Statewide NICU Central-Line-Associated Bloodstream Infection Rates Decline After Bundles and Checklists

WHAT’S KNOWN ON THIS SUBJECT: Evidence-based care bundles for inserting and maintaining central lines can reduce central-line–associated bloodstream infection (CLABSI) rates. The impact of adopting standardized bundle elements and related checklists across a statewide NICU quality-improvement network has not been studied.

WHAT THIS STUDY ADDS: Statewide adoption of standardized, evidence-based central-line insertion and maintenance bundles substantially reduced NICU CLABSI. Increased use of maintenance checklists was associated with fewer CLABSIs. We also measured the impact of the 2008 Centers for Disease Control and Prevention CLABSI definition change.

abstract

OBJECTIVE: In 2008, all 18 regional referral NICUs in New York state adopted central-line insertion and maintenance bundles and agreed to use checklists to monitor maintenance-bundle adherence and report checklist use. We sought to confirm whether adopting standardized bundles and using central-line maintenance checklists reduced central-line–associated bloodstream infections (CLABSI).

METHODS: This was a prospective cohort study that enrolled all neonates with a central line who were hospitalized in any of 18 NICUs. Each NICU reported CLABSI and central-line utilization data and checklist use. We used χ² to compare CLABSI rates in the preintervention (January to December 2007) versus the postintervention (March to December 2009) periods and Poisson regression to model adjusted CLABSI rates.

RESULTS: Each study period included more than 55 000 central-line days and more than 200 000 patient-days. CLABSI rates decreased 67% statewide (risk ratio: 0.33 [95% confidence interval: 0.27–0.41]; P < .0005); after adjusting for the altered central-line–associated bloodstream infection definition in 2008, by 40% (risk ratio: 0.60 [95% confidence interval: 0.48–0.75]; P < .0005). A total of 13 of 18 NICUs reported using maintenance checklists for 10% to 100% of central-line days. The checklist-use rate was associated with the CLABSI rate (coefficient: −0.57, P = .04). A total of 10 of 18 NICUs were independent CLABSI rate predictors, ranging from 1 site with greatly reduced risk (incidence rate ratio: 0.04, P < .0005) to 1 site with greatly increased risk (incidence rate ratio: 2.87, P < .0005).

CONCLUSIONS: Although standardizing central-line care elements led to a significant statewide decline in NICU CLABSI rates, site of care remains an independent risk factor. Using maintenance checklists reduced CLABSIs. Pediatrics 2011;127:436–444

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In 2007, New York state (NYS) Public Health Law Article 28 § 2819 mandated surveillance and public reporting of central-line–associated bloodstream infections (CLABSIs) in all ICUs, including NICUs. The NYS Department of Health required that all hospitals join the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network to standardize surveillance and reporting. Motivated to improve standardization, as previously reported,1 NYS-designated regional perinatal care centers, the state’s major referral NICUs, formed a quality-improvement network with 2 initial main objectives: (1) to learn about potential best practices for NICU central-line care from high-quality, peer-reviewed evidence and from the variability in the central-line–associated bloodstream infection (CLABSI) rates at the participating NICUs; and (2) based on the first objective, to craft a “bundle” of evidence-based care elements for insertion and maintenance of central lines.

Bundles, defined as a limited number of specific practices each essential for effective and safe patient care and that, when implemented together, result in additional improvements in patient outcomes, have been shown to reduce the rate of CLABSIs.2 For adults, the focus has been on a central-line insertion bundle;3 recent evidence3 indicates that a central-line maintenance bundle is important to prevent CLABSIs in children. As previously described,1 physicians, nurse practitioners, nursing staff, and infection-control personnel collaborated to identify pertinent bundle elements, and early in 2008 18 RPC NICUs adopted 1 common central-line insertion and 1 common central-line maintenance bundle and committed to reliably implementing the bundle practices. Our network adopted central-line maintenance bundles as well as insertion bundles because RPC NICU network experience indicated that central-line dwell time substantially exceeded that observed in adult ICUs, making it likely that maintenance practices would be of increased importance in the NICU population. The elements of our insertion and maintenance bundle appear in Table 1.

