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SLUG Bug: Quality Improvement With Orchestrated Testing Leads to NICU CLABSI Reduction

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abstract

OBJECTIVE: Reduce central line–associated bloodstream infection (CLABSI) rates 15% over 12 months in children's hospital NICUs. Use orchestrated testing as an approach to identify important CLABSI prevention practices.

METHODS: Literature review, expert opinion, and benchmarking were used to develop clinical practice recommendations for central line care. Four existing CLABSI prevention strategies (tubing change technique, hub care monitoring, central venous catheter access limitation, and central venous catheter removal monitoring) were identified for study. We compared the change in CLABSI rates from baseline throughout the study period in 17 participating centers. Using orchestrated testing, centers were then placed into 1 of 8 test groups to identify which prevention practices had the greatest impact on CLABSI reduction.

RESULTS: CLABSI rates decreased by 19.28% from 1.333 to 1.076 per 1000 line-days. Six of the 8 test groups and 14 of the 17 centers had decreased infection rates; 16 of the 17 centers achieved >75% compliance with process measures. Hub scrub compliance monitoring, when used in combination with sterile tubing change, decreased CLABSI rates by 1.25 per 1000 line-days.

CONCLUSIONS: This multicenter improvement collaborative achieved a decrease in CLABSI rates. Orchestrated testing identified infection prevention practices that contribute to reductions in infection rates. Sterile tubing change in combination with hub scrub compliance monitoring should be considered in CLABSI reduction efforts.

Health care–associated infections (HAIs) are a burden to patients and the health care system. It is estimated that up to 50% of HAIs are preventable.[1,2] In 2002, however, HAIs in US hospitals reportedly reached ~1.7 million, with >33 000 HAIs among infants in high-risk nurseries.[3] Central line–associated bloodstream infections (CLABSIs) have the highest cost per HAI and contribute to significant morbidities, mortality, and length of stay in the adult, pediatric, and neonatal populations.[4–6] The overall direct annual cost of US HAIs ranges from $35.7 to $45 billion for inpatient hospital services.[7] Although the actual cost of CLABSIs varies, the attributable cost to care is up to $69 000 per event.[7–11]

Despite the risks with their use, central venous catheters (CVCs) play an integral role in modern health care.[12] The need for CVCs is particularly important in children's hospital NICUs for patients who

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have diagnoses associated with impaired cardiorespiratory and intestinal function.[13] CVCs are necessary for fluids, nutrition, and medications. Although not CLABSI-specific, evidence is growing that patients with a neonatal infection are more likely to have long-term neurodevelopmental impairment and lower scores on motor and psychosocial development indices.[14] The processes to lower CLABSI rates could therefore have a powerful impact on NICU outcomes.

Centers participating in the Children's Hospitals Neonatal Database (CHND), a data repository developed for IIIc[15] NICUs, established the CHND Collaborative Initiatives for Quality Improvement (CIQI) in 2009 to lead quality improvement (QI) projects in children's hospital NICUs. CHND currently has 28 member tertiary and quaternary NICUs.[13] Clancy et al[16] as well as others[17] have recently described a need for this type of formal structure for collaborative QI projects. The purpose of the SLUG Bug (Standardizing Line Care Under Guideline Recommendations) collaborative was to provide potentially better practice recommendations for neonatal health care professionals in care and maintenance of CVCs and to prevent CLABSIs. The 12-month baseline mean CLABSI rate for the collaborative was 1.33 per 1000 line-days (center-specific rates varied from 0.23 to 3.4), which is below the rate of 1.55 per 1000 line-days reported by the National Healthcare Safety Network's Level III NICUs in 2011.[18] The SMART (Specific, Measurable, Attainable, Relevant, Timeframe) aim of SLUG Bug was to decrease collaborative baseline CLABSI rates by a clinically meaningful target of 15% over 12 months. A second objective of this project was to use orchestrated testing (OT) to identify important CLABSI prevention practices.

METHODS

SLUG Bug was developed and implemented by a multidisciplinary group of experts from 8 CHND member hospitals. The management team included representatives from neonatal nursing, neonatal advanced practice nursing, and neonatal physicians, as well as statistical and process improvement experts familiar with QI and guideline development methods. Inclusion criteria for the project involved CHND membership and agreement to participate for the entire project period. Each hospital had a Level IIIc[15] NICU designation, >40 admissions annually, >25 inpatient beds, and >50% of admissions being outborn.[13] Seventeen CHND hospital NICUs joined the QI collaborative and were committed to further reducing CLABSI rates.

A questionnaire was developed to describe specific CLABSI prevention policies. The 54-item survey was distributed to 25 CHND member NICUs with 24 responses. This benchmarking survey, a systematic literature review, and expert opinion were the basis for the development of a CLABSI reduction Clinical Practice Recommendation for children's hospital NICUs. The Clinical Practice Recommendation underwent a systematic review process that used the AGREE II instrument.[19] The areas outlined in the recommendation include suggestions for hand hygiene, central line insertion, central line maintenance, root cause analysis,[20] and recommendations for compliance monitoring (Table 1, see Appendix).

After reviewing the Clinical Practice Recommendation, each institution was asked to define local CVC care practices and identify process improvement opportunities. The evidence supporting hand hygiene, central line insertion, dressing changes, and root cause analysis is well established.[12,20,21] Other areas of central line care (including duration of hub care [HC] time, tubing change [TC] techniques, line entry, and removal plans) vary widely in local hospital practice; this variation was confirmed by hospital survey. For this collaborative, OT was used to determine if potential best practices could be identified from this variation.[22,23] A 2^{4-1} fractional factorial design matrix[22] of 8 distinct factor/level combinations (test groups) was developed by using 4 dichotomous factors: sterile versus clean TC technique, HC compliance monitoring versus not monitoring, CVC line entry access limitation versus no specific limitations, and CVC line removal tracking versus no tracking policy (Tables 2 and 3). Each center selected the practices in 1 of 8 test groups to adopt and/or maintain. Some had practices congruent to the selected test group and did not modify practice, whereas others planned to implement changes. No center discontinued CLABSI prevention practices. Centers agreed not to implement factors that were not assigned to their group, and they were discouraged from changing additional practices for the study period.

