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Central Line-Associated Bloodstream Infections Reduction and Bundle Compliance in ICUs: A National Study

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Abstract

Objectives—To 1) describe compliance with the central line (CL) insertion bundle overall, and with individual bundle elements, in US adult intensive care units (ICUs); and 2) determine the relationship between bundle compliance and central line-associated bloodstream infection (CLABSI) rates.

Design—Cross-sectional study.

Participants—National sample of adult ICUs participating in National Healthcare Safety Network (NHSN) surveillance.

Methods—Hospitals were surveyed to determine compliance with CL insertion bundle elements in ICUs. Corresponding NHSN ICU CLABSI rates were obtained. Multivariable Poisson regression models assessed associations between CL bundle compliance and CLABSI rates, controlling for hospital and ICU characteristics.

Results—984 adult ICUs in 632 hospitals were included. Most ICUs had CL bundle policies but only 69% reported excellent compliance (≥95%) with at least one element. Lower CLABSI rates were associated with compliance with just one element (IRR 0.77; 95% CI 0.64, 0.92); however, ≥95% compliance with all five elements was associated with the greatest reduction (IRR 0.67, 95% CI 0.59, 0.77). There was no association between CLABSI rates and simply having a

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written CL bundle policy, nor with bundle compliance <75%. Additionally, better-resourced infection prevention departments were associated with lower CLABSI rates.

Conclusions—Our findings demonstrate the impact of transferring infection prevention interventions to the real-world setting. Compliance with the entire bundle was most effective, although excellent compliance with even one bundle element was associated with lower CLABSI rates. The variability in compliance across ICUs suggests that at the national level there is still room for improvement in CLABSI reduction.

Introduction

Central line-associated bloodstream infections (CLABSIs) lead to significant morbidity, mortality, and cost among hospitalized patients.[1,2] Over the past decade, numerous interventions have been implemented to prevent CLABSIs, and between 2008 and 2013 CLABSI rates have decreased by 46% across the US.[3] Among the various CLABSI prevention efforts, one of the most widely adopted is the central line (CL) insertion bundle promoted by the Institute for Healthcare Improvement (IHI) and other groups.[4]

A care bundle is a set of evidence-based interventions that are intended to be implemented together, under the theory that the bundled interventions are more effective than implementation of individual interventions separately. The components of the CL insertion bundle include the following practices: 1) hand hygiene prior to insertion; 2) maximal barrier precautions; 3) chlorhexidine skin antisepsis; 4) optimal site selection (avoidance of femoral vein in adults); and 5) daily review of line necessity. Several studies have reported on the positive impact of the CL bundle when implemented as part of collaboratives, including the Keystone intensive care unit (ICU) project in Michigan ICUs[5] and the VA ICU project participating in the IHI campaign.[6] Both collaboratives reported significant decreases in CLABSI rates after implementation of the CL bundle.

The CL bundle has now been adopted by most hospitals across the US; in fact, its components are required of all accredited hospitals by The Joint Commission as part of its National Patient Safety Goal to prevent CLABSIs.[7] However, there are limited data regarding compliance with the bundle elements across US ICUs, as well as the impact on CLABSI rates, outside of a study or collaborative setting. Using data from a relatively small set of US hospitals in 2007 (n = 250), we previously found that the CL bundle was only effective when compliance was nearly perfect (≥95%).[8] Here we report on the largest study to date evaluating CL bundle compliance in nearly 1000 US adult ICUs, as well as the relationship between bundle compliance and CLABSI rates in those ICUs.

Methods

Objectives

The objectives of this study were to: 1) describe compliance with the CL insertion bundle overall, as well as with individual bundle elements, in US adult ICUs; and 2) determine the relationship between individual bundle element or overall bundle compliance and CLABSI rates.

Study Design, Setting, and Participants

This study was performed as part of the P-NICER (Prevention of Nosocomial Infections and Cost Effectiveness Refined) study, which evaluated infection prevention and control practices in hospitals across the US; the larger study is described in detail elsewhere.[9] All non-VA hospitals reporting into the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) CLABSI surveillance module were eligible to participate, and only adult ICUs were included in this analysis.

