Reducing the rate of catheter-associated bloodstream infections in a surgical intensive care unit using the Institute for Healthcare Improvement central line bundle

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The use of central venous catheters (CVCs) has become an increasingly common means of administering treatment and monitoring hemodynamics in critically ill patients. However, infections resulting from the use of these devices cause significant morbidity, mortality, and cost, particularly in the intensive care unit (ICU) where approximately 48% of patients have a CVC in place.¹ According to the published estimates from the Centers for Disease Control and Prevention (CDC), there are 80,000 catheter-related bloodstream infections (CRBSIs) among patients in ICUs each year, accounting for up to 24,000 deaths.² Each CRBSI extends a patient’s stay in the hospital by a mean of 7.5 days.³ Assuming

KEYWORDS:
Catheter-associated line infections; Infection control; Central venous catheters; Quality improvement; Healthcare cost; Checklist

BACKGROUND: Central line–associated bloodstream infections (CLABSIs) are a significant source of morbidity and mortality. This study sought to determine whether implementation of the Institute for Healthcare Improvement (IHI) Central Line Bundle would reduce the incidence of CLABSIs.

METHODS: The IHI Central Line Bundle was implemented in a surgical intensive care unit. Patient demographics and the rate of CLABSIs per 1,000 catheter days were compared between the pre- and postintervention groups. Contemporaneous infection rates in an adjacent ICU were measured.

RESULTS: Baseline demographics were similar between the pre- and postintervention groups. The rate of CLABSIs per catheter days decreased from 19/3,784 to 3/1,870 after implementation of the IHI Bundle (1.60 vs 5.02 CLABSIs per 1,000 catheter days; rate ratio .32 [.08 to .99, P < .05]). There was no significant change in CLABSIs in the control ICU.

CONCLUSIONS: Implementation of the IHI Central Line Bundle reduced the incidence of CLABSIs in our SICU by 68%, preventing 12 CLABSIs, 2.5 deaths, and saving $198,600 annually.

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Numbers of studies suggest that many, if not all, of these infections are preventable and that a few simple interventions, during placement and maintenance of CVCs, can independently reduce the incidence of CRBSIs and their ensuing morbidity, mortality, and cost. These interventions include the following: education programs for all medical personnel involved in the placement and maintenance of the catheters; proper hand hygiene; chlorhexidine skin antisepsis; maximal barrier precautions upon insertion; preferential use of the subclavian vein; and daily review of catheter necessity with prompt removal of unnecessary lines. Furthermore, in landmark studies, Berenholtz et al. and Pronovost et al. demonstrated reductions in CRBSIs using a checklist to standardize procedures, thereby ensuring that patients receive the highest quality of care.

Translating such evidence-based practices to standards of care at the bedside is a continuous challenge. To facilitate this process, the Institute for Healthcare Improvement (IHI) developed its Central Line Bundle and checklist as a cornerstone of its 100,000 lives campaign. The Bundle is a collection of the above-mentioned interventions, offered as a standardized package to hospitals, thereby facilitating their compliance with the recently updated Joint Commission’s Hospital Accreditation Program National Patient Safety Goals. Each of the components of the Central Line Bundle, in isolation and in various combinations, has been shown to repeatedly decrease the rate of CRBSIs. Of note, the first iteration of the IHI Central Line Bundle recommended a non-femoral site to decrease the risk of infection. This was later modified to specify that the subclavian vein site should be preferred and recognized that non-infectious risks should also be taken into consideration when choosing between sites. To date, however, studies examining the effectiveness of The IHI Bundle as a whole have been limited and few have focused exclusively on trauma/surgical patients or strictly enforced the subclavian vein site as being preferred over the internal jugular vein. Our study is unique in that our intervention included preferential use of the subclavian vein over the internal jugular/femoral vein.

