Effectiveness of stepwise interventions targeted to decrease central catheter-associated bloodstream infections*

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**Objective:** Determine the impact of three stepwise interventions on the rate of central catheter-associated bloodstream infections.

**Design:** Quasi-experimental study.

**Setting:** Three surgical intensive care units (general surgery, trauma, and neurosurgery) at a 1500-bed county teaching hospital in the Miami metro area.

**Patients:** All consecutive central catheter-associated bloodstream infection cases as determined by the Infection Control Department.

**Interventions:** Three interventions aimed at catheter maintenance were implemented at different times in the units: chlorhexidine “scrub-the-hub,” chlorhexidine daily baths, and daily nursing rounds aimed at assuring compliance with an intensive care unit goal-oriented checklist.

**Measurements and Main Results:** The primary outcome was the monthly intensive care unit rate of central catheter-associated bloodstream infections (infections per 1000 central catheter days). Over 33 months of follow-up (July 2008 to March 2011), we found decreased rates in each of the three intensive care units evaluated during the interventions, especially after implementation of chlorhexidine daily baths. Rates in unit A decreased from a rate of 8.6 to 0.5, unit B from 6.9 to 1.6, and unit C from 7.8 to 0.6. Secondary bloodstream infection rates remained unchanged throughout the observation period in units A and B; however, unit C had a decrease in its rates over time.

**Conclusions:** We report the progressive reduction of central catheter-associated bloodstream infection rates after the stepwise implementation of chlorhexidine “scrub-the-hub” and daily baths in surgical intensive care units, suggesting effectiveness of these interventions. (Crit Care Med 2012; 40: 1464–1469)

**Key Words:** central catheter-associated bloodstream infections; chlorhexidine; intensive care units

**H** ealthcare associated infections (HAIs) are among the most common adverse events occurring during hospital admissions. In 2002, 1.7 million patients suffered from HAIs with an associated 155,668 fatalities, or nearly 10%. Furthermore, infection rates were the highest in the intensive care units (ICUs) (13%) (1). The attributable cost of HAIs varies depending on the type of infection, and some estimate the cost to be $34,670 for surgical site infections and $29,156 for central line-associated bloodstream infections (CLABSIs) (2). Likewise, length of hospital stay increases by an average of 9.6 days among patients who develop HAIs (3).

CLABSIs constitute one of the most frequent hospital-acquired infections in the United States, with an associated mortality of up to 25% (4). A recent report by the Centers for Disease Control and Prevention showed that in 2009 the number of CLABSIs in American inpatient settings totaled 41,000 events (5). Interventions aimed at improving compliance with optimal insertion techniques have been proven to decrease the CLABSI rates by as much as 70% (6). Additionally, maintenance interventions to reduce the bacterial load on patients’ skin have been demonstrated to be effective at preventing subsequent CLABSIs (7). However, the incremental effectiveness of several interventions applied in a sequential fashion is still unknown.

We sought to determine the effectiveness of a series of stepwise interventions, which we hypothesized would incrementally lower CLABSI rates. These interventions targeted maintenance of central venous catheters and included a 15-sec “scrub-the-hub” process with chlorhexidine swabs, daily chlorhexidine baths, and daily ICU goal-oriented nursing rounds. We also assessed the effect of these interventions on the type of causative organisms, the number of days from catheter insertion to first positive blood culture, and the rate of secondary bacteremia during the various phases of the study.

**METHODS**

This quasi-experimental study was performed at Jackson Memorial Hospital, a 1500-bed safety net teaching hospital affiliated with the University of Miami Miller School of Medicine. This facility has approximately 300 ICU beds (adult, pediatrics, and neonatology) and serves a mixed patient population with a large, underserved and foreign national representation. This project was submitted to the Institutional Review Board, which determined that it did not constitute human subject research.

The areas selected for this project consisted of adult ICUs with known initiation dates for each intervention. Interventions
had to be fully implemented in the unit within a 4-wk timeframe to satisfy inclusion criteria. This requisite specifically excluded those units in which more gradual implementation occurred.

Unit A was the surgical ICU consisting of two adjacent 20-bed units totaling 40 beds. These two units shared nursing and ancillary staff, and were managed by the same nursing and medical administration. Unit A accepted patients that required intensive care management after surgeries, such as solid organ transplants, cardiothoracic, or intra-abdominal procedures. The bed configuration was a mixture of single-bed rooms and three to four patient open pods.