By late 2008, the neonatal care teams at all RPCs agreed to use checklists to monitor adherence to the bundle elements (surgeons were encouraged to collaborate, but we did not specifically monitor their participation; surgeon-inserted lines are rare in this population) and to report checklist adherence. Thus, we sought to confirm whether (1) adopting common insertion and maintenance bundles reduces NICU CLABSI rates in both individual institutions and statewide and (2) using central-line maintenance checklists in the NICU reduces CLABSI rates.

METHODS

Study Design, Population, and Study Period

This was a prospective cohort study of all neonates with any central line, hospitalized in any of the 18 RPC NICUs in NYS (1 of the original 19 RPCs was incorporated into another regional center in 2009). The study period was from January through December 2007 for the preintervention performance and from March through December 2009 for the postintervention performance. All participating NICUs obtained institutional review board approval of this quality initiative, with a waiver of informed consent.

Implementation of Bundles and Checklists

Checklist templates reflecting the insertion and maintenance bundle elements were created by the network and then optionally modified by each RPC to reflect site-specific needs. Each RPC decided if the checklists should be included within the medical record or used solely as a quality-improvement tool and whether the checklists would be deployed in paper form or via the electronic patient information system.

To promote implementation of the bundles and checklists at all sites, confer-

<table>
<thead>
<tr>
<th>TABLE 1 Central-Line Insertion and Maintenance Bundle Elements</th>
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<tr>
<td><strong>Insertion Bundle</strong></td>
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<tr>
<td>a) Establish a central line kit or cart to consolidate all items necessary for the procedure</td>
</tr>
<tr>
<td>b) Perform hand hygiene with hospital-approved alcohol-based product or antiseptic-containing soap before and after palpating insertion sites and before and after inserting the central line</td>
</tr>
<tr>
<td>c) Use maximal barrier precautions (including: sterile gown, sterile gloves, surgical mask, hat, and large sterile drape)</td>
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<tr>
<td>d) Disinfect skin with appropriate antiseptic (eg, 2% chlorhexidine, 70% alcohol) before catheter insertion</td>
</tr>
<tr>
<td>e) Use either a sterile transparent semipermeable dressing or sterile gauze to cover the insertion site</td>
</tr>
<tr>
<td>f) Daily review of catheter necessity with prompt removal when no longer essential</td>
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Adapted with permission from Schulman, et al.1
ence calls, periodic surveys, and biannual statewide workshops were held. Nine conference calls were held between February 2009 and April 2010, and 3 statewide workshops were held between December 2008 and June 2010 in different locations to facilitate participation. Each workshop was attended by ~50 to 60 participants. To provide additional expertise and support, representatives from the NYS Department of Health/Healthcare-Associated Infection and colleagues involved with similar NICU quality-improvement activity in California, Massachusetts (www.neoqic.org/), Ohio (www.healthykidosiohio.org/opqc), and Connecticut participated in the conference calls and/or workshops.

Data Collection

All NYS hospitals report CLABSI and central-line utilization data to the NYS Department of Health for each ICU within their facility (NYS Public Health Law Article 28 § 2819) using the CDC/National Healthcare Safety Network online reporting tool. NICU data are reported by birth-weight stratum. To facilitate secure, direct access to data describing birth-weight–stratified CLABSI events, the number of central-line days, and the number of patient-days, each RPC granted to the RPC network National Healthcare Safety Network data-sharing privileges. Members of the NYS Department of Health/Healthcare-Associated Infection audited a sample of 2009 hospital records to assess the accuracy of CLABSI reporting and to provide corrective feedback when errors were identified. Beginning in March 2009, each NICU provided to the network its self-reported, monthly, deidentified, birth-weight–stratified use of the maintenance checklists. To count checklist use for a given central line as 1 day of maintenance, a completed maintenance checklist was required.

Analysis

The unit of observation and the unit of analysis was the individual NICU. We used \( \chi^2 \) to test whether CLABSI rates in the preintervention period (2007) differed from the postintervention period (2009). Using stepwise addition to create Poisson regression models, we explored the contribution of the following risk factors to the rate of CLABSIs: (1) birth-weight categories; (2) study site maintenance checklist use rate, defined as the total number of days of reported maintenance checklist use per total number of days of central-line use; (3) central-line utilization rate, defined as the number of central-line days per number of patient-days; (4) low- versus high-volume NICUs, defined as 700 or fewer patient-days per month versus more than 700 patient-days per month, respectively (categorical cut point determined posthoc); and (5) study site. Because outcomes could be correlated within a site, we adjusted for clustering of outcomes by NICU. In addition, we explored possible interactions among variables but identified none. Data were analyzed and graphics produced using Stata 10.