The Children's Mercy Hospital (Kansas City, MO) Pediatric Institutional Review Board reviewed this project and determined it did not meet the definition of research involving human subjects. Data submitted and analyzed were unit based and contained no patient identifiers. Each participating site adhered to their local institution requirements to determine if additional institutional review board approval was needed.

Several key components of the IHI breakthrough series collaborative framework were used to facilitate the project by incorporating sessions directed at team learning and sharing; providing a communication structure that included monthly webinars, an active listserv forum, and access to an expert

clinician panel; and assigning QI advisors.[24] Each site assembled a multidisciplinary group of key stakeholders that included physician, nursing, and site leaders. On monthly collaborative calls, teams shared experiences and Plan-Do-Study-Act cycles (focused on implementation and monitoring of assigned factors) to facilitate transparency as well as learning across centers. Collaborative huddles fostered open discussion in smaller groups. The IHI Extranet, a data system for QI collaboratives, was used by the teams for reporting measures, accessing a listserv for project participants, and storing project resource documents. It also allowed teams to track and graph data over time and monitor improvement progress through submission of progress reports and IHI team assessment scores.[25,26]

The primary outcome measure was CLABSI rates according to the National Healthcare Safety Network's definition of CLABSI.[27] Process measures were defined and collected by self-report or direct observation (Table 4). For the groups assigned to compliance monitoring, a minimum of 10 observations per month from a consistent observer were required as described in the Clinical Practice Recommendation, with an expected target compliance of >75% and an ideal target of ≥90%. Each local team instituted tools and processes for data collection and shared information among sites to adapt as needed. The balancing measure was defined as unintended line replacement.

Baseline CLABSI rates were established on the basis of rates at each site from January 2011 to December 2011. The study period (January 2012–December 2012) focused on compliance monitoring, data sharing, and ongoing local Plan-Do-Study-Act cycles to achieve targeted improvement goals. Centers were expected to submit outcome and process measure compliance data monthly.

Monthly CLABSI rates ([CLABSI events divided by central line-days] × 1000) for each center were analyzed as time series outcome variables by using Statistical Process Control charts (Shewhart u charts).[28] Rational subgrouping was used to study both variation over time and variation between NICUs and test groups. Signals, indicating special cause, were identified by using standard control chart rules. After detecting special cause signals that supported a significant change, the limits for the u chart were calculated for both the baseline and study periods, and signals that indicated a change in the time series were identified.

TABLE 1 Clinical Practice Recommendations for CLABSI Prevention

Recommendations		Minimum Recommendations for Teams
Hand hygiene	Staff and family	Hand washing or use of hand sanitizer immediately before and after patient contact
Central line insertion	Use of insertion checklist	Dedicated teams; sterile barrier; site preparation scrub and dry; sterile dressing
Central line maintenance	HC practice	70% Alcohol prep or ChloraPrep as per NICU protocol • Scrub time = 15 s minimum and up to 60 s • Dry time = until dry
	TC technique	Sterile: minimum to include sterile gloves and mask with use of sterile barrier under the CVC - OR - Clean: minimum to include clean gloves with sterile gauze barriers under the CVC
	Dressing change technique	Define frequency, site preparation, and dressing type per specific NICU protocol. Dressing changes require sterile technique. All individuals actively involved in dressing change must wear mask and sterile gloves • For Broviac; PICC (central or midline); subclavian, jugular, or femoral central line o Weekly and as-needed if dressing becomes wet, soiled, or nonocclusive • Hand hygiene o Current dressing may be removed with clean gloves with hand hygiene performed after removal of gloves • Site dressing o Apply sterile dressing per manufacturer specifications o Track date/time of dressing change, insertion, and removal • Site preparation o <2 mo or corrected GA or weight as defined by unit-specific policy used to define immature skin; 70% alcohol preparation and /or Betadine preparation; scrub time minimum of 30 s and a dry time minimum of 30 s but up to 2 min recommended o >2 mo or corrected GA or weight as defined by unit-specific policy used to define mature skin; ChloraPrep or comparable chlorhexidine unit-based product; scrub time minimum suggested 30 s; dry time minimum suggested 30 s and up to 2 min o For groin/axilla; a 2-min scrub with minimum of 60 s dry time and up to 2 min recommended
	Daily line removal assessment	Daily assessment of central line need and utilization
	Frequency of line entry	Checklist for ongoing need for access, frequency of line entry, line complications, and/or mechanical problems
Root cause analysis		Establish formal reaction team for bedside analysis when CLABSI is identified

GA, gestational age; PICC, peripherally inserted central catheter.

Power was calculated by using a historical CLABSI rate from a sampling of CHND centers. Preliminary calculations found a baseline rate of 1.1 per 1000 line-days; however, once data from all of the participating centers were available, the actual baseline rate was later determined to be 1.33 per 1000 line-days. Average monthly line-days needed for each test group were estimated to be 1000, yielding an SE for each test group of 1.05. Thus, the SE of the difference in factor levels was 0.742. A baseline and study period of 6 months would allow the detection of a change in CLABSI rate >0.3 (under ideal experimental conditions). To achieve this power, a minimum replication of 6000 line-days per test group was required over the study period. Study-It software (McGraw-Hill Professional, New York, NY) was used to estimate and analyze each of the 4 factors' effect and their interactions and to create the appropriate response plots.[22] Main effect terms for each of the factors in the study were evaluated. This analytical approach assumes that the effects of all factors and interaction pairs can be evaluated. Correlation analysis with scatter plots was used to assess for any association between compliance and CLABSIs. This methodology does not involve confidence intervals or *P* values but does use statistical process control charts and repetition to verify the results.

TABLE 2 Study Factors and Their Definitions

Factor	Level	Definition
HC	Monitoring	Monitor compliance with unit-based HC policy
	Not monitoring	No compliance monitoring with unit-based HC policy
TC technique	Sterile	Defined by unit policy but must have a minimum to include hand hygiene and sterile gloves and mask with use of sterile barrier under the CVC
	Clean	Defined by unit policy but must have a minimum of hand hygiene and clean gloves with sterile gauze barriers under the CVC
CVC access	Special	Unit policy in place for limitation of CVC entry
	General	No unit policy in place for CVC entry
Line removal assessment	Yes	Unit policy to assess CVC daily need and utilization
	No	No unit policy to assess CVC daily need and utilization

The factors are outlined with their dichotomous definition for this project. Centers followed these definitions for reporting according to their OT matrix assignment.