Unit B was a trauma ICU consisting of a 20-bed unit with an open floor plan, with only two single-bed rooms. Most patients admitted to this unit suffered from trauma or burns injuries. Unit C (neurosurgical ICU) was a 40-bed unit with single rooms. Patients admitted to this unit consisted of traumatic and nontraumatic neurological surgical patients as well as non-neurosurgical patients, such as those who had suffered a stroke. These two units had separate nursing and medical leadership.

CLABSI. The Infection Control Department has had an active prospective CLABSI surveillance process for the past decade, which begins with the daily report of all positive blood cultures within each adult ICU. The infection preventionist assigned to the particular unit then screens each positive culture using a paper-screening tool based on the National Healthcare Safety Network’s definitions (8). These definitions include a positive blood culture with a known pathogen without an obvious source of bacteremia or the presence of an organism considered to be a skin contaminant (i.e., coagulase-negative staphylococci) in two separate blood cultures within a 72-hr period with signs or symptoms of infection (i.e., fever, hypotension). Positive catheter-tip cultures are not part of these definitions. All paper records containing CLABSI and bacteremias are stored in the Infection Control Department for a minimum of 5 yrs. For the purpose of this study and to standardize the observations across time, units, and infection control practitioners, a single reviewer (LSMP) performed a retrospective evaluation of all archived paper-screening tools within the Infection Control Department; the National Healthcare Safety Network’s definitions (8) were also used for this retrospective evaluation. Corrections in the classification of blood cultures (CLABSI vs. secondary bacteremia) were made if necessary.

Secondary bacteremias were used as controls. Monthly central catheter days and ventilator days were obtained from a preexisting Infection Control electronic database (updated monthly by each infection preventionist). Furthermore, monthly case-mix indexes (CMIs) for individual units were provided by the hospital’s Quality and Patient Safety Division.

Time Courses

Time courses were divided in each of the three ICUs into contiguous segments based on the time of initiation of the interventions. Due to its quasi-experimental nature, times of initiation varied in each of the ICUs, and not all ICUs implemented all three interventions. Subsequent phases always incorporated all interventions previously applied.

Baseline (Phase 1)

This phase was comprised of all the initial months of observation before the implementation of “scrub-the-hub.” No new interventions targeting CLABSI were started during this phase. During the baseline phase, the following interventions were already in place and standard across the institution: the use of chlorhexidine-impregnated dressings (Biopatch, Ethicon), chlorhexidine-impregnated (ARROW-Iard, Teleflex; >90% of all catheters used) or minocycline/rifampin-impregnated (Cook Spectrum, Cook Medical) central venous catheters, chlorhexidine skin disinfection at the time of catheter insertion, and Micro-CLAVE neutral intravenous connectors (Hospira). Additionally, an insertion checklist was available in the nursing computerized data entry, but adherence was not quantified during this study. This checklist included full sterile barrier precautions and hand hygiene before catheter insertion, among other infection prevention items.

“Scrub-the-Hub” (Phase 2)

This intervention consisted of a 15-sec scrub of the intravenous ports using a single Chloraprep swabstick (2% w/v chlorhexidine gluconate and 70% v/v isopropyl alcohol, CareFusion, TX) before any intravenous access. Unit A’s nursing staff came up with the idea and implementation of scrub-the-hub in the adult ICUs. The roll out of this intervention included an educational campaign initially targeting nurse educators and selected nursing staff (“train-the-trainers”) followed by education of all staff nurses. Additionally, educational materials regarding technique and rationale for “scrub-the-hub” were distributed among the staff. The supply manager removed all alcohol wipes from storage supplies, omnicells, patient rooms, and nursing stations at the initiation of this intervention and replaced them with packets of single-use chlorhexidine sponges. Thereafter, any procedure previously requiring alcohol wipes, such as insulin injections, were performed using chlorhexidine swabs. This intervention was implemented in all three ICUs. Exact months of implementation were confirmed using purchasing records from the Purchasing Department (Fig. 1).