RESULTS

Comparison of CLABSI Rates Pre- versus Postintervention

As summarized in Table 2, pre- and postintervention periods each comprised more than 55 000 central-line days and more than 200 000 patient-days. Approximately three-quarters of RPCs (13 of 18) reported using maintenance checklists; use rates varied between 10% and 100%. Statewide central-line utilization rates did not decline between the pre- and postintervention periods; individual RPC NICU central-line utilization rates varied from 0.10 to 0.37 central-line days per patient-day. After accounting for birth weight, checklist use, NICU patient volume, and NICU site, the central-line utilization rate was not associated with CLABSI risk.

Overall, statewide CLABSI rates in NYS’s RPC NICUs declined by 67%, from 6.4 CLABSIs per 1000 central-line days to 2.1 CLABSIs per 1000 central-line days (risk ratio: 0.33 [95% confidence interval: 0.27–0.41]; \( P < .0005 \)). Because the CDC CLABSI definition changed during the 2 study intervals, beginning in January 2008, 1 positive blood culture yielding a normal skin contaminant (eg, S. epidermidis) did not fulfill the case definition and “two or more positive blood cultures for a skin contaminant drawn on separate occasions” were required; we also report results after applying the current definition to all data. Statewide CLABSI rates adjusted for uniform CLABSI definition declined by 40%, from 3.5 CLABSIs per 1000 central-line days to 2.1 CLABSIs per 1000 central-line days (risk ratio: 0.60; [95% confidence interval: 0.48–0.75]; \( P < .0005 \)).

Figure 1 shows the effect of the interventions among individual NICUs. All unadjusted NICU-specific CLABSI rates decreased, ranging between 5% and 98% from baseline (RPC 1: rate fell from 9.5 to 0.2 infections/1000 central-line days). Performance adjusted for uniform CLABSI definition was more

| TABLE 2 Patient Exposure and Reported Maintenance Checklist Use in Pre- versus Postintervention Periods |
|-------------------------------------------------|-------------------------------|-------------------------------|
| Central-line days | 61 096 | 55 137 |
| Patient-days | 237 996 | 206 846 |
| Central-line utilization rate | 0.26 | 0.27 |
variable; rates ranged from an almost three-fold-increased rate to a 97% reduced rate from baseline (again, RPC 1). Compared with the preintervention period, the range of variation of adjusted rates among centers widened slightly, reflecting the exceptional improvement at RPC 1.

Predictors of CLABSI Rates
As shown in Fig 2, the maintenance checklist use rate was associated with the CLABSI rate. For each SD increment in checklist utilization rate (SD: 30%), the CLABSI rate decreased by 16.5% (coefficient: $-0.57, P = .04$). It is noteworthy that NICUs reporting maintenance checklist use rates of at least 15% generally had lower rates (risk ratio: 0.66 [95% confidence interval: 0.46–0.95]; $P = .02$) and a narrower range of rate variation across birthweight strata.

NICU patient volume also was associated with the CLABSI rate. Stratifying by average monthly patient volume (posthoc cut point: 700 patient-days per month) revealed that higher-patient-volume NICUs generally had lower CLABSI rates (risk ratio: 0.49 [95% confidence interval: 0.27–0.90]; $P = .02$) and narrower performance variation (Fig 3).