TABLE 3 Four Factor OT Design Matrix With 16 Centers

Group	Hub Care	TC	CVC Access	Line Removal Assessment	Hospital ID	CLABSI Rates		Change in CLABSI Rate for Groups
						Baseline Period	Study Period	
1	Not monitoring	Clean	General	No	B	0.624	0.467	−0.157
2	Monitoring	Sterile	General	No	C	2.343	0.480	−1.860
3	Monitoring	Clean	Special	No	D	1.031	0.591	−0.433
					E	1.265	0.844	
4	Not monitoring	Sterile	Special	No	F	1.230	0.547	−0.683
5	Monitoring	Clean	General	Yes	H	1.187	1.875	0.512
					A	0.944	2.166	
					K	2.184	1.628	
6	Not monitoring	Sterile	General	Yes	I	0.934	2.072	0.444
					J	3.407	1.510	
7	Not monitoring	Clean	Special	Yes	L	3.107	0.926	−0.534
					N	0.226	0.098	
8	Monitoring	Sterile	Special	Yes	O	2.001	0.9413	
					P	0.866	0.713	−0.548
					Q	0.485	0.470	
					R	2.502	1.465	
All groups						1.333	1.076	−0.257

This design matrix shows dichotomous factors with group and hospital assignments. The baseline period was January 2011 through December 2011, and the study period was January 2012 through December 2012. CLABSI rates are defined per 1000 line-days. Hospital G was removed because of nonadherence to assignment, and hospital M withdrew from the project.

RESULTS

The collaborative CLABSI rate decreased from a baseline rate of 1.333 to 1.076 per 1000 line-days, a 19.28% reduction. During the baseline period, there was no special cause signal that indicated random variation in rates across the participating sites from January 2011 to August 2011. However, after 8 months, the collaborative CLABSI rates showed a special cause signal on the u chart. After this signal, a new center-line was determined and was sustained for the remaining 4 months (Fig 1). A total of 235 990 line-days (116 987 in the baseline period and 119 003 in the study period) were analyzed. Three single-center groups (1, 2, and 4) consistently had <1000 line-days per month; group 6 had 8 months of <1000 line-days and group 7 had 3 months of <1000 line-days; and groups 3, 5, and 8 had >1000 line-days each month throughout the study period.

Fourteen of the 17 centers had a decrease in rates during the study period (Table 3). Among the 4 infection prevention factors, sterile TC decreased CLABSI rates by an average of 0.51. The addition of HC compliance monitoring produced the strongest effect (interaction of sterile TC with HC monitoring), with

an average decrease in CLABSI rates of 1.25 per 1000 line-days (Fig 2). Figure 3 displays the consistency and variation of the TC change and HC effects shown in Fig 2. Three of the 4 test groups using sterile TC demonstrated a decrease in CLABSI rates (Table 3, Fig 3). Group 2 (a single-center group) that performed both HC monitoring and sterile TC techniques demonstrated the greatest decrease. Three of the 4 groups using clean TC (5 centers; groups 1, 3, and 7) had baseline CLABSI rates below the collaborative mean and maintained low rates. Group 5, comprising 3 centers using clean TC, had a baseline mean of 1.39 and an increase in CLABSI rates at the completion of the study.

Most centers reported compliance by using a combination of self-reporting or direct observation. There was no association between compliance and CLABSI rates. Sixteen centers achieved >75% compliance, and 12 of these centers reached >90% compliance. HC compliance ranged from 92% to 100%, whereas TC technique compliance ranged from 82% to 100%. The CVC device utilization ratio did not change over time. Four teams reporting on the balancing measure (2 with specific monitoring for CVC removal and 2 without such monitoring) showed no change in need for line replacement. Using the IHI assessment score[25] as a measure of local team success, 11 of 17 centers achieved scores ≥3.5 (moderate achievement), and 6 of 17 achieved scores ≥4 (significant improvement).

TABLE 4 Project Measures and Definitions

	Measure	Definition
Outcome	CLABSI rate	(CLABSI events per month/the number of central line–days per month) × 1000
	Device utilization ratio	Total central line–days per month/total patient-days per month
Process	HC	Compliance with HC technique/number of HC encounters monitored. Minimum of 10 observations per month
	Limitations on CVC access	Total patients with CVC properly assessed for limitation of entry/total patients with CVC assessed for limitation of entry. Minimum of 10 observations per month
	Line removal assessment	Compliance with unit policy to assess CVC daily need/the number of CVC monitored. Minimum of 10 observations per month
	Tubing change compliance	Total number of properly performed TC according to unit policy and in accordance with matrix-assigned technique/total number of TC monitored. Minimum of 10 observations per month
	Staff hand hygiene[a]	Total number of properly performed hand hygiene observations / total number of observations. Minimum of 20 observations per month
Balancing	Unintended CVC replacement	Number of lines that were reinserted within 48 h after CVC removal because they were determined not to be medically needed/total number of lines

Four of the listed process measures were study factors in accordance with the matrix assignment.
[a] Hand hygiene was reported as a background variable throughout the study period.

