Supportive Cares.

	2006-2010: Preintervention	2011-2012: Bundles Initiated	2013-2015: Bundles + 1-2-3s
All CLABSIs			
Total CLABSI events	156	44	39
Overall CLABSI rate/1000 line days (95% confidence intervals)	4.84 (4.08-4.93)	3.29 (2.23-4.26)	2.16 (1.48-2.84)
Viridans group streptococci			
Events involving viridans group streptococci	36	10	8
Rate for viridans group streptococci/1,000 line days (95% CIs)	1.12 (0.75-1.48)	0.75 (0.28-1.21)	0.44 (0.16-0.75)
Coagulase-negative staphylococci			
Events involving coagulase-negative staphylococci	28	6	5
Rate for coagulase-negative staphylococci/1,000 line days (95% CIs)	0.87 (0.55-1.19)	0.45 (0.09-0.81)	0.28 (0.03-0.52)
Total line days	32 229	13 364	18 049

Note. CLABSI, central line–associated bloodstream infection; CI, confidence interval.

Post hoc Tukey pairwise comparisons identified significant differences in CLABSI rates involving coagulase-negative staphylococci only between the preintervention period (2006-2010) and the bundle plus supportive care protocols period (2013-2015); $z = -2.354$; $P = .047$). As with viridans group streptococci, these differences demonstrate the added benefit of the supportive care protocols to reduce CLABSIs resulting from coagulase-negative staphylococci.

Discussion

This project demonstrates one institution's experience using principles of PBE to guide the development of interventions to successfully reduce CLABSIs, specifically those resulting from viridans group streptococci and coagulase-negative staphylococci among children with cancer. Careful attention to patient characteristics as well as local knowledge allowed our team to better define risk factors for infection in our patient population and then prioritize specific interventions targeted at reducing CLABSI events involving these organisms.

Children with cancer are a relatively small subset of patients who develop CLABSIs and have distinct risk factors for infection in addition to those of other hospitalized patients. Interventions in addition to best practice bundles are needed to further reduce CLABSI rates. Injured mucous membranes compromise the child's

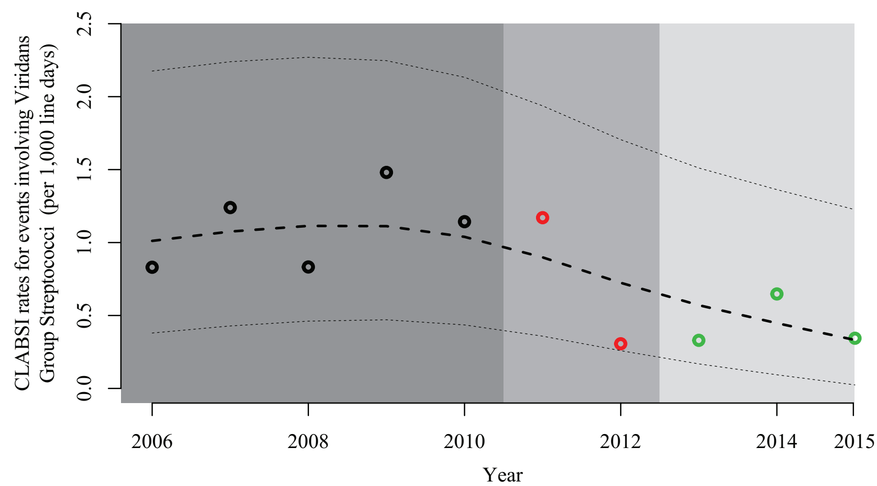

Figure 4. Plot illustrating changes in central line–associated bloodstream infection (CLABSI) rates involving viridans group streptococci preintervention, following implementation of best practice bundles, and the addition of 1-2-3 supportive cares.