Daily Chlorhexidine Baths (Phase 3)

Daily body baths were performed using impregnated 2% chlorhexidine cloths (Sage, Cary, IL) rather than the traditional soap-and-water bath. This intervention was initially implemented in unit A in August 2009, and was then launched across all other adult ICUs between the months of September and November 2009. The Purchasing Department was able to provide hospital-wide utilization records of chlorhexidine cloths. The specific months of implementation in units B and C were obtained from electronic communications detailing education, observations, and problems encountered by Infection Control in each of the participating units. As reported elsewhere (9), chlorhexidine cloths were used to scrub the body from the neckline to the toes. Once applied, chlorhexidine was not rinsed off. All products that were potentially noncompatible with chlorhexidine, including soap used previously for patients’ baths, were removed from the nursing stations and storage units. Furthermore, during the first few months after implementation, adequate application technique was directly observed by infection preventionists during night shifts (when most patient baths took place).

Daily Nursing Rounds (Phase 4)

The Associate Nurse Manager or charge nurses conducted daily rounds with bedside nurses for each patient. These rounds covered items from an ICU goal-oriented checklist, which incorporated several infection control measures tailored to decrease hospital-acquired infections. Items targeting CLABSI reduction included the catheter location (limiting the use of femoral sites) and assessment of the necessity for continued central venous catheterization. The Associate Nurse Manager or charge nurses ensured that any goal not being met was brought to the attention of the attending physician or immediately corrected. Additionally, nursing hand-offs were modified to include all the items of the checklist. This intervention was only applied in unit A.

Statistics. CLABSI rates were calculated on a monthly basis (cases per month/central catheter days) and expressed as number of infections/1000 central catheter days. Data were entered on an Excel spreadsheet (Microsoft, Seattle, WA) and included unit, date of admission to the hospital and unit, date of central venous catheter insertion, date of first positive blood culture, and type of organism identified. Monthly CMI, a standardized calculation based on the monthly average weight (as per the Centers of Medicare and Medicaid


The number of monthly CLABSI infection cases was analyzed separately for each unit. SAS PROC GENMOD was used to perform a generalized linear model for an outcome variable with a Poisson distribution. The model included the number of cases as the dependent variable. Independent variables were phase, month nested within phase, and CMI nested within phase. A natural log link function was used, and the natural log of ventilator days was used as an offset to control for variations in observation times. A deviance scale parameter was also used to control for overdispersion. The months were centered within each phase. CLABSI rates and 95% confidence intervals for each phase were estimated from the model parameters and transformed by an inverse link. The CLABSI rates were adjusted for the effect of monthly CMIs. Contrasts were also performed to compare the CLABSI rates between adjacent phases (e.g., phase 1 vs. 2).

A generalized linear model similar to the one used to analyze CLABSI rates was used to explore secondary bacteremias. The outcome variable was secondary infections with independent variables of month (centered) and CMIs. A natural log link was used, and an offset of ventilator days was used. A deviance scale parameter was also used to control for overdispersion. Adjusted rates for CMIs were computed as described above and shown in Figure 1.

Time-to-positive blood cultures were evaluated using SAS PROC LIFETEST to perform a Kaplan-Meier analysis. The data were combined from all units, and the analysis was stratified by phase. Log-rank statistics were used to determine significant differences in times. p values < .05 were defined as statistically significant. All analyses were performed using SAS, version 9.3 (SAS Institute, Cary, NC).

RESULTS

While CLABSI information from units A and B were available from July 2008 onward, information from unit C was available beginning in September 2008. During the 33 months of follow-up, a total of 186 CLABSI were detected (unit A: 98, unit B: 47, unit C: 41) among 42,430 central catheter days (4.38/1,000 central catheter days).
Secondary bloodstream infections were also determined (Supplemental Digital Content 1, [http://links.lww.com/CCM/A393]). A total of 119 secondary bacteremias were identified (unit A: 63, unit B: 36, unit C: 20). Secondary bacteremia rates did not change over time in unit A (\(p = .996\)) and unit B (\(p = .988\)). However, there was a statistically significant decrease in the secondary bloodstream infection rates in unit C (\(p = .028\)).

Discordance between the infection preventionists and the reviewer were found in 24 cases (unit A: 12, unit B: 10, unit C: 2). Twenty-three of these discrepancies corresponded to CLABSIIs (as per reviewer) that were originally labeled by infection preventionists as secondary bacteremias. Interobserver agreement indexes (\(\kappa\)) were calculated for all three units (unit A: 0.85, unit B: 0.76, unit C: 0.9).