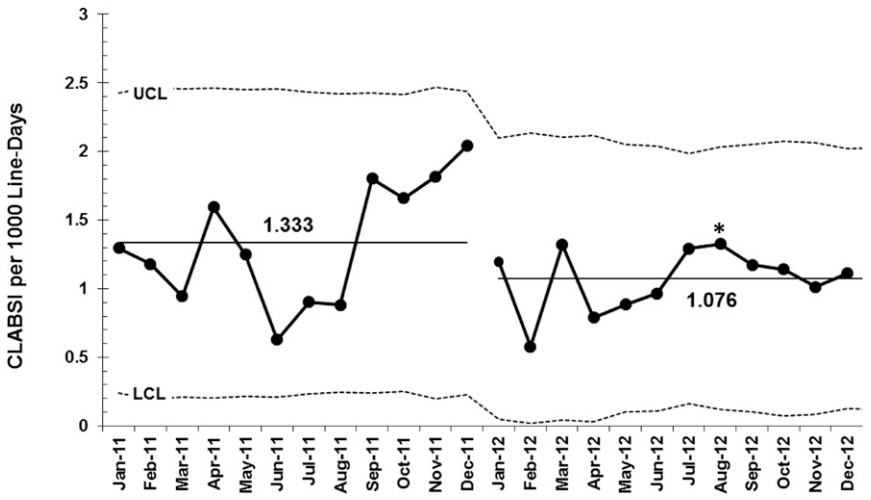

FIGURE 1
SLUG Bug CLABSI rates from extended baseline throughout the study period for 17 participating centers. The u chart displays a decrease in CLABSI rates, from 1.333 to 1.076 per 1000 line-days. Statistical Process Control special-cause signaling (8 consecutive points below the mean). There was no further signaling for the duration of the study period. The overall reduction was 19.28%. LCL, lower control limit; UCL, upper control limit.

DISCUSSION

The present QI project had 2 objectives: (1) to reduce CLABSI rates by 15% over 12 months; and (2) to identify potential best practices for CLABSI prevention. With regard to the first objective, all participating centers had active CLABSI prevention policies at the onset of the project and most had CLABSI rates lower than the national average. Nevertheless, we reported a collaborative reduction in CLABSI rates from baseline by nearly 20% in the first 8 months of the study period. Second, utilizing OT as a study design, this collaborative is the first to be able to identify specific factors that may further impact NICU CLABSI reductions.

The literature supports implementation of evidence-based guidelines or care bundles to reduce CLABSI rates across a wide range of settings.[1,29–35] Bizzarro et al[31] reported on their single-site reduction in NICU CLABSI from 8.4 to 1.28 per 1000 central line-days after an education initiative that included CVC management guidelines. In a large statewide study by Pronovost et al,[1] QI strategies and implementation of an evidence-based intervention

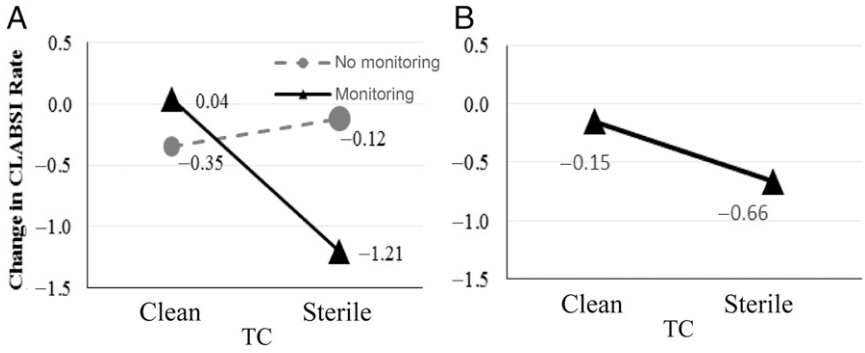

FIGURE 2

A, Interaction plot between TC and monitoring HC. B, Response plot for TC alone.

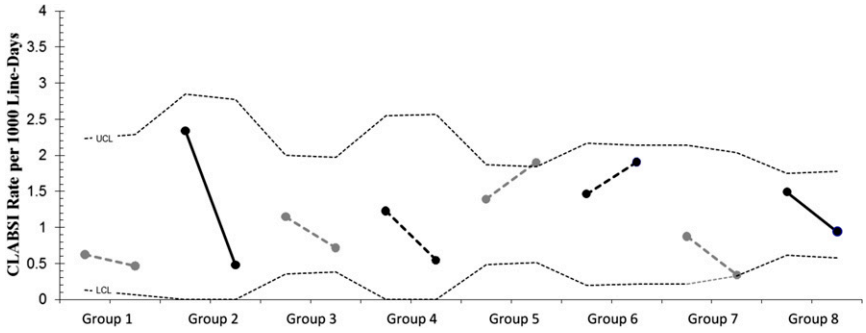

FIGURE 3

CLABSI control chart for each OT group. Eight groups (16 centers) showing change in CLABSI rates from baseline during the study period. Dashed gray lines are clean TC groups; dashed and solid black lines are sterile TC groups. Group 2, 3, 5, and 8 are HC monitoring. Solid black lines are sterile TC and HC monitoring. LCL, lower control limit; UCL, upper control limit.

decreased mean adult ICU CLABSI rates from 7.7 to 1.4. Miller et al[35] reported that the main driver for additional reduction of CLABSI rates in a PICU compared with an adult ICU was the daily maintenance care bundle. As with many of these studies, we incorporated evidence-based guidelines and literature. We also enlisted expert opinion and used the CHND network to benchmark best practices for prevention of CLABSIs.

QI collaboratives have variable results in demonstrating improvement, cost-effectiveness, and sustainability.[34,36,37] Although Wirtschafter et al[29] reported a decrease in CLABSI rates in a statewide QI-based study, they were unable to indicate which elements of the intervention were responsible for rate changes. Through the use of OT, we were able to evaluate specific CLABSI reduction practices over a relatively short period of time to identify which factors had the greatest effect.[28,38–40] Using OT, we found that of the 4 factors studied, sterile TC had an effect in decreasing CLABSI rates. The combination of sterile TC with HC compliance monitoring had the greatest effect. Our results suggest that if a NICU implements sterile TC practices, CLABSI rates should decrease by 0.51 per 1000 line-days. If this same NICU added HC compliance monitoring, the impact would then be larger, lowering rates by 1.25 per 1000 line-days. Sterile TC has not been considered a primary CLABSI prevention factor but rather has been recommended in conjunction with other interventions in standard CLABSI prevention bundles.[21] We suspect this combination of practices reflect a culture of heightened vigilance for line care.

