



Sustained Reduction and Prevention of Neonatal and Pediatric Central Line-Associated Bloodstream Infection Following a Nurse-Driven Quality Improvement Initiative in a Pediatric Facility

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Abstract

Purpose: Hospitals devote significant resources developing protocols to minimize the incidence of central line-associated bloodstream infections (CLABSIs), a source of increased patient morbidity and health care costs; however, few of these protocols, especially centralized protocols, are reported in the literature. This study characterizes the development and effectiveness of a pediatric hospital's centralized CLABSI prevention bundle.

Design and Methods: The study was designed as a retrospective interrupted time series to quantify the effectiveness of the prevention bundle that was developed and implemented by nursing leadership in infection control, and both the neonatal and pediatric intensive care units between 2006 and 2014. The study period was subdivided into pre-, peri-, post-, and second peri-intervention periods based on the implementation status of the bundle. Segmented linear regression was used to model and compare the CLABSI rates for each intervention period overall as well as the 5 individual hospital units.

Results: The hospital's modeled CLABSI rate during the preintervention period was 3.80 out of 1000 line days and was significantly reduced to 0.45 ($P < 0.001$). Clear decreases in unit CLABSI rates were observed and all units were below corresponding National Healthcare Safety Network CLABSI rates after the study.

Conclusions: The centralized CLABSI prevention bundle reduced and sustained low CLABSI rates overall and within each hospital unit demonstrating the success of the bundle.

Practice Implications: A centralized CLABSI prevention bundle can universalize central line care, simplify infection control, and improve quality of care to help sustain low CLABSI rates throughout the hospital.

Keywords: CLABSI, reduction, prevention, hospital wide prevention bundle, central line infection

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Introduction

Approximately 250,000 central line-associated bloodstream infections (CLABSIs) are acquired each year in US hospitals with death occurring in 28,000 cases.^{1,2} The estimated cost to treat each patient is \$29,156 and places a \$2.3 billion burden on the US health care system each year.¹ Additionally, the Centers for Medicare and Medicaid Services classify CLABSIs as never-events preventing hospitals from obtaining

reimbursement for treating these infections, amplifying the burden on the health care system.³ The personal suffering of patients and families from a hospital-acquired bloodstream infection is immeasurable, highlighting the importance of preventing these nosocomial infections.

Hospitals and individual units within a hospital devote significant resources to develop protocols to decrease the incidence of CLABSIs. Epidemiology studies combining CLABSI statistics from multiple hospitals clearly establish the efficacy of CLABSI bundles through a significant reduction in overall CLABSI rates.⁴⁻⁷ However, few hospitals publish their bundles in the literature, especially bundles designed to reduce risk of CLABSIs in pediatric patients. Studies that report on the effectiveness of a specific CLABSI bundle are either limited to an entire hospital without information for individual units,⁸⁻¹¹ or are limited to 1 hospital unit or patient type.¹²⁻¹⁸ Further, success of a specific bundle at 1 facility may not translate to another due to differences in patient types between facilities.

Effectiveness of each individual bundle varies with some hospitals experiencing significant success, whereas others are less effective. A recent comprehensive review helps demonstrate the variety of effectiveness of CLABSI bundles through meta-analysis of results from 14 pediatric intensive care units (PICUs) and 14 neonatal intensive care units (NICUs).⁷ The bundles in the identified studies mostly focused on implementation of improved education and well-established CLABSI prevention interventions (ie, checklists, hand hygiene, and skin antisepsis). The meta-analysis found that CLABSI bundles are effective in critically ill pediatric patients, but the reductions seen in 11 PICU bundles and 5 NICU bundles were not clearly significant. Only 10 of the PICU and NICU studies demonstrated sustainment with an adequate follow-up period. Elements of continuous improvements were implemented or discussed in 4 studies that aimed to further reduce CLABSI rates after bundle implementation.^{12,18-20} The review only considered critical care and did not consider bundle effectiveness for other hospitalized patients.⁷ These observations support the need for continued dissemination of successful CLABSI bundles, especially for pediatric patients.

We developed a hospitalwide CLABSI prevention and maintenance bundle that uses a unique combination of interventions that includes well-established interventions and interventions not reported extensively in the literature. The primary objective of this article is to report the overall effectiveness of the hospitalwide CLABSI prevention bundle, and the secondary objective is to assess the effectiveness of the CLABSI prevention protocol in each unit. Following an interrupted time series design, analysis of CLABSI rate data between 2006 and 2014, corresponding to development, implementation, and evaluation of the bundle, demonstrate these objectives through sustained reduction of CLABSI rates. Analysis of results for each individual unit further illustrates the applicability of the infection prevention interventions on the diverse patient population treated at the study hospital. Unit data compared with CLABSI rates reported by the National Healthcare Safety Network (NSHN) demonstrate how the hospital CLABSI prevention bundle reduced CLABSI rates to, at, or below national benchmarks. We report on the development and success of our CLABSI prevention bundle in significantly reducing CLABSI rates throughout our Children’s Hospital.