CLABSIIs were also analyzed based on the type of organism isolated in blood cultures (Fig. 2 and Supplemental Digital Content 2 [http://links.lww.com/CCM/A394]). Out of 195 organisms identified during the 33 months of follow-up, 93 (48\%) were Gram-positive organisms, 72 (37\%) were Gram-negative rods, and 30 (15\%) were yeasts. The organisms most frequently identified were Enterococcus species (22\%), followed by coagulase-negative staphylococci (15\%) and Candida species (15\%). The change in proportion of isolates of each type of organism is shown in Supplemental Digital Content 2 (http://links.lww.com/CCM/A394).

Table 1. Estimates of central catheter-associated bloodstream infection rates by phases

<table>
<thead>
<tr>
<th>Unit</th>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 1 vs. 2</th>
<th>Phase 3</th>
<th>Phase 2 vs. 3</th>
<th>Phase 4</th>
<th>Phase 3 vs. 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.6 (7.2–10.1)</td>
<td>4.9 (3.8–6.4)</td>
<td>&lt;.001</td>
<td>2.5 (1.8–3.3)</td>
<td>.001</td>
<td>0.5 (0.2–1.5)</td>
<td>.005</td>
</tr>
<tr>
<td>B</td>
<td>6.9 (4.3–11.0)</td>
<td>6.8 (3.7–12.7)</td>
<td>.996</td>
<td>1.6 (0.8–3.2)</td>
<td>.002</td>
<td>Not applicable</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>7.8 (5.5–11.0)</td>
<td>7.8 (5.5–11.0)</td>
<td>0.6 (0.2–1.9)</td>
<td>&lt;.001</td>
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Phase 1, baseline; Phase 2, chlorhexidine “scrub-the-hub”; Phase 3, chlorhexidine “scrub-the-hub” plus daily chlorhexidine baths; Phase 4, chlorhexidine “scrub-the-hub” plus daily chlorhexidine baths plus daily intensive care unit goal sheet nursing rounds. Central catheter-associated bloodstream infection rates per 1000 central catheter days (95\% confidence interval).

Additional, 34 observations of compliance with “scrub-the-hub” were performed across the units over 3 months. We observed 100\% compliance with usage of chlorhexidine swabs for “scrub-the-hub” before accessing any central catheter port. Alcohol swabs were not used by healthcare providers in any of the observations. Even though the recommended scrubbing time was 15 secs, the median duration of scrubbing during our observations was 9 secs per access observed (interquartile range 5–10). In regards to side effects, one patient in unit C experienced skin irritation and redness thought to be secondary to chlorhexidine baths, which warranted their discontinuation in this individual patient.

**DISCUSSION**

We report the sequential implementation of interventions aimed at decreasing CLABSIIs at three ICUs from a single institution. Chlorhexidine “scrub-the-hub” was associated with a reduction of CLABSI rates in one (unit A) of two units (A and B) in which it was independently applied whereas following daily chlorhexidine baths there was a further decrease of CLABSI rates in unit A (\(p = .028\)). The respiratory tract was the most frequent source of secondary bacteremia (54\%), followed by intra-abdominal infections (17\%).

Time-to-positive blood cultures (number of days from central catheter insertion to first positive blood culture) was calculated for all CLABSIIs. Kaplan-Meier analysis failed to show a significant difference in time-to-positivity throughout the phases (log-rank \(p = .614\)), although a trend toward an increase in median time was noted: phase 1, 10 days (6–19) (interquartile range); phase 2, 9 days (4–24); phase 3, 14.5 days (6.5–20); and phase 4, 16.5 days (2.5–31.5).

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**DISCUSSION**

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Secondary bacteremias remained constant during the study in two (units A and B) of the three units assessed. Additionally, controlling for CMIs did not impact the CLABSI rates throughout the study. The rates of other HAIs throughout the study were also generally constant. The rate of ventilator-associated pneumonias in unit A decreased during the study, but this coincided with the institution of a pneumonia-prevention bundle and thus was most likely unrelated to the CLABSI interventions. The rate of catheter-associated urinary tract infections did not change over time (data not shown).

Our data suggests that chlorhexidine “scrub-the-hub” and daily patient chlorhexidine baths could have independent and additive benefits in reducing CLABSI rates. Our findings are important for a number of reasons. First, this is the first report of additive effectiveness using these two interventions and may represent the incremental benefit of targeting intraluminal infections from the hub and extraluminal infections from the skin surface. Further, similar to the use of chlorhexidine antisepsis at the catheter insertion site (10), these interventions are aimed at reducing CLABSI rates in the “maintenance” phase and therefore supplement the proven insertion
techniques for reducing CLABSI (6). Finally, the repeated association of CLABSI rate reductions after implementation of these interventions in multiple, independent ICUs within our institution strengthens the likelihood that this result is indeed a result of the intervention.