There are limitations to the SLUG Bug project. CLABSI prevention is complex, and additional practices (beyond the scope of our project) may contribute to a low CLABSI rate. Several centers using clean TC had low CLABSI rates throughout the collaborative. These centers may have established practices, individual or in combination, that are important but were not monitored. Lastly, there was unequal distribution of centers and central line–days across groups. Due to this variability, the estimate of the magnitude of the effect was not as accurate as initially planned. However, one of the strengths of OT is that the analysis is based on group outcome rather than center outcome and, with sufficient replication (ie, central line–days across sites), it provides the strength to define the generalizable impact of the study factors.

Forgoing randomization may be considered a weakness, resulting in a biased estimation of factor effects and unequal line-day distribution. OT, as an application of planned experimentation without center randomization, uses graphical methods with repeated samples to identify improvement in real time over a wide range of conditions.[22,23] In addition, we did not capture the change in practice among centers as they entered the project. Some centers maintained their current central line care while others instituted a change in practice. It is through replication in future systems that the benefits of the OT results will be confirmed. This analytic approach to QI is a relatively new concept. We believe this method strengthens the project because it represents real-world dynamics and may lead to greater commitment as local teams (or centers) focus on areas of specific importance to their systems. As such, these results are more generalizable to clinical practice.

There are challenges in QI implementation across participating centers that may have competing commitments for time and personnel.[30] Despite the initial assignments, 1 center was moved to a different group to reconcile the clinical practice with the group factor assignment; 1 center never submitted data and was removed from all analytics; and the data from 1 center were retained for overall analysis but removed from the OT analysis because their practice did not coincide with the matrix group assignment.

This cohort included a complex patient population across institutions. The CLABSI Clinical Practice Recommendation is generalizable to other settings in which prolonged CVC use is medically necessary. Replication of these findings is important to confirm validity of the results.[22] Ongoing analysis will evaluate sustainability of these results. In addition, centers that transition to sterile TC can be followed to validate the impact of this practice. Decreasing the CLABSI rate offers benefits to patients, hospitals, and society. A decrease in the CLABSI rate by nearly 20% from a baseline rate of 1.333 would prevent ∼35 CLABSIs and save as many as 7 lives.[41] Based on published estimates of up to $69 000 attributable-cost per CLABSI, we could expect a cost-saving of up to $2.4 million.[6–11]

CONCLUSIONS

The CHND CIQI national project, SLUG Bug, demonstrated a decrease in CLABSI rates. OT methods allowed learning from practice variation across centers. This approach to future collaborative QI projects is feasible and effective. The study framework accommodated site-specific differences and identified practices that affect outcome. Our results support strong consideration for the use of sterile TC in conjunction with HC compliance monitoring to further reduce NICU rates of CLABSI.

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APPENDIX

CHNC CIQI Central Line Care Clinical Practice Recommendations

The purpose of this project was to provide potentially better practices recommendations for neonatal

health care professionals for the care and maintenance of central lines to prevent CLABSIs in infants in the NICU. Prevention of CLABSIs in the NICU will result in a decrease in both the morbidity and mortality associated with medical conditions that require care in the NICU, as well as an associated decrease in health care costs.

Hand Hygiene

The definition of hand hygiene (for staff and families) includes hand washing or use of hand sanitizer immediately before and after patient contact.[42–52]

Hand Hygiene Technique

Alcohol Based

When decontaminating hands with an alcohol-based hand rub, apply product to the palm of 1 hand and rub hands together, covering all surfaces of hands and fingers, until hands are dry. Follow the manufacturer's recommendations regarding the volume of product to use.

Soap and Water

When washing hands with soap and water, wet hands first with water, apply an amount of product recommended by the manufacturer to hands, and rub hands together vigorously for at least 15 seconds, covering all surfaces of the hands and fingers. Rinse hands with water and dry thoroughly with a disposable towel. Use towel to turn off the faucet.

Hand Hygiene Compliance

Direct observation of staff to include physicians, nurses, and all ancillary personnel. Minimum 20 observations per month

Reliable observers with consistent education and training; share results with staff

Report results

Develop monthly reports to share with staff

Consider monitoring hand hygiene compliance of families and visitors

Consider sharing reports of both staff and family/visitor hand hygiene with families/visitors

Attachment A (samples of reporting tools for Hand Hygiene)

CENTRAL LINE INSERTION BUNDLE

CVC: A vascular infusion device that terminates at or close to the heart or in 1 of the great vessels.[51,52] The following are considered great vessels for the purpose of reporting central line infections and counting central line–days in the National Healthcare Safety Network system: aorta, pulmonary artery, superior vena cava, inferior vena cava, brachiocephalic veins, internal jugular veins, subclavian veins, umbilical vessels, external iliac veins, and common femoral veins.

Central Line Insertion

Dedicated teams to place lines might be beneficial for promoting education and consistency of the insertion process. Team members may include trained registered nurses, neonatologists, neonatal nurse practitioners, surgeons, and interventional radiology physicians.[48,53,54]

Hand Hygiene Before Procedure/Sterile Barrier Precautions

Cover patient head to toe (head may be uncovered) with appropriate monitoring devices

All individuals actively involved in line placement must wear mask, head cover, sterile gown, and sterile gloves

All individuals not actively involved in line placement but present in patient "space" during line insertion must wear mask and head cover

Site Preparation

<2 months or corrected gestational age (GA) or weight as defined by unit-specific policy used to define immature skin[55]

70% Alcohol preparation and/or Betadine preparation

Scrub time: suggest 30-second minimum

Dry time: suggest 30-second minimum (up to 2 minutes)

≥2 months or corrected-GA or weight as defined by unit-specific policy used to define mature skin

ChloraPrep or comparable chlorhexidine unit-based product

Scrub time: suggest 30-second minimum

Dry time: suggest 30-second minimum (up to 2 minutes)

Groin (not a preferred site for central access)

Suggest 2-minute scrub with minimum of 60-second dry time (up to 2 minutes)

Document CVC tip by radiograph and in chart.