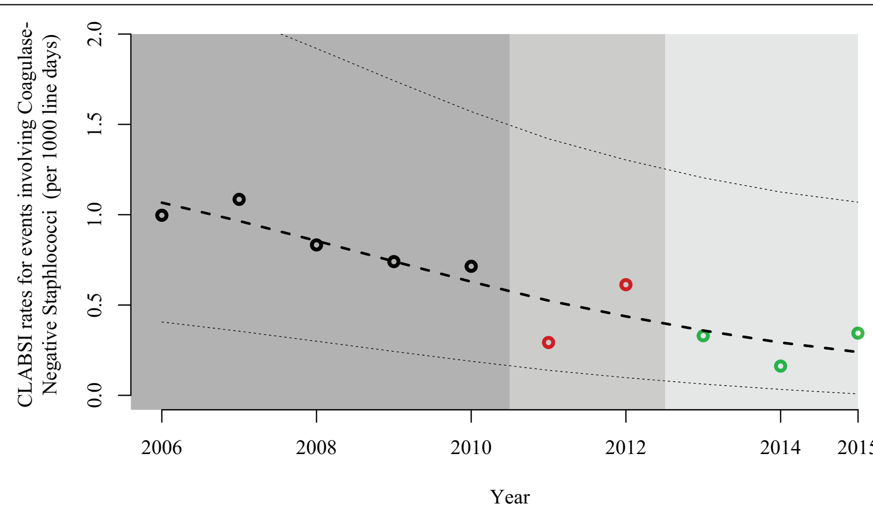

Figure 5. Plot illustrating changes in central line–associated bloodstream infection (CLABSI) rates involving coagulase-negative staphylococci preintervention, following implementation of best practice bundles, and the addition of 1-2-3 supportive cares.

primary barriers of defense against infection. Prolonged neutropenia and corticosteroid use further delay healing of these injured tissues. Even though a given bloodstream infection may be categorized as a CLABSI, pathogens may have entered through injured mucosal barriers.

Although best practice maintenance care bundles are important steps to reducing CLABSIs in children with cancer (Bundy et al., 2014; O'Grady et al., 2011), additional interventions targeted at patient characteristics and the types of organisms involved in these infections are necessary. Outcomes of this project provide evidence that strategies targeted at minimizing the bacterial load present in compromised skin and oral mucosal barriers can work synergistically with best practice central line maintenance bundles to reduce bloodstream infections in children and adolescents with cancer, specifically those involving viridans group streptococci and coagulase-negative staphylococci. Although rates of CLABSI events involving both viridans group streptococci and coagulase-negative staphylococci decreased following implementation of the best practice maintenance bundles, statistically significant declines in events involving both of these organisms were not achieved until after implementation of the supportive care protocols.

Implications for Practice

Project outcomes emphasize the importance of fundamental principles of nursing practice to reduce the risk of infection and to promote patient well-being in patients who are at an increased risk of infection. The interventions included in these protocols did not require additional costs or purchased resources to implement. They are also strategies that can be implemented and emphasized across high-or low-resource practice settings.

This project also demonstrates the importance of staff engagement in successfully implementing the protocols. Formalizing oral care and supportive care expectations into protocols added further clarity regarding practice-related expectations. The 1-2-3 mnemonic formalized the essence of the protocols in a manner that was easy to remember and to present to families. Supporting both the nursing staff as well as the patient care technician staff to understand the rationale for the supportive care protocols also served to engage patients and families.

Fostering patient and parent engagement was also essential to the project's success. Our preintervention feedback suggested that frequently neither staff nor parents assumed an active role in prioritizing basic cares. Other institutions have reported similar experiences (Best et al., 2015). Using multiple strategies to communicate and reinforce daily expectations including education, visual reminders, and interdisciplinary rounding with families have collectively helped to change the culture regarding basic supportive care practices.

Limitations

A limitation of this project is that it was conducted at a single institution in the context of a quality improvement project rather than a controlled experiment. The quality improvement approach did, however, support using principles of PBE and implementation of the supportive care protocols as components of the project. The project also did not seek to prospectively compare the 1-2-3 supportive cares with another intervention; rather the 1-2-3 supportive cares were implemented within the unit as the standard of care. Preintervention practices in relation to the 1-2-3 supportive cares are not known. Anecdotal data from clinical staff, however, suggest that both patient/family and staff-related factors contributed to limited preintervention practices. Analyses presented in this report, however, include infection-related data collected over the course of 10 years which strengthens the ability to document sustained outcomes in response to key changes implemented as a result of the project.

Multiple factors contribute to CLABSIs, and the analyses did not attempt to control for these factors. For example, in July 2013, the hospital implemented the use of alcohol- impregnated caps for all patients with central lines. While this intervention may have contributed to decreases in CLABSIs resulting from coagulase-negative staphylococci, it is less likely to have impacted CLABSIs resulting from viridans group streptococci.

An additional limitation is that CDC criteria for defining a positive blood culture event as a CLABSI continue to be refined. As such, an event that met criteria to be defined as a CLABSI in a given year, may not have met criteria to be defined as a CLABSI in another year. We elected not to retroactively reclassify any of these events. Each CLABSI event included in these analyses was identified based on criteria in place at the time of the event.

Directions for Future Research

Additional multisite efforts are necessary to evaluate the efficacy and effectiveness of these general supportive cares as additional strategies to reduce CLABSIs. Such efforts will support the development of a more robust database of patient characteristics, a key aspect of PBE research (Horn & Gassaway, 2007). These efforts will also serve to further stratify pediatric oncology patients by risk to evaluate which patients are most likely to experience the greatest benefit from given interventions. Multisite efforts could also help evaluate the clinical and cost effectiveness of interventions set forth in these supportive care protocols versus other commonly implemented interventions such as chlorhexidine bathing. Case-control studies comparing characteristics of hematology/oncology patients who develop CLABSIs with those who do not will also lead to an improved understanding of risk factors for infection as well as interventions that are likely to be of greatest benefit.