In the Fall of 2011, hospitals that agreed to participate filled out a web-based survey about hospital characteristics as well as infection prevention practices including for ICU-specific CLABSI prevention. Hospitals were asked: 1) whether a written policy was in place for each CL bundle component; and 2) for each component, to indicate observed levels of compliance during the last time period it was monitored. Levels of compliance were categorized as excellent (≥95%), usually (75–94%), sometimes (25–74%), rarely or never (<25%), or don't know/compliance not monitored. Hospitals were asked the same questions about ventilator bundle and CAUTI prevention bundle practices (i.e., whether they had a written policy and their level of compliance with each bundle component). Compliance for all of these bundles was reported based on whatever method of monitoring was being utilized in the ICU.

Other hospital characteristics obtained using the P-NICER survey or the NHSN annual survey (2011) included geographic location, hospital bed size, ICU bed size, ICU type, medical school affiliation, and resources for infection prevention and control (e.g., number of infection preventionists per 100 beds). All procedures were approved by the institutional review boards at Columbia University Medical Center and the RAND Corporation.

Outcome

Hospitals reported ICU-specific monthly CLABSI rates through NHSN. By joining the P-NICER NHSN research group, participating hospitals allowed the research team access to their CLABSI rates. For NHSN reporting, CLABSIs are defined using criteria developed by CDC, recognized as the gold standard for CLABSI surveillance.

Statistical Analysis

Descriptive statistics were computed and facility characteristics and CLABSI rates in the last quarter of 2011 were compared for hospitals that did and did not join the P-NICER NHSN research group. The study team did not have access to NHSN data for non-respondents and, therefore, the latter analyses were performed by the CDC using χ^2 tests or ANOVA.

We estimated multivariable Poisson regression models, with state level fixed effects, in which the unit of analysis was the ICU-month. The number of CLABSI infections in an ICU-month was the outcome and CL bundle compliance was the exposure, controlling for ICU characteristics, hospital characteristics, and time. We specified the number of CL days in an ICU-month in the models to account for the total population's "at risk" time during the month. To better understand the impact of each individual bundle element as well as combinations thereof on CLABSI rates we estimated models with alternative specifications. The first set of models included indicators for simply having a written policy and for the various levels of compliance with each individual bundle element. The second set of models included indicators for the number of bundle elements within the various levels of compliance. These models and levels of compliance were determined a priori, based on findings from previous studies and recommendations for the use of care bundles.[8,10,11]

In all models we addressed two potential sources of bias. First, there might be systematic self-reporting bias across hospitals if, for example, some hospitals over-reported bundle compliance in the survey and under-reported CLABSI rates to NHSN in order to appear better than they were. Second, if CLABSI rates are driven more by an organizational "culture of safety" than by specific bundled interventions, then bundle compliance could be merely a proxy for a better organizational culture in a hospital or ICU and we might therefore see a spurious correlation between bundles and CLABSI rates. In order to address these potential sources of bias, we included other care bundles, i.e., for ventilator care and catheter-associated urinary tract infection (CAUTI), as additional controls. If systematic over-reporting was a problem, the same over-reporting would be expected for these other care bundles and we might thereby see the same association between ventilator or CAUTI bundle compliance and CLABSI rates. Similarly, if bundles and infection rates were driven by general quality, we would expect to see CLABSI rates associated with better compliance with any of the bundles, whether with the CL bundle or the ventilator or CAUTI bundles. Conversely, a finding that these other care bundles were not associated with CLABSI rates would substantially mitigate these concerns.

Results

A total of 984 adult ICUs in 632 hospitals were included (Table 1); hospitals were located in 51 states and territories. Mean ICU bed size was 14.0 (SD 8.3), mean hospital bed size was 243.6 (SD 214.7), and most ICUs (52%) were medical/surgical. The mean CLABSI rate was 0.96 per 1000 CL days (SD 1.29). Compared with those that did not participate, hospitals that completed the P-NICER survey and joined the NHSN research group had higher numbers of patient days and admissions (p-values <0.001), more beds (ICU, specialty, and all others; p-values <0.05), and a higher number of infection preventionists per hospital (p-value = 0.006). Participating hospitals were more likely to be affiliated with a medical school (p-value 0.009) and located in the Northeast or Midwest (p-value <0.001). For most ICU types in hospitals that did and did not participate, the pooled mean CLABSI rates in the last quarter of 2011 were similar; however, CLABSI rates were significantly higher (p-value = 0.04) for burn ICUs in hospitals that did not participate (data not shown).