Methods

Study Facility

The study hospital is a 152-bed hospital freestanding not-for-profit pediatric medical center located in Tennessee. During the study period from 2006-2014, there was a yearly average of 38,454 patient days, 6664 admissions, and 11,085 central line days. The hospital has 5 main units, the PICU, NICU, a general inpatient unit serving hematology-oncology patients, a medical unit, and an inpatient surgery unit. **Figure 1** displays monthly patients with lines and central line days by unit to demonstrate distribution of central lines throughout the hospital. The hospital institutional review board approved the study protocol and waived the requirement of informed consent.

Study Design

This retrospective study followed an interrupted time series design to assess the effectiveness of a pediatric hospitalwide

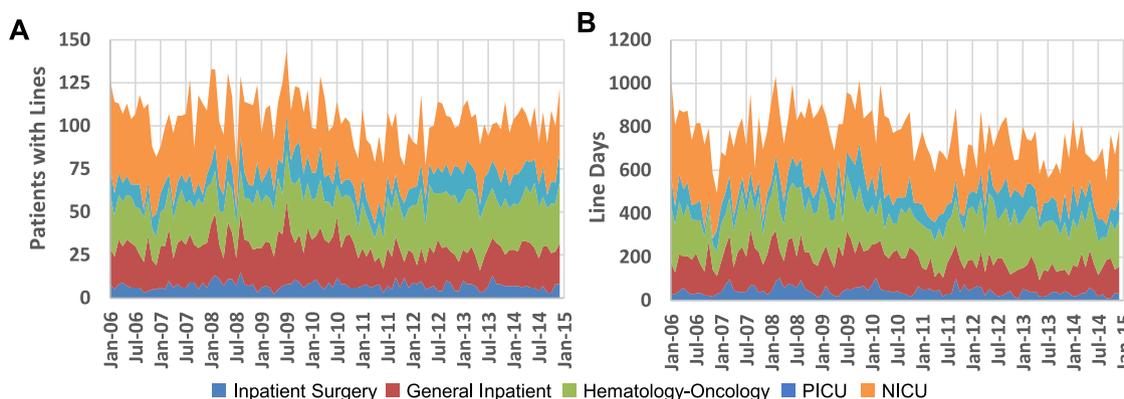


Figure 1. Distribution of central line utilization in the hospital by unit. A, Number of patients with a central line by month B, Number of line days in each unit by month. PICU = Pediatric intensive care unit; NICU = Neonatal intensive care unit.

CLABSI prevention bundle designed and implemented between 2006 and 2011. All patients (aged 0 months to 21 years) admitted to the hospital who received a central line, as defined by the NHSN, comprised the study population. The NHSN defines a central line as an intravascular catheter that terminates at or close to the heart or 1 of the great vessels and is used for infusion, withdrawal of blood, or hemodynamic monitoring.²¹ Exclusion of a patient from the study occurred only if the patient had received a central line before admission and developed a bloodstream infection within 48 hours of admission with supporting clinical or laboratory evidence of an infection at the time of admission. This exclusion criterion is in line with NHSN definitions issued by the Centers for Disease Control and Prevention (CDC).

Development of the CLABSI Prevention Bundle

In 2006, the hospital identified 23 CLABSIs in the level-3 NICU, 4 in the PICU, and 20 throughout the other inpatient units for a CLABSI rate of 4.99 per 1000 line days. As a facility, qualitatively we knew these infections prolonged hospital stays, increased health care cost, and caused anxiety for patients and families, but the hospital assumed CLABSIs to be an inherent risk with central lines. At the time, no specific interventions were in place for prevention of central line infections beyond the insertion bundle nor did we have a standardized maintenance bundle beyond a 7-day aseptic dressing change policy. Hospital leadership was not aware of implementable interventions that could prevent CLABSIs and improve quality of care for our patients. Fortunately, CLABSI prevention developed into a national initiative. In 2007, the state of Tennessee became a leader in the CLABSI prevention initiative, mandating daily central line necessity review and the reporting of monthly CLABSIs by acute care facilities, including pediatric facilities, to the state and CDC the following year. Infection control and nursing leadership formed a task force to meet the state mandate and investigate potential preventative interventions that pertained to the pediatric population. Soon after formation of the task force, in 2007, the group implemented chlorhexidine gluconate (CHG) skin cleansing before insertion of a central line as a preventative measure against CLABSIs. As part of this new initiative, the directors of the NICU, PICU, infection control, nursing leaders in the NICU and PICU, and the neonatal nurse practitioners attended a Tennessee Hospital Association (THA) meeting to learn how other member hospitals reduced CLABSI occurrences and sustained the reduction. At this meeting, we learned of added basic interventions and networked with other hospitals; however, it was the personal stories of families regarding deaths from hospital-acquired infections that became the catalyst for the nursing leaders to become passionate champions for CLABSI prevention. Following the THA meetings, we immediately expanded the membership of the CLABSI prevention task force to include all stakeholders and make this quality improvement initiative interprofessional. The interprofessional task force members included physicians, nurse practitioners, nurses, pharmacy representatives, respiratory therapists, patient care assistants, housekeepers, and equipment cleaning technicians.