A Poisson regression model indicated that 10 of 18 NICUs independently predicted CLABSI, ranging from 1 site with greatly reduced risk (IRR: 0.04, $P < .0005$) to 1 site with greatly increased risk (IRR: 2.87, $P < .0005$). Each NICU’s adjusted CLABSI risk is compared with overall network results in Fig 4. Several patterns were demonstrated: fewer infections than predicted for all patients in the NICU (RPC 1); fewer infections than predicted for some patients in the NICU (RPCs 10 and 17); expected numbers of infections for all patients in the NICU (RPCs 4, 6, 7, 8, 9, 11, and 18); expected numbers of infections for some patients in the NICU (RPCs 2, 3, 5, 10, and 12–17); and more infections for some patients in the NICU (RPCs 2, 3, 5, 10, and 12–16). No NICU experienced more infections than predicted for all patients.
Pathogens Causing CLABSIs in the Pre- versus Postintervention Periods

The proportion of specific pathogens causing CLABSIs in our network is shown in Fig. 5. Coagulase-negative staphylococci (CONS) were most common in both pre- and postintervention periods, accounting for 59% and 42% of CLABSIs, respectively. However, after applying the same CLABSI definition to both study periods, the proportion of CLABSIs caused by CONS was virtually identical (41% vs 42%).

DISCUSSION

To our knowledge, this is the first report to demonstrate a significant statewide reduction in CLABSI rates in the NICU population associated with participating in a multihospital quality-improvement initiative intended to standardize central-line care. The statewide reduction in NICU CLABSIs reported here extends the proof of concept about evidence-based, monitored, central-line bundle and checklist effectiveness in multihospital collaboratives from the Michigan adult ICU collaborative and from a PICU collaborative to the NICU. Particularly, in light of some agencies’ considering CLABSIs to be “never events,” it is important to note that no NICU achieved an overall CLABSI rate of 0. Unlike the Michigan study but similar to the PICU report, the statewide reduction in the NICU CLABSI rate reported here was achieved through implementation of both central-line insertion and maintenance bundles. However, our study design enabled us only to study the independent effect of the latter. Future studies could explore the independent effects, and interaction, of both bundles. Such exploration can be exceedingly difficult to measure and account for because during the intervention new behaviors develop and the culture of the unit(s) changes.

Our explicit accounting for the impact of a change in the CDC CLABSI definition in 2008 (Figs 1 and 5) should be helpful to others tracking institutional CLABSIs over recent years. The 45% decline in 2007 rates and the decline in CONS as a causal pathogen from 59% to 42% after applying the 2008 CDC case definition are considerable. Although our network’s postintervention CONS incidence is similar to CONS incidence reported in the literature before the CDC definition change, our network’s preintervention unadjusted CONS incidence was higher, inviting reflection on the optimal case definition for initiatives that seek to eliminate preventable morbidity. Our ability to adjust for case definition also revealed, in contrast with at least 1 earlier report, that our efforts had no preferential effect on the relative inci-
dence of CONS; all bacterial and yeast pathogens were affected.

Other groups also have reported on efforts to prevent NICU infection.4,5,13–16 Interventions and magnitude of protective effect varied, but all indicate that applying current evidence for central-line care leads to fewer NICU infections. Until our network’s initiative, no NICU infection prevention collaborative achieved 100% enrollment among candidate hospitals and complete agreement on standardization of specified care. We believe that repetitive, structured social interaction in our network, through conference calls, e-mails, and workshops, was an important to standardizing central-line care. Social interaction helped participants feel that they were a meaningful part of an important community of practice, a new term for an age-old social phenomenon: a group of people with common interests who develop, share, and apply their knowledge and expertise toward solving defined problems. Communities of practice can be highly effective means of leveraging knowledge within and among organizations.17 Our conference calls and workshops focused on providing updated performance data and sharing stories about checklist and bundle successes and barriers to implementation. We repeatedly spoke about checklists as a cognitive tool to remind front-line care providers of the right thing to do at the right time, irrespective of competing complexities and distractions in the NICU environment (18), and as a means to promote staff perception of bundle elements as essential aspects of the daily work (not “extra work”).

Although CLABSI rates adjusted for uniform definition fell 40% statewide, substantial performance variation among the NICUs persists. Therefore, current bundles and checklists only partially solve the CLABSI problem. Preintervention (2007) definition–adjusted CLABSI rates varied 13-fold for all birth-weight groups combined compared with a ninefold rate variation among all birth-weight groups in the postintervention...
(2009) period. However, postintervention rate values and performance variation are strikingly better among NICUs reporting at least 15% checklist use, where rate variation for all birth weights combined, as well as for the highest-risk stratum (birth weight <751 g), is approximately one-half of that among NICUs reporting less than 15% checklist use (Fig 2). Our data are unable to address the optimal rate of checklist use because reported checklist use may not be the same as actual checklist use. Furthermore, we cannot assess the effect of a locally designed checklist configuration. We speculate that the 15% checklist use cut point value may be a proxy measure of a crucial level of NICU cultural change. A similar pattern is seen when performance results are stratified by patient volume (Fig 3).