Ninety-eight percent of ICUs had CL bundle policies, but only 69% reported ≥95% compliance with at least 1 bundle element. Excellent compliance (i.e., ≥95% in the last period monitored) for individual elements was reported by between 30–65% of ICUs (Table 2) and was least common for daily assessment of CL necessity (30%) and most common for chlorhexidine use (65%). Excellent compliance was most frequently not reported for any of the bundle elements (only 31% of ICUs). However, 20% of ICUs reported excellent compliance with all elements and 49% reported compliance at least usually (≥75%) (Table 3).

Multivariable Analyses

In multivariable analysis, simply having a written policy for CL bundle elements was not associated with lower CLABSI rates (data not shown). Models in which compliance was defined as ≥95% showed the strongest associations with lower CLABSI rates. Models in which compliance was defined at levels <95% produced results that were generally in the same direction, but substantially weaker in magnitude, to those in which compliance was defined as 95% or greater. Therefore, here we present only the latter results and they are the focus of our discussion.

When evaluating CL bundle compliance at ≥95%, no individual bundle element was significantly associated with decreased CLABSI rates, although trends suggested each element was protective (Table 4, Model 1). When evaluating the impact of the *number* of bundle elements with ≥95% compliance (Table 4, Model 2), lower CLABSI rates were seen for compliance with just one element (incidence rate ratio [IRR] 0.77; 95% CI 0.64, 0.92). Compliance with 2–4 elements also led to significant CLABSI reduction; however, ≥95% compliance with all 5 elements was associated with the greatest reduction in CLABSI rates (IRR 0.67; 95% CI 0.59, 0.77). In both Models 1 and 2, we found that compliance with the ventilator bundle was associated with a significant increase in CLABSI rates (IRR 1.06; 95% CI 1.03, 1.08). There was no association between compliance with the CAUTI bundle and CLABSI rates (IRR 1.00; 95% CI 0.94, 1.06).

Institutional characteristics significantly associated with lower CLABSI rates included smaller overall hospital size but larger ICU bed size, ICU type, and non-teaching hospitals. We found that certain infection prevention and control department resources were associated with lower CLABSI rates, including a larger number of infection preventionists per 100 beds, as well as having an electronic surveillance system.

Discussion

This is the largest study to date evaluating CL bundle compliance in the US and includes data from nearly 1000 adult ICUs. Furthermore, this is the largest study to evaluate the relationship between CL bundle compliance and CLABSI rates, including the level of compliance at which lower CLABSI rates are seen, as well as the specific contribution of individual bundle elements and the number of elements needed.

We found that while adoption of the CL bundle was widespread, there was often less than full compliance with the bundle. This is an issue because lower CLABSI rates were seen only in ICUs with high CL bundle compliance. There was no association between CLABSI rates and simply having a written policy for the CL bundle, nor with bundle compliance less than 75%. These results are similar to our previous study, but here we provide updated data, and the significantly larger sample size in this study allowed for more robust findings.[8]

We found that as long as at least one CL bundle element was performed very well, lower CLABSI rates were achieved; however, it did not appear to matter with which of the 5 bundle elements compliance was high. Controlling for compliance with other elements, no one element independently decreased CLABSI rates (Model 1). Furthermore, after the first element, additional elements did not add much to CLABSI reduction unless excellent compliance with all 5 elements was achieved (Model 2). Nevertheless, compliance with all 5 CL bundle elements was most strongly associated with lower CLABSI rates, with a 33% reduction in CLABSIs. This supports the IHI bundle concept, which states that all elements of the bundle should be implemented together. In reality, however, we found substantial variability and excellent compliance with the entire bundle was rare, with fewer than 20% of adult ICUs achieving this across the US.

As expected, we found that CLABSI rates correlated with ICU type (e.g., burn/trauma ICUs had higher rates than surgical ICUs). Smaller hospitals and those not affiliated with medical schools had lower infection rates, possibly due to a lower acuity of patients and less tertiary care. However, larger ICUs had lower CLABSI rates, perhaps because of the presence of resources such as experienced intensivists.

Better-resourced infection prevention and control departments, with more infection preventionists per 100 beds as well as electronic surveillance systems, were also associated with lower CLABSI rates. It is notable that infection preventionists appear to have a measurable impact on CLABSI prevention. Infection preventionists are likely able to provide educational support and emphasis on appropriate infection prevention efforts, although it is also possible that they are a proxy for institutions that place a higher priority on infection prevention in general.

