Eliminating catheter-related bloodstream infections in the intensive care unit*

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LEARNING OBJECTIVES

On completion of this article, the reader should be able to:

1. Identify key elements of the insertion technique that will minimize catheter-related bloodstream infections in the intensive care unit.
2. Describe other interventions that will minimize catheter-related bloodstream infection in the intensive care unit.
3. Describe the application of this knowledge in the clinical environment.

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Objective: **To determine whether a multifaceted systems intervention would eliminate catheter-related bloodstream infections (CR-BSIs).**

Design: **Prospective cohort study in a surgical intensive care unit (ICU) with a concurrent control ICU.**

Setting: **The Johns Hopkins Hospital.**

Patients: **All patients with a central venous catheter in the ICU.**

Intervention: **To eliminate CR-BSIs, a quality improvement team implemented five interventions: educating the staff; creating a catheter insertion cart; asking providers daily whether catheters could be removed; implementing a checklist to ensure adherence to evidence-based guidelines for preventing CR-BSIs; and empowering nurses to stop the catheter insertion procedure if a violation of the guidelines was observed.**

Measurement: **The primary outcome variable was the rate of CR-BSIs per 1,000 catheter days from January 1, 1998, through December 31, 2002. Secondary outcome variables included adherence to evidence-based infection control guidelines during catheter insertion.**

Main Results: **Before the intervention, we found that physicians followed infection control guidelines during 62% of the procedures. During the intervention time period, the CR-BSI rate in the study ICU decreased from 11.3/1,000 catheter days in the first quarter of 1998 to 0/1,000 catheter days in the fourth quarter of 2002. The CR-BSI rate in the control ICU was 5.7/1,000 catheter days in the first quarter of 1998 and 1.6/1,000 catheter days in the fourth quarter of 2002 ($p = .56$). We estimate that these interventions may have prevented 43 CR-BSIs, eight deaths, and $1,945,922 in additional costs per year in the study ICU.**

Conclusions: **Multifaceted interventions that helped to ensure adherence with evidence-based infection control guidelines nearly eliminated CR-BSIs in our surgical ICU. (Crit Care Med 2004; 32:2014–2020)**

KEY WORDS: intensive care units; infection, nosocomial; catheterization, central venous; total quality management; organizational innovation

Catheter-related bloodstream infections (CR-BSIs) are associated with significant morbidity, mortality, and costs (1, 2). Patients in intensive care units (ICUs) are at an increased risk for CR-BSIs because 48% of ICU patients have indwelling central venous catheters, accounting for 15 million central catheter days per year in United States ICUs (1). Assuming an average CR-BSI rate of 5.3 per 1,000 catheter days and an attributable mortality of 18% (0% to 35%), as many as 28,000 ICU patients die of CR-BSIs annually in the United States alone (2–4). Therefore, efforts to decrease the rate of CR-BSIs and to improve the quality of ICU care are paramount.

Although the rates of CR-BSI are high, they are preventable. Numerous interventions have reduced the incidence of CR-BSI and the ensuing morbidity, mortality, and costs (5–8). In addition, the Centers for Disease Control and Prevention (CDC) (www.cdc.gov), the Society of Critical Care Medicine, the Society of Healthcare Epidemiologists of America, the Infectious Disease Society of America, and several other societies have recently developed evidence-graded guidelines for the prevention of catheter-related infections (9). Several of the guideline recommendations are supported by well-done clinical trials or systematic reviews and include the following: appropriate use of hand hygiene; chlorhexidine skin preparation; full-barrier precautions during central venous catheter insertion; subclavian vein placement as the preferred site; and maintaining a sterile field while inserting the catheter (1).

Despite this evidence, a gap exists between best evidence and best practice (10). The aim of this project was to eliminate CR-BSIs in our ICU. To accomplish this aim, we used a quality improvement model that can be broadly applied to other ICUs. We also estimated the number of CR-BSIs that we may have prevented and the potential savings as a result of our improvement.

MATERIALS AND METHODS

Study Setting. The Johns Hopkins Hospital is a 926-bed tertiary care hospital with seven ICUs and medical, surgical, psychiatric, and neurologic services. Two ICUs participated in this project. The intervention surgical ICU (SICU) is a 16-bed surgical ICU that cares for adult patients undergoing general, orthopedic, transplant, trauma, and vascular surgery. The concurrent control ICU is a 15-bed unit that cares for adult patients undergoing cardiac surgery.