Contamination of the access port (hub) is a known risk factor for the development of CLABSIs (11). In a study done by Mahieu et al (12), the incidence of CLABSIs among colonized catheter hubs was higher than among those uncolonized (50% vs. 3%). Furthermore, Safdar and Maki (11) reported, in a prospective study, that contamination of the hubs (intraluminal source) was associated with 26% of CLABSIs (nine out of 35), and skin colonization (extraluminal sources) caused 45% of cases. The authors also determined that the treatment group (skin decontamination at the catheter insertion site) resulted in a decreased number and proportion of extraluminal infections while the control group had a relatively higher proportion of intraluminal CLABSIs (11). Despite the recommendation for disinfection of intravenous hubs by the Society for Hospital Epidemiology of America and Infectious Diseases Society of America (13), we believe our report is the first one to show a clinical impact on CLABSI rates by implementing such an intervention, namely, decontaminating the hubs with chlorhexidine swabs before each intravenous access.

Simmons et al (14) have previously evaluated the impact of the duration of “scrub-the-hub” on the bacterial contamination of the hubs. According to their study, scrubbing 3, 10, or 15 sec did not show statistically significant differences in the bacterial loads of the hubs, however, the data demonstrated significantly lower bacterial loads when compared to those hubs not scrubbed.

Chlorhexidine is a long-acting antiseptic aimed at decreasing the bacterial load on patients’ skin and thus diminishing the degree of extraluminal contamination. Several previously published studies showed the effectiveness of this intervention in other patient populations (7, 15, 16, 18, 19). Our positive results in this surgical ICU population are aligned with those other findings (18, 19) and differ from that of Popovich et al (17), who failed to see a benefit in a surgical ICU.

The limitations of the study include its quasi-experimental nature and consequently its lack of standardization. The ICUs started interventions at different times, mainly due to their independent nursing and medical leaderships; in the past, such variables have determined the different adoption times of Infection Control interventions at our institution. Nevertheless, data were gathered from three different ICUs, totaling 80 beds, and the interventions were performed at slightly different times of the year, which might partially control for confounding factors. Furthermore, we were unable to find reliable data regarding the source of blood culture sticks (new stick vs. central catheter hubs), which could have influenced the yield of isolation of skin contaminants. Additionally, there were four different infection preventionists throughout the study (two in unit A, one in unit B, and one in unit C) that evaluated the positive cultures in these three units. Nonetheless, a single reviewer re-examined all positive blood culture assessments performed by the Infection Control Department; however, the latter reviewer was not blinded and thus was subjected to misclassification bias. Survival analyses were unable to find statistically significant differences in time to CLABSI, most likely due to the loss of power throughout the phases (decreased number of CLABSIs over time) and the lack of individualized data on central catheter days among patients who did not develop CLABSIs during their unit admissions.

These limitations notwithstanding, several features of our study strengthen the argument that the association between the interventions reported and reductions in CLABSI rates is indeed due to the effectiveness of these measures in reducing infections in the maintenance phase. First, the reductions in CLABSI rates consistently followed the introduction of the interventions described – despite differential timing of these interventions in different units – arguing against nonspecific seasonal or Hawthorne effects with time. Second, this association is noted in three independent units, which makes chance less likely. Finally, these interventions did not produce nonspecific reductions in other hospital-acquired infections, such as secondary bacteremias (units A and B) or catheter-associated urinary tract infections (data not shown). Thus, our association is suggestive that interventions aimed at reducing CLABSIs during the maintenance phase of central venous catheters can be effective, a result that awaits definitive randomized testing for proof.

American healthcare institutions have entered an era of pay-for-performance, with marked emphasis on prevention of hospital-acquired infections. To reach the goal of zero infections, interventions aimed at infection prevention from
insertion through timely removal of the catheter are required. It stands to reason that bundled interventions encompassing best practices for catheter insertion (checklists, chlorhexidine skin disinfection, insertion cart, full barrier precautions, hand hygiene, location selection) as well as those addressing maintenance (daily chlorhexidine baths and catheter hub disinfection), are necessary to decrease CLABSI. A future study will evaluate the impact of the implementation of a more accountable catheter insertion checklist on our current CLABSI rates; another intervention in our quest for zero infections.

REFERENCES