Although the majority of studies that identified the interventions included in the IHI Central Line Bundle evaluated their impact on CRBSIs, the quality improvement aspect of the Bundle instructs hospitals to track their rates of central line–associated bloodstream infections (CLABSIs). Unlike CRBSI, CLABSI does not require culture of the catheter segment to establish a diagnosis and is therefore a standard and widespread alternative in most clinical settings. In our county hospital surgical ICU (SICU), rates of central line infections are above the national average (5.8 infections per 1,000 catheter days compared to 5.3 in major medical/surgical teaching hospitals). The purpose of this study was to evaluate the effectiveness of a comprehensive educational campaign combined with adoption of the IHI Bundle and checklist to reduce the line infection rates in our county hospital SICU. Furthermore, because of the conflicting evidence on the relative infection prevention benefits of the subclavian site over the internal jugular site, our study included the “subclavian preferred” element of the bundle. We hypothesized that the use of this relatively simple and inexpensive intervention would decrease rates of line infections within 6 months of initiating the IHI Central Line Bundle.

Patients and Methods

Study location and patient population

This study was conducted at the Los Angeles County/University of Southern California Medical Center, a 600-bed academic tertiary care hospital that offers medical, surgical, obstetrical, gynecological, psychiatric, and pediatric services. Data were collected from 2 ICUs. The intervention ICU is a 16-bed surgical intensive care unit (SICU) with neighboring 8-bed mixed ICU/step-down unit that cares for adult patients with primary surgical conditions. The study population included all patients in our SICU with a CVC in place. There were no patients with tunneled catheters during the study period. Peripherally inserted CVCs (PICC lines) were rarely used and were not included in the compliance analysis. The concurrent control ICU, which did not implement the Bundle, is a 16-bed unit that cares for adult patients with predominantly medical conditions.

Intervention

Beginning in December 2005, a performance improvement initiative was initiated utilizing the FOCUS-PDCA methodology in the SICU of our Level-1 trauma center (http://www.sentinel-event.com/focus/ppframe.htm). We organized a multidisciplinary team including trauma surgeons, intensivists, infection control staff members, the trauma program manager, and an ICU charge nurse to implement the initiative and survey its impact. Spearheading the intervention was a computerized training module and examination for all physicians and nurses involved in the insertion and maintenance of intravascular catheters in the SICU. The module, adapted from Berenholtz et al., featured an outline of standardized infection control practices, and taught proper techniques for central line insertion and management. A postmodule examination was given and surgical house staff were required to answer at least 90% of the questions correctly to maintain their CVC insertion privileges.

Simultaneously, the IHI Central Line Bundle was implemented in our SICU. The bundle consists of the following: (1) proper hand hygiene; (2) chlorhexidine skin preparation; (3) preferential use of the subclavian vein; (4) maximal barrier precautions; and (5) a daily assessment of catheter need. Hand hygiene methods included both alcohol-based scrubs and soap and water. To encourage compliance with these interventions, we used a catheter insertion checklist to monitor adherence to each Bundle element (Fig. 1). The same checklist was also used daily to assess whether the CVC could be removed. The checklist was placed in a covered folder at each patient’s bedside.
SICU nurses were responsible for filling out the checklist during catheter insertion and were instructed to intervene and stop the procedure if they noticed any violation of the guidelines. If a site other than the subclavian vein was chosen, a suitable reason had to be given for the insertion to be considered compliant: coagulopathy, need/potential for long-term dialysis, thromboses, infected skin, catheter already occupying the site, or a combination thereof. All surgical house staff are trained in insertion in all 3 CVC sites (subclavian, jugular, and femoral) and must demonstrate proficiency before being able to insert lines in the SICU. Ultrasound guidance was routinely used for jugular lines and according to the surgeon’s preference for the subclavian and femoral sites. Physicians were responsible for completing the daily assessment of need portion of the checklist. To further facilitate physician compliance during catheter insertion, we created a mobile Central Line Insertion Cart containing all equipments and supplies that are necessary for the insertion and management of CVCs.