The task force assessed potential changes to the bundle at weekly meetings using the Plan, Do, Study, and Act (PDSA) process to incorporate new interventions into the CLABSI prevention bundle and altering processes that did not improve CLABSI rates. In the Plan phase of PDSA, comprehensive literature reviews and consultations with infection prevention experts at other hospitals (pediatric and general) facilitated identification of potential interventions for preventing CLABSI infections. A critical part of the planning process included nursing simulations of line changes, draws, insertions, and removals without interventions to determine potential risk for infection. The simulation results guided selection of interventions to evaluate in the Do and Study PDSA phases of the bundle development process. Following staff education and training, evaluations of new interventions occurred in the NICU and PICU to assess effectiveness. This process included trials of medical devices (ie, administration set components) when required to implement an intervention that focused on ease of use and effectiveness of the device. Evaluations of new interventions occurred over approximately 1 month. The task force considered the results of the intervention evaluation at the next meeting and implemented the intervention if the evaluation results demonstrated a benefit after completing the PDSA cycle. Random auditing of at least 10% of lines on each unit by staff nurse CLABSI-prevention champions ensured bundle compliance and evaluated necessity of the line. Target compliance was 90% for each bundle component. One-to-one training of individual staff members corrected isolated deviations from the bundle, and if unit compliance fell below 90%, then unit retraining ensured staff competence.

Using the described process, the task force developed an initial CLABSI bundle, composed of insertion, maintenance, and prevention elements. Implementation of the bundle occurred in June 2008 in the NICU and PICU (Table 1). Initial elements were primarily adapted or modified from the consensus guidelines issued by the Healthcare Infection Control Practices Advisory Committee (HICPAC) of the CDC in 2002.²² The literature reviews were used to identify appropriate devices for implementation of specific interventions.²³⁻²⁵ Modified bundle elements or additional interventions to HICPAC guidelines included daily aseptic administration set hub cap changes for the PICU, 48-hour administration tubing set changes for total parenteral nutrition, and 24-hour changes for lipids and any line in which blood sampling occurred, a mask with syringe and intravenous bag changes in the PICU, and hand hygiene before entering the NICU. These modifications to the HICPAC recommendations resulted from outcomes of nursing simulation studies. Weekly meetings of unit-based multidisciplinary teams monitored effectiveness of bundle elements, identified obstacles to bundle compliance, and continued to review literature for potential new elements. The bundle with PICU variances extended to the remaining hospital units during January 2009 following successful implementation in the NICU and PICU. For the purposes of data analysis, the period between January 2006 and May 2008 was defined as the preintervention period.

Between June 2008 and January 2011, the interprofessional task force continued to meet weekly or monthly to update and refine the CLABSI prevention bundle. The task force

Table 1. Initial Central Line-Associated Bloodstream Infection (CLABSI) Prevention Bundle Protocol Implemented June 2008

Insertion	Maintenance	Prevention
<ul style="list-style-type: none"> • Strict hand hygiene • Chlorhexidine gluconate-alcohol skin antiseptics, alcohol skin antiseptics in patients with sensitivity • Full sterile barrier precautions • Chlorhexidine gluconate-impregnated intravenous line sponge at insertion site 	<ul style="list-style-type: none"> • Daily aseptic administration set hub cap changes • Daily administration tubing set changes for lipids or medications, all other changes are at 48 h • 7-d dressing change • Hand hygiene observations before manipulation of lines • Neutral displacement needleless connector use • Mask with syringe and intravenous line bag changes in pediatric intensive care unit • Sutureless stabilization device changed every 7 d if used 	<ul style="list-style-type: none"> • Hand hygiene before entering the neonatal intensive care unit • Handwashing before and after each patient interaction • Weekly multidisciplinary team meetings (nursing, nurse practitioners, infection control) • Scrub the Hub educational campaign using chlorhexidine gluconate

implemented 6 additional interventions between implementation in June 2008 and the end of 2009 (Table 2). These interventions were implemented based on new clinical evidence, clinical experience at our facility, and clinical experience communicated within the Children’s Hospital Association Network and the THA.^{12,22,26-29} A critical addition to the bundle was the institution of CLABSI-specific focus groups in 2010 involving nurses, nurse practitioners, and physicians who cared for patients that developed a CLABSI. These focus groups identified possible root causes of the CLABSI and any deviations from the bundle. Findings from these meetings directly led to implementation of the following interventions: cleaning of high-touch surface areas every shift, change of administration tubing at 96 hours unless used for lipids or blood (note variations for the NICU in Table 2), and administration set cap change after blood draw. Clinical experience and nursing simulations were responsible for other interventions instituted in 2010 and 2011 (Table 2). This period was designated the peri-intervention period for the study.

The bundle remained unchanged between February 2011 and December 2012 forming the postintervention period; however, in 2012 we joined a patient safety collaborative, Solutions for Patient Safety (SPS), that now includes more than 100 children’s hospital to further enhance our CLABSI prevention efforts. As part of our participation in the collaborative, we reviewed our CLABSI prevention bundle against the bundle elements recommended by SPS. This audit concluded that we were compliant with the recommendations and no changes were immediately made; however, participation in the SPS collaborative immediately influenced education initiatives and improved methods to document bundle compliance.