Further application of PBE can also guide strategies to address other organisms involved in CLABSIs in pediatric hematology/oncology patients. Organisms common to the lower gastrointestinal tract and associated with mucosal barrier injury are frequently involved in CLABSI events involving individuals with cancer and have been less amenable to interventions such as maintenance care bundles and chlorhexidine bathing (Climo et al., 2013).

Conclusion

This project demonstrates the role of using principles of PBE to guide the development of interventions to improve clinical care when evidence-based resources are limited. By carefully evaluating sources of evidence within our practice setting, we developed and implemented targeted interventions to complement current quality improvement initiatives that resulted in significant reductions in CLABSIs involving viridans group streptococci and coagulase-negative staphylococci in children with cancer.

The outcomes of this project have resulted in the generation of new evidence to guide future practice.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The pre-intervention retrospective review of CLABSIs between 2006-10 was supported by grant from the Utah Organization of Nurse Leaders.

References

American Dental Association. (2016). *Brushing your teeth*. Retrieved from http://www.mouthhealthy.org/en/az-topics/b/brushing-your-teeth

Bailey, L. C., Reilly, A. F., & Rheingold, S. R. (2009). Infections in pediatric patients with hematologic malignancies. *Seminars in Hematology*, *46*, 313-324. doi:10.1053/j.seminhematol.2009.03.010

Best, D., Osterkamp, E., Demmel, K., Kiniyalocts, S., Mock, S., Mulligan, K., . . . Dandoy, C. E. (2015). Increasing activities of daily living as easy as 1-2-3. *Journal of Pediatric Oncology Nursing*. Advance online publication. doi:10.1177/1043454215616607

Bundy, D. G., Gaur, A. H., Billett, A. L., He, B., Colantuoni, E. A., & Miller, M. R. (2014). Preventing CLABSIs among pediatric hematology/oncology inpatients: National collaborative result. *Pediatrics*, *134*, e1678-e1685. doi:10.1542/peds.2014-0582

Centers for Disease Control and Prevention. (2016). *National and state healthcare-associated infections progress report*. Retrieved from http://www.cdc.gov/HAI/pdfs/progress-report/hai-progress-report.pdf

Climo, M. W., Yokoe, D. S., Warren, D. K., Perl, T. M., Bolon, M., Herwaldt, L. A., . . . Wong, E. S. (2013). Effect of daily chlorhexidine bathing on hospital-acquired infection. *New England Journal of Medicine*, *368*, 533-542. doi:10.1056/NEJMoa1113849

DiGiorgio, M. J., Fatica, C., Oden, M., Bolwell, B., Sekeres, M., Kalaycio, M., . . . Fraser, T. J. (2012). Development of a modified surveillance definition of central line–associated bloodstream infections for patients with hematologic malignancies. *Infection Control and Hospital Epidemiology*, *33*, 865-868. doi:10.1086/667380

Finlayson, S. G., Levy, M., Reddy, S., & Rubin, D. L. (2016). Toward rapid learning in cancer treatment selection: An analytical engine for practice-based clinical data. *Journal of Biomedical Informatics*, *60*, 104-113. doi:10.1016/j.jbi.2016.01.005

Gerdy, C., & Linder, L. (2012a, October). *Implementation of a structured education plan to reduce CLABSI Rates*. Paper session presented at the Association of Pediatric Hematology/Oncology Nurses Annual Conference, Pittsburgh, PA.

Gerdy, C., & Linder, L. (2012b, October). *Quality improvement strategies to decrease CLABSI rates*. Paper session presented at the Association of Pediatric Hematology/Oncology Nurses Annual Conference, Pittsburgh, PA.

Glenny, A. M., Gibson, F., Auld, E., Coulson, S., Clarkson, J. E., . . . Pizer, B. (2010). The development of evidence-based guidelines on mouth care for children, teenagers and young adults treated for cancer. *European Journal of Cancer*, *46*, 1399-1412. doi:10.1016/j.ejca.2010.01.023

Harris, D. J., Eilers, J., Harriman, A., Cashavelly, B. J., & Maxwell, C. (2008). Putting Evidence Into Practice®: Evidence-based interventions for the management of oral mucositis. *Clinical Journal of Oncology Nursing*, *12*, 141-152. doi:10.1188/08.CJON.141-152

Horn, S. D., Corrigan, J. D., Bogner, J., Hammond, F. M., Steel., R. T., Smout, R. J., . . .Whiteneck, G. G. (2015). Traumatic brain injury—Practice-based evidence study: Design and patients, centers, treatments, and outcomes. *Archives of Physical Medicine and Rehabilitation*, *96*, S178-S196. doi:10.1016/j.apmr.2014.09.042

Horn, S. D., & Gassaway, J. (2007). Practice-based evidence study design for comparative effectiveness research. *Medical Care*, *45*(Suppl. 2), S50-S57.