**Study design**

We designed a prospective before–after interventional cohort study with concurrent controls. Between November 2004 and November 2005, we collected baseline data on
central line infection rates in both the study ICU and the control ICU. As our primary outcome variable, we chose to measure central line associated bloodstream infections (CLABSIs) per 1,000 catheter days. Unlike CRBSI, CLABSI does not require culture of the catheter segment to establish a diagnosis and is therefore a standard and widespread alternative in most clinical settings. However, CLABSI, when compared to CRBSI, is less specific in determining causation between catheter colonization and bacteremia. At our hospital, the Department of Infection Control and Epidemiology defines CLABSI using National Nosocomial Infection Surveillance System (CDC)-based definitions. Diagnoses were made by trained hospital epidemiologists according to these definitions.

We also collected data on patient demographics including age, Apache II score, and average catheter utilization rate (CUR, defined as total catheter days divided by the total number of patients in intervention unit) in both pre- and postintervention groups to ensure comparable populations and practice patterns.

The intervention began in December 2005 and CLABSI data from this month were omitted from the analysis. During the month of March 2006, 3 months into the intervention, we conducted an audit of 34 checklists to assess physician compliance with each of the Bundle steps. The daily management of CVCs did not change during the study period with the exception of daily assessment of need. Throughout the study, we used the triple lumen ARROWg+ard Blue Plus (Teleflex, Inc, Limerick, PA), a second-generation antimicrobial catheter, as the predominant CVC in both our SICU and control ICU. Other central lines used included uncoated, large volume infusion catheters, and temporary hemodialysis catheters. We did not replace or exchange catheters at routine intervals. Decisions regarding placement, management, replacement, or exchange of catheters were as per the discretion of the attending physician on daily rounds. Catheter segment cultures were not routinely sent.

To control for evolution in hospital practices, CLABSI data was contemporaneously collected from a neighboring ICU at our hospital. During the postintervention period, data were collected from the control ICU from the months Jan 2006 to April 2006. Epidemiology and infection control tracked CLABSI data in both ICUs; however, the control ICU did not have a formal education intervention or IHI Bundle implementation.

The Institutional Review Board at our institution approved the study and waived the need for informed consent.

Data analysis

Catheter days were determined by counting each patient with a CVC at midnight. Patients with more than one catheter in place were only counted once. Preintervention data were collected from November 2004 to November 2005 and postintervention data were collected from January 2006 to Jun 2006. Postintervention data in the control ICU was collected from January 2006 to April 2006. Data for the total number of line days occurring in the 8-bed mixed SICU/step-down unit that participated in our intervention group was not available for 3 months during the preintervention period and 2 month in the postintervention period. Therefore, the average number of line days per month from the 19 months preceding the intervention (41 ± 16) was imputed for the missing values to obtain the total number of line days for the entire study period.

Statistical analysis was performed using OpenEpi, an open source statistics program. We compared the rates of CLABSI per 1,000 catheter days using the mid-P exact test and Byar methods. We also compared age and Apache II scores before and after the intervention using an independent samples t test. A P value of <.05 was required to reach statistical significance. We used 95% confidence intervals.

Results

Between November 2004 and November 2005, there were 1,141 total patients in our SICU accounting for a total number of 3,784 line days (Table 1). After the intervention took place, from January 2006 to Jun 2006, there were 535 patients and 1,870 total line days. Patients in both pre- and postintervention groups had similar ages, Apache II scores, and CUR.

During the 3rd month of our intervention (March 2006), we found the overall physician compliance with the complete IHI bundle to be 58% (19/33 cases audited during this time period). The most common noncompliance item was the daily assessment of catheter need, which was completed 70% of the time. In terms of compliance with bundle elements at the time of insertion, 91% (30/33) of the insertion checklists were completed. Of these, compliance rates were as follows: hand hygiene 100%, chlorhexidine preparation 93%, and maximal-barrier precautions 100%. A non-subclavian site was used 5 times out of the 33 lines inserted, but it was justifiably chosen in 3 of these cases, leaving only 2 noncompliant cases for this bundle element (31/33, 94% compliant).

During the 6-month postintervention phase, there were 3 CLABSIs in 1,870 catheter days compared to 19 CLABSIs in 3,784 catheter days in the 1-year preintervention phase (1.60 vs 5.02 CLABSI per 1,000 catheter days, rate ratio .320 [.075 to .987, P = .047, mid-P exact test], rate difference −3.42 [−6.31 to −.52, P < .05, Byar method]) (Fig. 2). We therefore estimate a net reduction of CLABSI by 68%.