The task force updated the CLABSI prevention bundle with new interventions in 2013 and 2014. Focus groups following specific CLABSI occurrences from 2011 and 2012 led to 2 NICU-specific changes to the bundle in 2013. The first intervention was cleaning the umbilical cord from the bottom of the

stump to the top with CHG before line insertion and before umbilical venous catheter and umbilical artery catheter line removal in response to several CLABSIs occurring within 24 hours after removal of an umbilical venous catheter and umbilical artery catheter line. The task force identified the intervention in the literature and confirmed appropriateness with nursing simulations.³⁰ Focus group findings also exposed occasional peripherally inserted central catheter (PICC) line dressings were coming loose and redressed causing unintentional migration of the lines within the vessel. This discovery led to the NICU-specific policy of required removal of exposed PICC lines following establishment of another line. This policy change eliminated redressing of the exposed PICC line, which increased the risk of inoculation of bacteria. Due to concerns for fragile skin integrity of neonatal patients we instituted the policy of changing NICU dressings only when they became loose, wet, or compromised due to risk of losing the line during a dressing change. In 2014, the PICU adopted daily CHG bathing for all patients older than age 2 months following a recommendation made by the SPS. Other changes to the bundle focused on maximizing cleanliness of patient environments. Table 2 summarizes these interventions and this period was analyzed as a second peri-intervention period.

Data Analysis

Monthly CLABSI (No. of CLABSI events/line days × 1000) rates were calculated for the hospital overall. Descriptive statistics were calculated for each intervention period and yearly CLABSI rates. Subanalysis of CLABSI rates were performed for each unit of the hospital, categorized as the NICU, PICU, hematology–oncology, inpatient surgery, and general inpatient wards. It is important to note that the hospital does not have a registered hematology–oncology unit; however, the hospital designates 1 unit for admission of hematology–oncology patients. For this study, national CLABSI rates for hematology–oncology units were used for comparison purposes due to the same patient

Table 2. Bundle Interventions Implemented During Peri-Intervention Periods

Period	Year	Intervention
First peri-intervention period	2008	<ul style="list-style-type: none"> • CHG gluconate scrub of administration set hub at every access (15-s scrub, 3-s dry) • Neutral displacement needleless connector on all central lines • Aseptic administration tubing change policy initiated
	2009	<ul style="list-style-type: none"> • Adoption of silver antimicrobial IV patch at insertion site • Central line maintenance bundle for changing administration set tubing initiated • Administration set changes required to have disinfected table, sterile kit, hat, mask, sterile cover gown, and sterile gloves
	2010	<ul style="list-style-type: none"> • 2-person Broviac dressing and administration set line changes in the NICU to prevent patient contamination of line • Implementation of focus groups to determine root cause of CLABSI events • Maintenance bundle updated to include: Aseptic technique for all line interactions and standardized dressing change protocol • PICU and medical floors: 24-h administration sets and needleless component changes for lipids and blood product and 96 h for nonlipids • NICU: 96-h administration set tubing change for all fluids/solutions except lipids and blood draws. Lines used for lipids and blood draws remain at 24-h change • Administration set hub/access site cap change after each blood draw in all units except NICU • Disinfection of patient area at each shift in NICU and PICU, disinfection includes all items used in the immediate area of the patient, such as bed (including linen), bedside table, overbed tables, IV pump, feeding pumps, diaper scales, and bedside supply cabinets
	2011	<ul style="list-style-type: none"> • Closed system for UAC in NICU (Figure S1)
Second peri-intervention period	2013	<ul style="list-style-type: none"> • Monthly rotation and terminal cleaning of bedside supply cabinets in NICU to ensure cleanliness of supplies and cabinets used with long-term-stay infants. PICU cleans and disinfects cabinet at least monthly and at discharge • NICU dressing changed when loose, wet, or compromised; all other units maintain 7-d dressing change • Umbilical cord cleaned with CHG before and after line removal • Exposed PICC lines removed after another line established. No manipulation of line to insert back under skin
	2014	<ul style="list-style-type: none"> • CHG daily body wipe for children older than age 2 mo in PICU following SPS recommendations. Daily linen changes re-emphasized

CHG = Chlorhexidine gluconate; IV = Intravenous line; NICU = Neonatal intensive care unit; PICU = Pediatric intensive care unit; SPS = Solutions for Patient Safety collaborative; UAC = Umbilical artery catheter.

type. Segmented linear regression modeled the mean CLABSI rate for the pre-, peri-, post-, and the second peri-intervention periods for the hospital overall and for each unit. A first order autoregressive parameter corrected for serial autocorrelation as indicated by a Durbin-Watson test for autocorrelation. Wald tests were used for significance testing between the modeled CLABSI rates for the 4 defined intervention periods.^{12,31} Pooled unit CLABSI rates were compared with NHSN pooled rates corresponding to the end of each intervention period to demonstrate how our units perform against the national benchmark.^{6,32-34} The standardized infection ratio (SIR) was calculated for each unit during the pre-, peri-, post-, and second peri-interventions periods. A mid-*P* exact test determined whether the calculated SIR was significantly different from 1 following the methods used by the NSHN.^{6,35} Statistical significance required a *P* value < .05. Data

organization occurred in Microsoft Excel (Redmond, WA) and analyzed in the R statistical programming environment (R Foundation for Statistical Computing, Vienna, Austria) using R Studio (Boston, MA).