Site Dressing

Apply sterile dressing per manufacturer specifications

Central Line Insertion Compliance

Checklist for compliance with insertion on each line placed

Attachment B (samples of reporting tools for line insertion)

CENTRAL LINE USE AND MAINTENANCE

Maintenance bundle compliance to include dressing change, chart documentation, daily assessment need, medication delivery, TC, and

blood draw components of policy/procedure.[48,51,54–60]

Central Line Dressing Change

Dressing Change Per NICU Protocol

Broviac: weekly and as-needed if dressing becomes wet, soiled, or nonocclusive

Peripherally inserted central catheter (central and midline): weekly and as-needed if dressing becomes wet, soiled, or nonocclusive

Subclavian/jugular/femoral: change weekly and as-needed if dressing becomes wet, soiled, or nonocclusive

No occlusive dressing for umbilical artery catheter and umbilical venous catheter

Some centers use 2 staff members for dressing changes

Position line hub and catheter away from dirty areas such as ostomy, diaper, or exposed viscera

Hand Hygiene Before Procedure

Current dressing may be removed with clean gloves and hand hygiene performed after removal of gloves

Barrier Precautions for Dressing Change

Dressing changes require sterile technique. All individuals actively involved in dressing change must wear mask and sterile gloves

- Some centers add clean gown/head covering
- Some centers use sterile barrier to cover patient head to toe

Site Dressing

Apply sterile dressing per manufacturer specifications

Track date/time of dressing change, insertion, and removal

Site Preparation

<2 months OR corrected-GA or weight as defined by unit-specific policy used to define immature skin

- 70% Alcohol preparation and/or Betadine preparation
- Scrub time: 30-second minimum
- Dry time: 30-second minimum (up to 2 minutes recommended)

≥2 months OR corrected-GA or weight as defined by unit-specific policy used to define mature skin

- ChloraPrep or comparable chlorhexidine unit-based product
- Scrub time: suggest 30-second minimum
- Dry time: suggest 30-second minimum (up to 2 minutes)
- Groin/axilla
  - 2-minute scrub with minimum of 60-second dry time (up to 2 minutes recommended)

Central Line HC/Blood Draws/Medication Infusion

Definition of Hub/Entry Point

Any time there is an opening or access of the CVC at the hub/cap/manifold for a break in the system.

Review Unit-Based Protocols for Central Line Set-up

Minimize/standardize number of entry ports

Consider line set-ups to avoid entry ports remaining in bed

Blood Draws/Medication Delivery/Fluid and TC

Blood Draws/Medication Delivery/Fluid Change

Hand hygiene before procedure

Limit line entry access (medications and blood draws)

Follow HC (discussed later)

TC

Hand hygiene before procedure

Sterile versus clean technique (scant literature to support either protocol; divided practices exist among participating centers)

Options include:

- Sterile technique: minimum should include sterile gloves and mask with use of sterile barrier under the CVC
- Clean technique: minimum should include clean gloves with sterile gauze barriers under the CVC

Scrub the hub[53,61]

- 70% Alcohol preparation or ChloraPrep as per NICU protocol
- Scrub time: 15-second minimum (up to 60 seconds)
- Dry time: until dry

Multiple medication/simultaneous line entry

- Repeat HC per NICU protocol

TC schedule

- Hyperalimentation tubing: 24 to 72 hours (up to 96 hours may be safe)
- Lipids: 24 hours
- Crystalloids: 24 to 96 hours (up to 7 days may be safe)

Monitor Compliance for Maintenance Bundle Compliance

Attachment C (samples of self-reporting tools for central line use and maintenance)

Minimum of 10 monthly self-report monitors (each self-report includes a 12-hour shift) for maintenance bundle compliance to include dressing change, medication delivery, TC, and blood draw components of policy/procedure

Minimum 10 monthly observations

Report results

Develop reports to share with staff

REMOVAL

Daily CVC Need and Assessment Documentation

Daily assessment of central line need and utilization[57–59]

Things to consider

→Mechanical issues in the past 24 hours (line clotted/tissue plasminogen activator used, line to be repaired)

→Frequency of line entry

Monitor Compliance for Daily Need for CVC

Attachment D (samples of self-reporting tools for central line removal)

Checklist for ongoing need for access, frequency of line entry, line complications, and/or mechanical problems

Report results to staff

CVC CLABSI Review Form

Attachment D (samples of self-reporting tools for CLABSI review)

Root cause analysis[49,50]

Formal reaction team for bedside analysis suggested when CLABSI is identified

ABBREVIATIONS

CHND: Children's Hospitals Neonatal Database
CIQI: Collaborative Initiatives for Quality Improvement
CLABSI: central line–associated bloodstream infection
CVC: central venous catheter
HAI: health care–associated infection
HC: hub care
IHI: Institute for Healthcare Improvement
OT: orchestrated testing
QI: quality improvement
SLUG Bug: Standardizing Line Care Under Guideline Recommendations
TC: tubing change

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REFERENCES (*REFERENCES 42–60 ARE FOLLOWED BY STRENGTH OF EVIDENCE RATING*)

1. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med*. 2006;355(26):2725–2732
2. Centers for Disease Control and Prevention. Making health care safer; reducing bloodstream infection. Available at: www.cdc.gov/VitalSigns/pdf/2011-03-vitalsigns.pdf. Accessed November 14, 2014
3. Klevens RM, Edwards JR, Richards CL Jr, et al. Estimating health care-associated infections and deaths in US hospitals, 2002. *Public Health Rep*. 2007;122(2):160–166
4. Payne NR, Carpenter JH, Badger GJ, Horbar JD, Rogowski J. Marginal increase in cost and excess length of stay associated with nosocomial bloodstream infections in surviving very low birth weight infants. *Pediatrics*. 2004;114(2):348–355
5. Pittet D, Tarara D, Wenzel RP. Nosocomial bloodstream infection in critically ill patients. Excess length of stay, extra costs, and attributable mortality. *JAMA*. 1994;271(20):1598–1601
6. Nowak JE, Brilli RJ, Lake MR, et al. Reducing catheter-associated bloodstream infections in the pediatric intensive care unit: business case for quality improvement. *Pediatr Crit Care Med*. 2010;11(5):579–587
7. Scott RD II. The direct medical costs of healthcare-associated infections in U.S. hospitals and the benefits of prevention. Available at: www.cdc.gov/HAI/pdfs/hai/Scott_CostPaper.pdf. Accessed June 8, 2014
8. Chandonnet CJ, Kahlon PS, Rachh P, et al Health care failure mode and effect analysis to reduce NICU line-associated bloodstream infections. *Pediatrics*. 2013;131(6). Available at: www.pediatrics.org/cgi/content/full/131/6/e1961
9. Sagana R, Hyzy RC. Achieving zero central line-associated bloodstream infection rates in your intensive care unit. *Crit Care Clin*. 2013;29(1):1–9
10. Brilli RJ, McClead RE Jr, Crandall WV, et al. A comprehensive patient safety program can significantly reduce preventable harm, associated costs, and hospital mortality. *J Pediatr*. 2013;163(6):1638–1645
11. Wilson MZ, Rafferty C, Deeter D, Comito MA, Hollenbeak CS. Attributable costs of central line-associated bloodstream infections in a pediatric hematology/oncology population. *Am J Infect Control*. 2014;42(11):1157–1160
12. The Joint Commission. Preventing central line–associated bloodstream infections: a global challenge, a global perspective. Available at: www.jointcommission.org/assets/1/18/