The average CLABSI rate in the control ICU was 10.1 (54 CLABSIs in 5,327 catheter days) during the 12-month preintervention period, and 13.9 (24 CLABSIs in 1,721 catheter days) during the 4-month postintervention period (rate ratio 1.37 [.84 to 2.21, P = .200, mid-P exact test], rate difference .38 [−.24 to 1.00, P = .200, Byar method]).

Based on our data and CDC estimates on cost and mortality, we estimate that our intervention prevented 12 CLABSIs per year. Assuming an average cost of $16,550 per CLABSI and a mortality rate of 20%, we also estimate...
that we prevented 2.5 deaths and at least $198,600 in additional hospital costs per year.

**Comments**

There is a growing body of evidence suggesting that CLABSI may be entirely preventable. The challenge of eliminating these and other nosocomial infections may be addressed by encouraging compliance with already established evidence-based infection control practices. We sought to test the effectiveness of the IHI Central Line Bundle and checklist, with an emphasis on using the subclavian vein as the preferred site, to reduce the incidence of CLABSI in a resource constrained, county hospital setting. Over a 6-month period, our intervention reduced the incidence of CLABSI by 68%, while the infection rates in our control ICU did not change significantly. This quality improvement intervention likely resulted in decreased patient morbidity, mortality, and costs.

In a landmark study, Berenholtz et al\(^9\) demonstrated that by utilizing a checklist to encourage best practices of sterile central line insertion, it is possible to virtually eliminate the morbidity associated with central line infections. This finding was reproduced on a larger scale in hospitals across the state of Michigan.\(^10\) Since then, several studies have used various combinations of the Central Line Bundle elements to decrease the rates of line infections. These studies, however, differ from ours in several ways. Many have relied on “avoidance of the femoral vein whenever possible,”\(^15,16\) while our study discouraged the use of both the femoral and internal jugular veins and required the use of the subclavian vein unless an appropriate reason was specified.\(^13\) Furthermore, previous studies measured CRBSI,\(^9,10\) which is not the standard methodology used by most hospital infection control departments to track the rates of central line sepsis. Instead, our study used the more widely utilized CLABSI, which enhances the generalizability of our findings to common everyday practice. Finally, other studies have focused solely on pediatric populations,\(^17,18\) while ours only included adult surgical and trauma ICU patients in a county hospital with significant constraints on financial resources. Our findings demonstrate that a low-cost intervention can be used in this setting to prevent CLABSI and reduce morbidity, mortality, and cost.

During both the pre- and postintervention period, we observed an especially high rate of CLABSI in our control ICU. It should be noted that the practitioners in this ICU did not participate in any of the educational activities associated with our intervention, nor did this ICU endorse any standardized line insertion practice. Additionally, the femoral vein site was commonly chosen in this ICU based on the experience level and comfort of the physicians inserting the catheters. However, after noting the success

**Table 1** Comparison of patient characteristics and CLABSI rates in the pre- and postintervention cohorts

<table>
<thead>
<tr>
<th></th>
<th>Preintervention cohorts</th>
<th>Postintervention cohorts</th>
<th>P value</th>
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<tr>
<td><strong>Surgical intensive care unit</strong></td>
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<tr>
<td>Patients</td>
<td>1,141</td>
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<td></td>
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<td>Age (y)</td>
<td>43 ± 19</td>
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<td>20 ± 7</td>
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</tr>
<tr>
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<td>Catheter days</td>
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<td><strong>Control intensive care unit</strong></td>
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<tr>
<td>CLABSI</td>
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<td>Catheter days</td>
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<tr>
<td>Rate per 1,000 catheter days</td>
<td>10.1</td>
<td>13.9</td>
<td>.200†</td>
</tr>
</tbody>
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Data are expressed as mean ± standard deviation.

CLABSI = central line associated bloodstream infection; CUR = catheter utilization rate (total catheter days/patients).