Results

Overall Effectiveness of CLABSI Prevention Protocol

Figure 1 displays line days and number of patients with lines stratified by hospital unit to illustrate the distribution of central lines in the hospital. The data demonstrate that central lines are most commonly used in the NICU, followed by the hematology–oncology and general inpatient wards. The mean number of patients with a central line per month was 105 ± 14 and the mean number of line days per month was 767 ± 116 . [Table 3](#)

Table 3. Central Line-Associated Bloodstream Infection (CLABSI) Rates for Hospital in Each Intervention Period With Corresponding National Healthcare Safety Network (NHSN) Data

Unit	Preintervention period			Peri-intervention period			Postintervention period			2nd peri-intervention period		
	CLABSI rate ^a	NHSN rate, 2006-2008 ³²	SIR	CLABSI rate ^a	NHSN rate, 2010 ³³	SIR	CLABSI rate ^a	NHSN rate, 2012 ³⁴	SIR	CLABSI rate ^a	NHSN rate, 2013 ⁶	SIR
Overall	3.89 (89/22861)	NA	NA	1.89 (51/27044)	NA	NA	0.36 (6/16440)	NA	NA	0.48 (8/16592)	NA	NA
NICU	5.14 (45/8763)	2.89	1.78*	2.18 (21/9622)	1.63	1.30	0.36 (2/5562)	1.30	0.29*	0.87 (5/5730)	1.13	0.78
VLBW	8.74 (35/4004)	3.26	2.68*	3.28 (16/4876)	2.06	1.55**	0.84 (2/2368)	1.68	0.50	1.23 (3/2438)	1.43	0.86
LNBW	2.10 (10/4759)	2.16	0.97	1.05 (5/4746)	0.91	1.16	0.00 (0/3194)	0.71	0.00	0.61 (2/3292)	0.65	0.93
Hemo-onc	3.08 (17/5525)	2.87	1.07	1.81 (12/6632)	1.91	0.95	0.61 (3/4881)	1.83	0.34*	0.42 (2/4771)	2.10	0.20*
PICU	4.59 (11/2394)	2.96	1.55**	3.42 (12/3508)	1.77	1.94*	0.47 (1/2128)	1.43	0.33	0.43 (1/2301)	1.23	0.35
General inpatient	2.49 (12/4811)	1.76	1.42	0.70 (4/5740)	1.21	0.58	0.00 (0/2898)	0.97	0.00**	0.00 (0/3023)	1.08	0.00*
General surgery	2.90 (4/1378)	3.13	0.93	1.30 (2/1542)	1.31	0.99	0.00 (0/971)	0.96	0.00	0.00 (0/767)	1.13	0.00

Hemo-onc = Hematology-oncology; LNBW = Low-to-normal birth weight; NA = Not applicable; NICU = Neonatal intensive care unit; PICU = Pediatric intensive care unit; SIR = Standardized infection ratio; VLBW = Very-low birth weight.

^aData in parentheses are infections/line days.

* $P < .05$.

** $P < .1$.

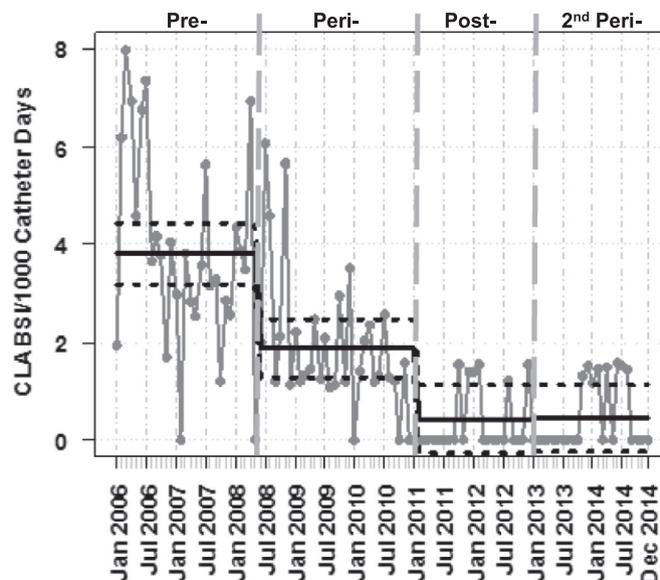


Figure 2. Hospitalwide monthly central line-associated bloodstream infection (CLABSI) rates (gray circles) observed during the study period. Solid black line represents segmented regression model fit with 95% confidence intervals represented by black dashed line. Grey dashed lines indicate transition between intervention periods.

summarizes the number of CLABSIs, line days, the pooled CLABSI rate, and the corresponding pooled CLABSI rate reported by NHSN by intervention period for the overall hospital and for each unit.

Figure 2 displays the CLABSI rates per 1000-line days by month for the entire hospital and the modeled mean CLABSI rate for each intervention period. The model estimates for the pre-, peri-, post, and second peri-intervention CLABSI rates were 3.80 ± 0.63 (95% confidence interval), 1.88 ± 0.60 , 0.42 ± 0.70 , and 0.45 ± 0.69 . A significant decrease in the modeled CLABSI rates resulted for the peri, post, and second peri-intervention period compared with the preintervention period ($P < .001$). The

decrease in the modeled rates between the peri- and post- and second peri- intervention periods was also significant ($P = .0086$ and $P = .010$), but no significant decrease occurred between the post- and second peri-intervention period.