Our findings demonstrate the impact of taking infection prevention interventions that have been proven to be effective in study and collaborative settings and transferring them to the real-world setting. The Keystone ICU project in Michigan involved implementation of the 5 components of the CL bundle and saw a significant reduction in CLABSI rates. Compliance with the intervention was not described, but it is reasonable to assume that as attention to the intervention was high, compliance was probably good.[5] The VA ICU CLABSI initiative was implemented across all VA ICUs and saw “composite” compliance with the CL bundle increase from 85% to 98% by the end of the study period. They found that CLABSI rates significantly correlated with this compliance, although they did not separate out the impact of individual bundle elements.[6] Similar findings have been reported from other collaboratives as well.[12,13] Marsteller et al demonstrated more definitively a causal relationship between the CL bundle and CLABSI rates through a multicenter phased, cluster-randomized controlled trial, but they also did not measure compliance to the bundle, nor did they distinguish the impact of the CL bundle (or its individual components) from that of other interventions that were implemented in order to improve the culture of safety in the institutions.[14] However, outside of such collaboratives and the VA system, we found that there is significantly greater heterogeneity in the mix of adult ICUs across the US.

Limitations of this study include the fact that CL bundle compliance data were collected by self-report from the hospitals’ infection prevention and control departments, leading to the possibility of self-reporting bias. By contrast, CLABSI rates were accessed directly from NHSN, but it is possible that institutions trying to appear better might under-report CLABSI rates to NHSN as well as over-report CL bundle compliance in our survey. This possibility is largely mitigated by our analysis of compliance with the ventilator and CAUTI bundles and their association with CLABSI rates. One would expect hospitals that are trying to appear better to also over-report compliance with the other care bundles, leading to a spurious association between ventilator or CAUTI bundle compliance and CLABSI reduction. However, we found the opposite, with higher ventilator bundle compliance associated with higher CLABSI rates. This makes self-reporting bias much less likely. It also suggests that CL bundle compliance is not just a proxy for hospitals with a better general culture of safety but rather that there is a very specific association between these particular CL-targeted interventions and lower CLABSI rates. Furthermore, it suggests that institutional resources and time are finite, and when attention is shifted towards care of ventilated patients, CLABSI prevention may suffer and rates may increase.

Another potential bias is sample selection. We compared participating hospitals to those in NHSN that did not participate and based on this comparison it is likely that our sample is composed of higher performers; therefore, our findings would be conservative. Finally, there is always the possibility of unmeasured confounding affecting the observed associations between compliance with CL bundle elements and CLABSI rates, although we did control for numerous different factors as described above.

In this large national survey of adult ICUs in the US, lower CLABSI rates were significantly associated with CL bundle compliance, as long as the compliance was high (≥95%). Compliance with the entire bundle was most effective, but even excellent compliance with one bundle element was associated with significantly lower CLABSI rates. The variability in compliance across ICUs suggests that at the national level there is still more room for improvement in CLABSI reduction.

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Table 1

Description of participating hospitals and adult ICUs

Hospital characteristics (n=632)	Value
Number of hospital beds, mean (SD)	243.6 (214.7)
Affiliated with a medical school, n (%)	237 (37.5)
Electronic surveillance system, n (%)	248 (39.2)
IP full-time equivalents per 100 beds, mean (SD)	1.14 (1.14)
HE full-time equivalents per 100 beds, mean (SD)	0.18 (0.49)
ICU characteristics (n=984)	
Number of ICU beds, mean (SD)	14.0 (8.3)
ICU type, n (%)	
Medical	214 (21.7)
Medical/Surgical	511 (51.9)
Surgical	218 (22.2)
Other	41 (4.2)
Number of CLABSIs, mean (SD)	3.44 (4.78)
Number of central line days, mean (SD)	3,285 (2,980)
CLABSIs/1000 central line days, mean (SD)	0.96 (1.29)

Notes: Medical ICU types include: Medical, Medical cardiac, Neurologic, Respiratory; Surgical ICU types include: Neurosurgical, Surgical, Surgical cardiothoracic; Other ICU types include: Burn, Trauma; ICU = intensive care unit; SD = standard deviation; IP = infection preventionist; HE = hospital epidemiologist; CLABSI = central line-associated bloodstream infection