*Independent samples t test utilized.

†Mid-P exact test and Byar method utilized.

**Figure 2** Rate of central line–associated bloodstream infections per 1,000 catheter days per intensive care unit before and after intervention. P < 0.05.
of our intervention, the IHI bundle was adopted by our control ICU.

There are several limitations to our study. Since the analysis of the intervention utilized a before–after comparison approach, we could not directly account for unmeasured changes affecting the rates of CLABSI. Specifically, we did not obtain baseline compliance data in the intervention SICU and we did not have compliance data at any time point in the control ICU. However, since infection rates in our control ICU contemporaneously trended upward, we feel confident that shifting hospital practice and other confounders were minimal. We also acknowledge that one of the concerns that lead some physicians to choose the internal jugular or femoral sites over the subclavian has to do with insertion-related complications, such as arterial puncture, pneumothorax, and/or hemothorax, and we did not have access to data relating to these complications. However, the surgeons at our institution generally rely on this site in several settings and proficiency with all potential sites is equal among our house staff. Since complication data were not collected, we are unable to make any conclusions regarding the overall risks and benefits of specific site selection. The study design was also nonrandomized. To account for potential patient and practice differences, we compared age, Apache II scores, and CUR in our study population before and after the intervention and found no significant differences.

The IHI considers compliance an “all or nothing” indicator. Therefore, we sought to evaluate the Bundle in its designed form by implementing all of the Bundle’s components simultaneously. Unfortunately, as a result, we cannot determine the exact mechanism of the observed effect, nor the relative impact of each Bundle component. Furthermore, because of the lack of baseline compliance data and the low number of postintervention CLABSI (3 infections in 6 months), we were unable to statistically correlate each specific compliance element with outcome.

Quality improvement initiatives rely on 2 main approaches. First, it is necessary to determine the best evidence-based practice to designate as standard of care. In our study, the IHI Bundle provided these guidelines, outlining 5 critical measures proven to reduce the incidence of CLABSI. Second, it is necessary to systematically adapt the clinical environment to enhance compliance with established guidelines. In our study, we implemented an education program required for physicians and nurses involved in catheter insertion and care. A lecture highlighting the evidence regarding CLABSI served to standardize knowledge of the problem within the department and thus eliminate barriers created by lack of awareness. We also utilized a catheter insertion checklist and empowered nurses to intervene in cases where guidelines were not followed. Checklist technology has been successful in reducing human error in the aerospace industry for decades and is becoming a popular quality improvement measure in several medical settings by offering a consistent reminder of standard of care to practitioners.

Government agencies are employing various strategies to ensure adherence to established, evidence-based quality care. Since October 2008, the Centers for Medicare and Medicaid Services no longer reimburse hospitals for several clearly defined hospital-acquired conditions, including ventilator-associated pneumonia, catheter-associated urinary tract infections, pressure ulcers, and CRBSIs. Recent legislation passed in several states mandating the reporting of nosocomial infections offers further incentive to hospitals to comply with evidence-based standards. The Joint Commission’s Hospital Accreditation Program National Patient Safety Goals, as of January 1, 2010, also requires hospitals to adopt an ambitious assortment of quality improvement measures, including the use of catheter checklists and a standardized protocol for CVC insertion. Finally, as our healthcare system undergoes reforms, significant attention will be paid to ‘pay for performance’ mechanisms of physician payment rewarding adherence to best practice of care. Such policy measures have obligated adherence to infection control measures.

Conclusions

Nosocomial infections, particularly CLABSI, are a preventable cause of morbidity and mortality in hospitals. They therefore present a discernible opportunity for much needed quality improvement measures in various healthcare settings. Our study advances a distinct performance improvement initiative to meet this goal by demonstrating the effectiveness of the IHI Central Line Bundle. We incorporated a central line cart, educational campaign as part of the IHI Bundle in our SICU with preferential subclavian line placement, and significantly reduced the incidence of CLABSI. This relatively simple intervention has the potential to prevent deaths and reduce healthcare costs.

References