Effectiveness of CLABSI Prevention Bundle in Individual Hospital Units

The secondary objective of this study was to demonstrate effectiveness of the CLABSI prevention bundle with NICU, PICU, hematology–oncology, general inpatient, and general surgery patients to illustrate applicability of the bundle to a diverse set of patients. Table 4 displays the modeled mean CLABSI rate for

Table 4. Modeled Mean Central Line-Associated Bloodstream Infection Rates for Each Hospital Unit

Unit	Preintervention Rate	Peri-intervention Rate	<i>P</i> value ^a	Postintervention Rate	<i>P</i> value ^a	Second Peri-intervention Rate	<i>P</i> value ^a
Neonatal intensive care	4.84 ± 1.16	2.20 ± 1.11	.003	0.41 ± 1.30	< .001	0.79 ± 1.27	< .001
VLBW	7.55 ± 2.23	3.41 ± 2.12	.020	0.72 ± 2.49	< .001	1.00 ± 2.44	< .001
LNBW	1.95 ± 0.96	0.84 ± 0.91	.232	0.01 ± 1.07	.021	0.66 ± 1.05	.180
Hemocology–oncology	2.82 ± 1.25	1.82 ± 1.19	.523	0.65 ± 1.40	.058	0.48 ± 1.37	.033
Pediatric intensive care	4.07 ± 1.87	3.39 ± 1.78	.919	0.43 ± 2.10	.029	0.27 ± 2.06	.019
General inpatient	2.45 ± 0.85	0.67 ± 0.81	.007	0.00 ± 0.95 ^b	< .001	0.00 ± 0.93 ^b	< .001
General surgery	2.62 ± 1.64	0.96 ± 1.56	.339	0.00 ± 1.84 ^b	.093	0.00 ± 1.89 ^b	.088

LNBW: Low-to-normal birth weight; VLBW: Very-low birth weight.

^a*P* value compared against preintervention.

^bModeled rate < 1.0e-14.

each unit during the intervention periods. A significant reduction in the CLABSI rate between the pre- and second peri-intervention period occurred in all units except general surgery. However, the modeled mean rate in general surgery was near zero and the *P* value indicated a trend toward significance (*P* < 0.1). The largest absolute reduction in CLABSIs occurred in the NICU and PICU.

In the NICU, it is standard practice to analyze CLABSI rates based on infant birth weight due to the increased risk of infection in very-low birth weight (VLBW) infants (<1500 g). The NHSN typically reports birth weight data in 5 categories (see [Table S1](#)); however, due to limited number of patients in certain categories, we chose to group patients into 2 categories, 1 for VLBW (<1500 g) and 1 group for low-to-normal birth weight (LNBW) (>1501 g). The modeled CLABSI rates for VLBW significantly decreased across each intervention period compared with the preintervention period. For the LNBW infants, the modeled rate decreased across intervention periods, but a significant decrease occurred only between the pre- and postintervention periods ([Table 4](#)). These observations suggest the bundle had the greatest effect in VLBW infants.

Pooled CLABSI rates from each individual unit were compared with published NHSN pooled CLABSI rates for comparable units by calculating an SIR for each unit in each intervention period ([Table 3](#)).^{6,32-34} The SIR in the preintervention rate was > 1 for all units except general surgery, indicating poor performance compared with national averages. By the post- and second peri-intervention periods, the SIR for each unit was < 1, indicating that the hospital had achieved CLABSI rates superior or equivalent to national rates ([Table 3](#)).

Discussion

Unacceptable CLABSI rates at our hospital prompted a nursing-led interprofessional quality improvement initiative that resulted in a universal comprehensive CLABSI prevention bundle ([Tables 1 and 2](#)). The bundle allowed us to significantly reduce the overall CLABSI rate from an unacceptable modeled preintervention rate of 3.80 to a postintervention rate of 0.42, and we demonstrate sustainment through a modeled rate of 0.45 for the second peri-intervention period ([Figure 2](#)). These observations support the overall effectiveness of the CLABSI prevention bundle; however, the consistent and sustained reduction of CLABSIs in each hospital unit illustrates the true influence of the prevention bundle ([Tables 3 and 4](#)). Unit CLABSI rates are below the national NHSN benchmarks for each patient type.⁶ Further, our PICU and NICU achieved CLABSI rate reductions that are among the best for the PICU and NICU bundles reviewed by Ista et al⁷ with regard to incidence risk ratio (IRR) reductions. The NICU IRR was 0.17 (95% CI 0.06-0.40) and the PICU IRR was 0.095 (0.004-0.55) with the PICU IRR being the best of the 14 PICU studies included in the review.⁷ These observations support general applicability to all of our patients highlighting the strength of this CLABSI prevention bundle.

Although we cannot make a definitive conclusion concerning the effectiveness of a specific intervention, we believe that several unique interventions in our CLABSI prevention program directly contributed to the success of the bundle. These inter-

ventions include weekly multidisciplinary focus groups during the design and implementation of the bundle; focus groups following each CLABSI event; use of an ionic silver intravascular dressing combined with CHG skin cleansing for patients with central lines; per-shift environmental cleaning of patient areas; aseptic administration set hub/access site cap changes for blood draws with a maximum of 24 hours between changes in all units but the NICU; use of a closed intravenous line system in the NICU; and coordination with nursing, lab, and respiratory care for blood draws to decrease the number of administration set line entries.