We suspect that much of the remaining variation in performance may be explained, aside from the variation in actual application of bundle elements, by different hospital cultures, different behaviors among individual providers, and different NICU patient profiles. Such heterogeneity has been summarized in a rule of thumb: "When you’ve seen one NICU, you’ve seen one NICU."19 Checklist configurations or methods of use may vary, and NICUs may differ in how they train and provide feedback to individual providers. It is important to reiteratively refine our methods as we continue to track exposures and outcomes; for example, it may be feasible to standardize provider training and exactly how a bundle element is delivered and to optimize checklist design and use,18,20,21 as guided by peer-reviewed literature and our network’s best performers. Also, it is important to understand whether the absence of reported checklist use by 5 of 18 RPCs was a proxy measure of differences in bundle implementation and/or qualitative differences in these RPCs’ local culture of improvement. Although our intervention was effective statewide, it

FIGURE 5
Pathogens causing CLABSIs in the pre-versus postintervention periods. Total number of organisms in 2007 (former CDC case definition) = 372; total number of organisms in 2007 (2008 CDC case definition) = 216; total number of organisms in 2009 = 125. GNB indicates other gram-negative bacilli; GBS, group B streptococci; GPB, other gram-positive bacilli.
remains to be learned whether our study design aggregated heterogeneous patients or exposures and how the effects of defined care exposures are contingent and conditional on the place and the people providing that care (ie, “for whom might it work and under what circumstances”). For example, might CLABSI risk for neonates with a primary surgical diagnosis differ from others requiring a central line or does central-line type or dwell time (duration) matter?

We report only a long-term summary measure, composite CLABSI rate, for each of our study periods, while recognizing that the American Board of Pediatrics Quality Improvement Projects for Maintenance of Certification Program strongly recommends so-called run charts and statistical process control charts for improvement data. Such charting tools show how performance varies over time during a specified study period (eg, a month-to-month change). By discriminating values representing statistical noise from those signaling a process change, the methods may reveal short-term trends and unusual values that would otherwise be obscured in a long-term summary measure. A statistical process control chart provides useful insight about performance and opportunities for improvement when it reflects a discrete, homogeneous system of care. The wide variation in CLABSI incidence among our Network’s NICUs suggests that our NICUs represent multiple, heterogeneous systems of care and argues against combining all hospitals’ outcomes into a single statistical process control chart.

Our results are subject to several limitations. First, using the individual NICU as our unit of observation and unit of analysis limits our ability to fully explore risk-factor and outcome relationships. The findings shown in Fig 4 are thus derived from a Poisson model containing a similar number of estimated parameters and clusters (NICUs), constraining model predictive accuracy. We could not fully assess other factors that may have influenced CLABSI rates, including unmeasured baseline risks; variation among NICUs, as well as among providers, in applying bundle elements; variation among NICUs in designing, completing, and reporting on their checklists; unmeasured care elements not specified in current bundles; and the role of chance.

Second, despite our ability to adjust for the change in case definition for CLABSIs during our study, NICU-specific policies on obtaining a blood culture varied because not all NICUs routinely obtained 2 blood cultures to diagnose late-onset sepsis. Finally, public reporting of performance data could bias CLABSI rates downward. For example, negative administrative consequences of CLABSI occurrence within an institution may affect a decision to attribute a positive blood culture result to a source other than a central line. We encourage the development of uniform and credible measures to aid unbiased performance evaluation, such as bloodstream infections per 1000 patient-days.

CONCLUSIONS

Applying standardized evidence-based central-line care across all regional referral NICUs in NYS significantly reduced CLABSI rates. However, site of care continues to affect CLABSI risk. In addition, within our network higher reported use of checklists was associated with lower CLABSI rates. It is now clear that many NICU LSIs that occurred in past years were instances of preventable harm.

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