CLABSI_Monograph.pdf. Accessed June 8, 2014

13. Murthy K, Dykes FD, Padula MA, et al. The Children's Hospitals Neonatal Database: an overview of patient complexity, outcomes and variation in care. *J Perinatol*. 2014;34(8):582–586
14. Stoll BJ, Hansen NI, Adams-Chapman I, et al; National Institute of Child Health and Human Development Neonatal Research Network. Neurodevelopmental and growth impairment among extremely low-birth-weight infants with neonatal infection. *JAMA*. 2004;292(19):2357–2365
15. Stark AR; American Academy of Pediatrics Committee on Fetus and Newborn. Levels of neonatal care. *Pediatrics*. 2004;114(5):1341–1347
16. Clancy CM, Margolis PA, Miller M. Collaborative networks for both improvement and research. *Pediatrics*. 2013;131(suppl 4):S210–S214
17. Miller M. Roles for children's hospitals in pediatric collaborative improvement networks. *Pediatrics*. 2013;131(suppl 4):S215–S218
18. Dudeck MA, Horan TC, Peterson KD, et al. National Healthcare Safety Network report, data summary for 2011, device-associated module. *Am J Infect Control*. 2013;41(4):286–300
19. Brouwers MC, Kho ME, Browman GP, et al; AGREE Next Steps Consortium. AGREE II: advancing guideline development, reporting and evaluation in health care. *CMAJ*. 2010;182(18):E839–E842
20. US Department of Health & Human Services, Agency for Healthcare Research and Quality Patient Safety Network. Root cause analysis. Available at: http://psnet.ahrq.gov/primer.aspx?primerID=10. Accessed February 2, 2015
21. O'Grady NP, Alexander M, Burns LA, et al; Healthcare Infection Control Practices Advisory Committee. Guidelines for the prevention of intravascular catheter-related infections. *Am J Infect Control*. 2011;39(4 suppl 1):S1–S34
22. Moen RD, Nolan TW, Provost LP. *Quality Improvement Through Planned Experimentation*. 3rd ed. New York, NY: McGraw-Hill Professional; 2012
23. Provost LP. Analytical studies: a framework for quality improvement design and analysis. *BMJ Qual Saf*. 2011;20(suppl 1):i92–i96
24. Institute for Healthcare Improvement. The breakthrough series: IHI's collaborative model for achieving breakthrough improvement. Available at: www.ihi.org/resources/Pages/IHIWhitePapers/TheBreakthroughSeriesIHIsCollaborativeModelforAchievingBreakthroughImprovement.aspx. Accessed June 8, 2014
25. Institute for Healthcare Improvement. FAQs. Available at: www.ihi.org/about/pages/faqs.aspx. Accessed February 28, 2015
26. Institute for Healthcare Improvement. Assessment scale for collaboratives. Available at: www.ihi.org/resources/Pages/Tools/AssessmentScalefor Collaboratives.aspx. Accessed June 8, 2014
27. Centers for Disease Control and Prevention National Healthcare Safety Network. Central-line associated blood infection (CLABSI) event-device associated module. Available at: www.cdc.gov/nhsn/PDFs/pscManual/4PSC_CLABScurrent.pdf. Accessed May 5, 2015
28. Provost LP, Murray SK. *The Health Care Data Guide: Learning from Data for Improvement*. San Francisco, CA: Jossey-Bass; 2011
29. Wirtschafter DD, Pettit J, Kurtin P, et al. A statewide quality improvement collaborative to reduce neonatal central line-associated blood stream infections. *J Perinatol*. 2010;30(3):170–181
30. Schulman J, Stricof RL, Stevens TP, et al; New York State Regional Perinatal Centers; New York State Department of Health. Development of a statewide collaborative to decrease NICU central line-associated bloodstream infections. *J Perinatol*. 2009;29(9):591–599
31. Bizzarro MJ, Sabo B, Noonan M, Bonfiglio MP, Northrup V, Diefenbach K; Central Venous Catheter Initiative Committee. A quality improvement initiative to reduce central line-associated bloodstream infections in a neonatal intensive care unit. *Infect Control Hosp Epidemiol*. 2010;31(3):241–248
32. Kilbride HW, Powers R, Wirtschafter DD, et al. Evaluation and development of potentially better practices to prevent neonatal nosocomial bacteremia. *Pediatrics*. 2003;111(4 pt 2):e504–e518
33. Kilbride HW, Wirtschafter DD, Powers RJ, Sheehan MB. Implementation of evidence-based potentially better practices to decrease nosocomial infections. *Pediatrics*. 2003;111(4 pt 2):e519–e533
34. Miller MR, Niedner MF, Huskins WC, et al; National Association of Children's Hospitals and Related Institutions Pediatric Intensive Care Unit Central Line-Associated Bloodstream Infection Quality Transformation Teams. Reducing PICU central line-associated bloodstream infections: 3-year results. *Pediatrics*. 2011;128(5). Available at: www.pediatrics.org/cgi/content/full/128/5/e1077
35. Miller MR, Griswold M, Harris JM II, et al. Decreasing PICU catheter-associated bloodstream infections: NACHRI's quality transformation efforts. *Pediatrics*. 2010;125(2):206–213
36. Hulscher ME, Schouten LM, Grol RP, Buchan H. Determinants of success of quality improvement collaboratives: what does the literature show? *BMJ Qual Saf*. 2013;22(1):19–31
37. Schouten LM, Hulscher ME, van Everdingen JJ, Huijsman R, Grol RP. Evidence for the impact of quality improvement collaboratives: systematic review. *BMJ*. 2008;336(7659):1491–1494
38. Neuhauser D. Why design of experiments just may transform health care. *Qual Manag Health Care*. 2005;14(4):217–218
39. Merwin E, Thornlow D. Methodologies used in nursing research designed to improve patient safety. *Annu Rev Nurs Res*. 2006;24:273–292
40. McAlister FA, Straus SE, Sackett DL, Altman DG. Analysis and reporting of factorial trials: a systematic review. *JAMA*. 2003;289(19):2545–2553