Table 2

Presence of and compliance with individual CLABSI bundle policies in adult ICUs (n=984)

CLABSI bundle elements	Presence of written policy n (%)	Proportion of time policy was correctly implemented n (%)			
		All of the time (≥95%)	Usually (75–94%)	Sometimes (25–74%)	Rarely/Never/ No monitoring
Hand hygiene	923 (93.8)	528 (53.7)	169 (17.2)	16 (1.6)	210 (21.3)
Maximal barrier precautions	962 (97.8)	554 (56.3)	164 (16.7)	16 (1.6)	228 (23.2)
Chlorhexidine use	966 (98.2)	640 (65.0)	98 (10.0)	10 (1.0)	218 (22.2)
Optimal catheter site selection	916 (93.1)	387 (39.3)	261 (26.5)	35 (3.6)	233 (23.7)
Daily assessment of central line need	865 (87.9)	299 (30.4)	249 (25.3)	66 (6.7)	251 (25.5)

Notes: ICU = intensive care unit; CLABSI: central line-associated bloodstream infection

Table 3

Compliance with multiple CLABSI bundle policies in adult ICUs (n=984)

CLABSI bundle elements	Proportion of time policy was correctly implemented n (%)	
	All of the time (≥95%)	All of the time or Usually (≥75%)
All five elements	192 (19.5)	477 (48.5)
Just four elements	194 (19.7)	183 (18.6)
Just three elements	155 (15.8)	56 (5.7)
Just two elements	73 (7.4)	16 (1.6)
Just one element	61 (6.2)	13 (1.3)
No elements	309 (31.4)	239 (24.3)

Notes: ICU = intensive care unit; CLABSI: central line-associated bloodstream infection

Table 4

Multivariable regression analysis of associations between ≥95% compliance with central line bundle elements and CLABSI rates in adult ICUs

Variables	Model 1: Impact of each individual element		Model 2: Impact of complying with any one or multiple elements	
	IRR	95% CI	IRR	95% CI
≥95% compliance with				
Hand hygiene	0.91	0.80, 1.05	--	--
Maximal barrier precautions	0.96	0.83, 1.11	--	--
Chlorhexidine use	0.89	0.78, 1.02	--	--
Optimal catheter site selection	0.90	0.80, 1.00	--	--
Daily assessment of central line need	0.99	0.89, 1.10	--	--
CLABSI bundle elements (indicator variables with reference = no elements)				
All five elements	--	--	0.67 ***	0.59, 0.77
Just four elements	--	--	0.72 ***	0.63, 0.82
Just three elements	--	--	0.83 **	0.74, 0.94
Just two elements	--	--	0.82 *	0.70, 0.95
Just one element	--	--	0.77 **	0.64, 0.92
Compliance with ventilator bundle	1.06 ***	1.03, 1.08	1.06 ***	1.03, 1.08
Compliance with CAUTI bundle	1.00	0.94, 1.06	1.00	0.94, 1.06
Hospital and ICU characteristics				
Number of hospital beds	1.08 **	1.03, 1.13	1.08 ***	1.03, 1.13
Number of ICU beds	0.94 **	0.91, 0.98	0.95 **	0.91, 0.98
Surgical ICU (vs. Medical/Surgical)	0.86 **	0.78, 0.95	0.86 **	0.78, 0.95
Medical ICU (vs. Medical/Surgical)	1.08	0.98, 1.20	1.09	0.99, 1.20
Burn or Trauma ICU (vs. Medical/Surgical)	1.64 ***	1.42, 1.90	1.62 ***	1.40, 1.87
Affiliated with a medical school	1.32 ***	1.19, 1.45	1.29 ***	1.17, 1.43
Electronic surveillance system	0.91 *	0.83, 0.99	0.90 *	0.83, 0.98
IP full-time equivalents per 100 hospital beds	0.87 *	0.78, 0.97	0.88 *	0.79, 0.98
HE full-time equivalents per 100 hospital beds	1.00	0.87, 1.16	0.99	0.86, 1.15

Notes: CLABSI = central line-associated bloodstream infection; ICU = intensive care unit; CAUTI = catheter-associated urinary tract infection; IRR = incidence rate ratio; CI = confidence interval; In addition to what is shown in the table, calendar year and month were also controlled for;

* p<0.05,

** p<0.01,

*** p<0.001