The interprofessional task force involving nursing leadership and key stake holders was directly responsible for initiating and optimizing the CLABSI prevention bundle based on member's collective expertise and clinical experience. Using an interdisciplinary group allows us to quickly identify deficiencies in the bundle, assess the deficiencies, and identify new interventions to address these issues considering the needs of all our patient types. This system allowed us to optimize the bundle within 2.5 years and achieve sustained reduction in our CLABSI rate. Use of CLABSI-specific focus groups starting in 2010 identified most root causes of individual CLABSI occurrences with several outcomes resulting in changes to the CLABSI prevention bundle. Through the outcomes of these meetings we integrated patient environment cleaning; administration set cap changes following blood draws into the bundle; and in 2013, NICU-specific changes in the bundle to prevent CLABSI infections resulting from umbilical central lines and exposed PICC lines. Both the CLABSI task force and CLABSI-specific focus groups continue to play a critical role in sustaining our low CLABSI rates by allowing us to respond quickly to emergent issues with the bundle as demonstrated.

The hospital bundle uses an ionic silver catheter dressing in lieu of the more common CHG dressings. The task force chose to use the silver dressing because it is applicable to all of our patients,^{28,29} whereas CHG dressings are contraindicated for some neonates and have been reported to cause skin breakdown in critically ill patients from prolonged CHG exposure.³⁶⁻³⁸ Our bundle still uses a CHG-alcohol skin scrub (in VLBW population we wipe off with sterile saline due to risk of burns) before line insertion because CHG-alcohol can provide up to 48 hours of effective antiseptics.³⁹⁻⁴¹ This temporary use of CHG allows for the antimicrobial effects of ionic silver and CHG to be used synergistically as a barrier against infection.^{42,43} The antimicrobial mechanisms of ionic silver and CHG begin by binding to the bacterial cell wall, disrupting the wall allowing passage of silver ions and CHG molecules into the cell.⁴⁴⁻⁴⁶ Once in the cell, CHG binds to the intracellular membrane lysing the membrane leading to bacterial cell death.⁴⁶ Silver ions disrupt several cellular processes that lead to cell death, including disruption of cell and organelle membranes, impairing cellular respiration, and denatures bacterial DNA and RNA inhibiting replication.⁴⁴⁻⁴⁶ To our knowledge, this is the first article that reports the combined use of CHG and silver for skin antiseptics around a vascular access site.

The cleanliness of the environment is critical for preventing hospital-acquired infections by decreasing bacterial bioburden

on equipment and furniture. Clinicians and family enter and leave a patient's room multiple times throughout the day, introducing bacteria to the environment. As a preventative intervention, we require staff to clean high-touch areas within patient care environments using germicidal and viricidal disposable wipes during each shift to limit potential exposure to pathogenic bacteria. Multiple focus groups for individual CLABSI occurrences identified nonadherence to these practices as possible causes for the infection.

Although it is common for administration set tubing and hub/access sites to undergo a change within 24 hours of infusion of blood product or lipids, this policy does not appear to be extended to blood draws, as reported in other published bundles.^{8,9,11-14,47} The administration set hub/access cap on the central line represents the primary access point to the patient and may be accessed multiple times during a 24-hour period for infusions and/or blood draws for testing. Blood is an ideal medium for bacteria to proliferate and most bloodborne infections result from bacteria that are naturally present on the skin.⁴⁸ For these reasons, we enforce an administration set hub/access site cap change in all units except the NICU following blood draws to decrease the risk of infection to the patient. To help minimize the number of line accesses for blood, the PICU and medical units coordinate blood draws with the daily line changes associated with blood and lipids. This practice helps to ensure that hub/access site cap changes occur only once during a 24-hour period. In the NICU, the administration set, including the hub/access site, changes occur at 96-hour interval to minimize risk of line disruption; however, a 24-hour change takes place following lipid infusions to reduce the risk of losing the line. The variation in practice between the NICU and other units is necessary to minimize risk of losing intravenous access in a neonatal patient. To compensate for this variance, the NICU adopted the use of a closed administration line system.

In an interrupted time series study, it is difficult to evaluate the influence of 1 intervention unless application or removal of the intervention is isolated. During January 2011, our NICU instituted a closed intravenous-line system (see [Figure S1](#)) corresponding to the end of the peri-intervention period, resulting in a sustained reduction in CLABSI rates within the NICU. A brief increase in CLABSI rate occurred in 2015 that corresponded to the discontinuation of the closed line system by the vendor of the product. The task force believed the loss of the system contributed to an increase in infections and responded to the increased infection rate with initiatives to improve hand hygiene and dress code compliance. The closed system helps to eliminate the risk of cross-contamination by incorporating 3 neutral displacement connectors that have designated uses: 1 for saline flush, 1 for collecting waste, and 1 for collecting lab samples. This configuration allows the bedside nurse to avoid changing syringes as performed with an open system eliminating the risk of cross-contamination. The nursing leadership in our NICU considered this a critical component to the CLABSI prevention bundle for neonatal patients due to the number of blood draws required for blood gases and lab work. The NICU has since identified an appropriate replacement system allowing the reinstatement of the intervention. For this inter-

vention, there appeared to be a direct correlation with CLABSI rate changes supporting its individual effectiveness.