41. Blanchard AC, Fortin E, Rocher I, et al. Central line-associated bloodstream infection in neonatal intensive care units. *Infect Control Hosp Epidemiol*. 2013;34(11):1167–1173

42. Helder OK, Brug J, Looman CW, van Goudoever JB, Kornelisse RF. The impact of an education program on hand hygiene compliance and nosocomial infection incidence in an urban neonatal intensive care unit: an intervention study with before and after comparison. *Int J Nurs Stud*. 2010;47(10):1245–1252 [IIb]

43. Sakamoto F, Yamada H, Suzuki C, Sugiura H, Tokuda Y. Increased use of alcohol-based hand sanitizers and successful eradication of methicillin-resistant Staphylococcus aureus from a neonatal intensive care unit: a multivariate time series analysis. *Am J Infect Control*. 2010;38(7):529–534 [III]

44. Crivaro V, Di Popolo A, Caprio A, et al. Pseudomonas aeruginosa in a neonatal intensive care unit: molecular epidemiology and infection control measures. *BMC Infect Dis*. 2009;9:70–77 [IIb]

45. Gill CJ, Mantaring JB, Macleod WB, et al. Impact of enhanced infection control at 2 neonatal intensive care units in the Philippines. *Clin Infect Dis*. 2009;48(1):13–21 [IIb]

46. Picheansathian W, Pearson A, Suchaxaya P. The effectiveness of a promotion programme on hand hygiene compliance and nosocomial infections in a neonatal intensive care unit. *Int J Nurs Pract*. 2008;14(4):315–321 [IIb]

47. Pessoa-Silva CL, Hugonnet S, Pfister R, et al. Reduction of health care associated infection risk in neonates by successful hand hygiene promotion. *Pediatrics*. 2007;120(2). Available at: www.pediatrics.org/cgi/content/full/120/2/e382 [IIb]

48. Wirtschafter DD, Pettit J, Kurtin P, et al. A statewide quality improvement collaborative to reduce neonatal central line-associated blood stream infections. *J Perinatol*. 2010;30(3):170–181 [IV]

49. Pronovost P, Needham D, Berenholtz S, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. *N Engl J Med*. 2006;355(26):2725–2732 [IV]

50. Centers for Disease Control and Prevention. Guideline for hand hygiene in health-care settings. Available at: www.cdc.gov/mmwr/PDF/rr/rr5116.pdf [IV] Accessed November 14, 2015

51. 5 Million Lives Campaign. *Getting Started Kit: Prevent Central Line Infections How-to Guide*. Cambridge, MA: Institute for Healthcare Improvement, 2008. Available at: www.ihi.org/ihi/programs/campaign/centrallineinfection.htm [IV] Accessed November 14, 2015

52. Centers for Disease Control and Prevention, Healthcare Infection Control Practices Advisory Committee (HICPAC). 2011 Guidelines for the prevention of intravascular catheter-related infections. Available at: www.cdc.gov/hicpac/BSI/BSI-guidelines-2011.html [IV] Accessed November 14, 2015

53. Powers RJ, Wirtschafter DW. Decreasing central line associated bloodstream infection in neonatal intensive care. *Clin Perinatol*. 2010;37(1):247–272 [IV]

54. Linck DA, Donze A, Hamvas A. Neonatal peripherally inserted central catheter team. Evolution and outcomes of a bedside-nurse-designed program. *Adv Neonatal Care*. 2007;7(1):22–29 [IV]

55. Pettit J, Wyckoff M, eds. *NANN (National Association of Neonatal Nurses) Peripherally Inserted Central Catheters Guideline for Practice*. 2nd ed. Glenview, IL: National Association of Neonatal Nurses; 2007 [IV]

56. Schulman J, Stricof R, Stevens TP, et al; New York State Regional Perinatal Care Centers. Statewide NICU central-line-associated bloodstream infection rates decline after bundles and checklists. *Pediatrics*. 2011;127(3):436–444 [IIb]

57. Costello JM, Morrow DF, Graham DA, Potter-Bynoe G, Sandora TJ, Laussen PC. Systematic intervention to reduce central line-associated bloodstream infection rates in a pediatric cardiac intensive care unit. *Pediatrics*. 2008;121(5):915–923 [III]

58. Miller MR, Griswold M, Harris JM II, et al. Decreasing PICU catheter-associated bloodstream infections: NACHRI's quality transformation efforts. *Pediatrics*. 2010;125(2):206–213 [IV]

59. Bizzarro MJ, Sabo B, Noonan M, Bonfiglio MP, Northrup V, Diefenbach K; Central Venous Catheter Initiative Committee. A quality improvement initiative to reduce central line-associated bloodstream infections in a neonatal intensive care unit. *Infect Control Hosp Epidemiol*. 2010;31(3):241–248 [IIb]

60. Sharpe EL. Tiny patients, tiny dressings: a guide to the neonatal PICC dressing change. *Adv Neonatal Care*. 2008;8(3):150–162, quiz 163–164 [IV]

61. Kaler W, Chinn R. Successful disinfection of needless access ports: a matter of time and friction. *JAVA*. 2007;12(3):140–142 [IIb]

SLUG Bug: Quality Improvement With Orchestrated Testing Leads to NICU CLABSI Reduction

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