Horn, S. D., Sharkey, S. S., Hudak, S., Gassaway, J., James, R., & Spector, W. (2010). Pressure ulcer prevention in long-term care facilities: A pilot study implementing standardized nurse aide documentation and feedback reports. *Advances in Skin and Wound Care*, *23*, 120-131.

Johannsen, K. H., Handrup, M. M., Lausen, B., Schrøder, H., & Halse, H. (2013). High frequency of streptococcal bacteraemia during childhood AML therapy irrespective of dose of cytarabine. *Pediatric Blood and Cancer*, *60*, 1154-1160. doi:10.1002/pbc.24448

Kelly, M., Conway, M., Wirth, K., Potter-Bynoe, G., Billett, A. L., & Sandora, T. J. (2011). Moving CLABSI prevention beyond the ICU: Risk factors in pediatric oncology patients. *Infection Control and Hospital Epidemiology*, *32*, 1079-1085. doi:10.1086/662376.

Linder, L. (2011, September). *Factors associated with hospital-acquired central line bloodstream infections in children with cancer*. Paper session presented at Association of Pediatric Hematology/Oncology Nurses Annual Conference, Anaheim, CA.

O'Grady, N. P., Alexander, M., Burns, L. A., Dellinger, E. P., Garland, J., Heard, S. O., . . . Healthcare Infection Control Practices Advisory Committee. (2011). Summary of recommendations: Guidelines for the prevention of intravascular catheter-related infections. *Clinical Infectious Diseases*, *52*, 1087-1099. doi:10.1093/cid/cir138

R Foundation for Statistical Computing. (2016). *The R project for statistical computing*. Retrieved from https://www.r-project.org

Scott, R. D. (2009). *The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention*. Retrieved from http://www.cdc.gov/hai/pdfs/hai/scott_costpaper.pdf

Sonis, S. T. (2009). Mucositis: The impact, biology, and therapeutic opportunities of oral mucositis. *Oral Oncology*, *45*, 1015-1120. doi:10.1016/j.oraloncology.2009.08.006

Srinivasan, A., Wise, M., Bell, M., Cardo, D., Edwards, J., Fridkin, S., . . . Pollock, D. (2011). Vital signs: Central line-associated blood stream infections—United States, 2001, 2008, and 2009. *Morbidity and Mortality Weekly Report*, *60*, 243-248.

Steinberg, J. P., Robichaux, C., Tejedor, S. C., Reyes, M. D., & Jacob, J. T. (2013). Distribution of pathogens in central line–associated bloodstream infections among patients with and without neutropenia following chemotherapy: Evidence for a proposed modification to the current surveillance definition. *Infection Control and Hospital Epidemiology*, *34*, 171-175. doi:10.1086/669082

Wilson, M. Z., Deeter, D., Rafferty, C., Comito, M. M., & Hollenbeak, C. S. (2014). Reduction of central line-associated bloodstream infections in a pediatric hematology/oncology population. *American Journal of Medical Quality*, *29*, 484-490. doi:10.1177/1062860613509401

Wilson, M. Z., Rafferty, C., Deeter, D., Comito, M. A., & Hollenbeak, C. S. (2014). Attributable costs of central line-associated bloodstream infections in a pediatric hematology/oncology population. *American Journal of Infection Control*, *42*, 1157-1160. doi:10.1016/j.ajic.2014.07.025

Wisplinghoff, H., Bischoff, T., Tallent, S. M., Seifert, H., Wenzel, R. P., & Edmond, M. B. (2004). Nosocomial bloodstream infections in US hospitals: Analysis of 24,179 cases from a prospective nationwide surveillance study. *Clinical Infectious Diseases*, *39*, 309-317.

Author Biographies

Lauri A. Linder, PhD, APRN, CPON, is an assistant professor at the University of Utah College of Nursing, Salt Lake City, Utah. She is also a clinical nurse specialist at the Cancer, Blood, and Transplant Service, Primary Children's Hospital, Salt Lake City, Utah.

Cheryl Gerdy, MSN, RN, CPON, is the service line director for the Cancer, Blood, and Transplant Service, Primary Children's Hospital, Salt Lake City, Utah.

Rouett Abouzelof, MS, RN, is the infection prevention manager for the Primary Children's Region, Primary Children's Hospital, Salt Lake City, Utah.

Andrew Wilson, PhD, MStat, is an assistant professor (clinical) at the University of Utah College of Nursing, Salt Lake City, Utah.