Although this study's time frame was between 2006 and 2014, we believe it is important to comment on the bundle performance and sustainment in 2015 and 2016. Between March and July 2015, our NICU experienced an increase of CLABSIs with 6 individual events observed during this time. We conducted our own root cause investigations utilizing the event-specific focus groups as well as a special focus group aimed at identifying common potential causes. Through this process we identified that the NICU was failing to consistently clean and disinfect patient positioning devices on a daily and as-needed basis. The focus groups also identified that wrist and hand jewelry, and hair not kept up and away from the face by staff were potential sources of bacteria. Family and staff noncompliance with hand hygiene principles, especially after cellular telephone use, and lack of coordination with respiratory therapy and lab blood collection to minimize central line accesses potentially contributed to the increase in CLABSIs. Each issue is addressable through simple changes in prevention practices and performance of re-training where necessary.

Department leadership addressed these issues through re-training of staff, increased emphasis of hand hygiene to family and staff, and institution of controls to increase coordination between respiratory therapy and the laboratory for blood draws. To help ensure continued high compliance with our bundle, we instituted education and quality practices following SPS recommendations and our units achieved designation as high reliability units through SPS programs. These simple changes to our bundle addressed the issues identified by the focus groups and highlight the importance of use of continuous improvement initiatives within our CLABSI prevention bundle. Between July 10, 2015, and December 31, 2016, we experienced 1 CLABSI in our NICU (rate = 0.36) and 1 in a hematology-oncology inpatient (rate = 0.45). Our medical unit, which has an average of 133 central line days per month, has 7 years without a CLABSI occurrence, and the PICU has 3 years without an occurrence. Our CLABSI rates remain below national benchmark data, demonstrating the effectiveness of these oversight procedures and the effectiveness of the prevention bundle when adhered to correctly.

The study had several inherent limitations that require further discussion. First, the retrospective interrupted times series design limits analysis to existing data routinely collected for monitoring CLABSI rates. Due to the design, the study could have been susceptible to unintentional bias from unmeasured factors that may have influenced the observed CLABSI rates. Bias in the study is unlikely because the infection control department at the hospital was actively tracking CLABSI rates throughout the study period using a standardized method. Further, the results of this study demonstrate a direct causal effect based on the full implementation of the CLABSI prevention bundle. Adequate documentation of compliance in a database did not occur before 2013, preventing definitive demonstration of high compliance throughout the study period. Insertion compliance for the entire hospital between 2013 and 2016 ranged from 94% to 99%. Compliance to the maintenance bundle, first monitored in 2014,

increased from 79% to 91% in 2015 and 2016. Deviations from the maintenance bundle were due to improper documentation of line necessity, late dressing changes, or administration set tubing changes. The success of the CLABSI bundle demonstrated in this research supports a level of high compliance to bundle elements despite limited documentation of compliance. Another weakness was the gradual implementation and modification of the bundle over time, which prevented direct assessment of each intervention's effectiveness in the bundle. Effectiveness of individual interventions would require a randomized controlled trial with control and intervention groups. These trials are not always feasible or ethical due to the resources required to perform the study and the potential of exposing patients to substandard care in a control group. Although not necessarily a weakness, the bundle implemented in our NICU has several necessary bundle variations due to the small size and critical illness of our smallest patients to maintain central access. In most instances, interventions included in our facility bundle were first trialed in the NICU before introduction to the rest of the hospital. We note where NICU variations exist in the Methods as well as Table 2. The final limitation is that this study reports experiences at 1 pediatric medical center and the observed CLABSI prevention success may not transfer to other institutions due to several factors, including differences in patient population (including acuity), patient-to-nurse ratios, resources, and culture. As the literature indicates, there are many successful bundles that reduce CLABSI rates in specific units; however, some facilities still struggle with CLABSI prevention. The primary purpose of this article was to communicate the success of a bundle developed specifically for our pediatric patient populations with hopes that the bundle and its interventions help other medical facilities achieve the same level of excellence in CLABSI prevention.

Conclusions

The institution of a universal CLABSI prevention bundle developed through a nursing-led multidisciplinary collaborative led to a significant sustained reduction of CLABSI rates at our pediatric hospital in all units. The general applicability of the bundle helped to ensure compliance across all units and promotes a culture of collaboration throughout the hospital. A unique aspect of our bundle includes use of continuous improvement efforts to ensure that the bundle remains highly effective and that we react quickly to newly identified deficiencies. At our hospital, staff takes the occurrence of a CLABSI personally and we work to ensure the same circumstances do not occur again to deliver the best quality of care to our patients. We learned that CLABSI prevention requires an ever-evolving program to ensure continued sustainment of low CLABSI rates. We continue to assess new interventions reported in the literature and by other CLABSI-reducing facilities to modify our bundle as necessary in an ongoing effort toward achieving CLABSI rates of zero at our hospital.

Disclosures

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