Study Design. We designed a prospective cohort study with concurrent controls. Central venous catheters are routinely placed by the anesthesiologists in the operating room or by surgery, anesthesia, and critical care residents in the ICU. The decision to use a single or multilumen catheter was at the discretion of the intraoperative anesthesia or critical care team in the ICU. Both ICUs are a mandatory consult model in which the patient's surgeon remains the attending physician of record and all patients in the ICU are co-managed by an intensivist-led team, including ICU attending physicians and fellows, anesthesia and surgery residents, a pharmacist, and nurses. The intensivist-lead team visits every patient daily in the ICU to review patient information and to develop a care plan for the day. The nurse/patient staffing ratio is 1:1 or 1:2. The patient's primary nurse is routinely present during central catheter insertion in both ICUs. This patient care model did not change during the study period. The management of central venous catheters once they are inserted did not change during the study period, with the exception of the change in daily patient visits in the study SICU to ask whether catheters could be removed. We did not replace or exchange catheters over a guidewire at scheduled time intervals. The decision to replace or exchange catheters over a guidewire if the patient developed evidence of a systemic infection was at the discretion of the critical care team in the ICU. In general, we exchanged catheters over a guidewire if the patient demonstrated evidence of a systemic infection, the catheter malfunctioned, or we changed to a catheter with fewer lumens. If the patient developed significant hemodynamic instability, we generally replaced the catheters, established a new site, and sent the intradermal portion of the old central catheters for culture. The study population included all patients with a percutaneous central venous catheter in the ICU. All percutaneous central venous catheters for intravenous fluid, medication, dialysis, or administration of total parenteral nutrition were included. Our CR-BSI rates do not include tunneled catheter or central arterial catheter infections. The institutional review board at our institution approved the study and waived the need for informed consent.

Measures. The primary outcome variable was the rate of CR-BSIs per 1,000 catheter days. Hospital epidemiology and infection control (HEIC) at our institution defines catheter-related nosocomial bloodstream infections using National Nosocomial Infection Surveillance System (CDC)-based definitions (3). Surveillance is performed prospectively by trained infection control practitioners. Catheter-related infections are attributed to patients who have a central venous catheter and who have been in the ICU for at least 48 hrs. Patients with a central venous catheter who develop a bloodstream infection within 48 hrs of ICU discharge also have a CR-BSI. Secondary outcome variables included adherence to evidence-based infection control practices during central venous catheter insertion. We also interviewed SICU nurses to evaluate their perception of the burden of our intervention. Data were collected from January 1, 1998, through December 31, 2002.

Improvement Model. We created an interdisciplinary team including the SICU codirectors, ICU physicians, nurses, and infection control practitioners to gain visibility and credibility for this initiative. We based these interventions on the conceptual model for adhering to practice guidelines developed by Cabana et al. (11) that seeks to evaluate physician awareness, agreement, and ability to use a guideline. We also used principles from the human factors literature in patient safety to enhance physicians' ability to comply with the CDC guidelines (12). Specifically, we sought to enhance provider awareness, to reduce com-

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***See also p. 2150.**

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plexity, to create independent redundancies, and to empower nurses to enforce adherence to evidence-based infection control practices and to ensure patients receive those therapies that they ought to receive.

Our SICU team's improvement model included five interventions: a) implementing an educational intervention to increase provider awareness of evidence-based infection control practices for inserting and maintaining central catheters; b) creating a catheter insertion cart to make it easier for providers to obtain all of the materials needed to follow CDC guidelines for sterile central venous catheter insertion; c) asking daily whether central venous catheters can be removed; d) implementing a checklist to ensure adherence to evidence-based guidelines for preventing CR-BSIs; and e) empowering nurses to stop the procedure if evidence-based guidelines are not followed.

Intervention 1: Implementing an Educational Intervention to Increase Provider Awareness of Evidence-Based Infection Control Practices (Introduced: February 1999)

Reducing nosocomial infections has been a major focus at our institution. As part of this effort, HEIC adopted nationally recognized definitions for CR-BSIs in January 1998 and provided feedback of CR-BSI rates to all ICUs. In February 1999, HEIC developed, in collaboration with clinicians, and the hospital's Medical Board passed a vascular access device policy based on the CDC guidelines (www.hopkins-heic.org/prevention/vad.html). The procedures detailed in this policy include the standard requirements for training, vascular access device site selection, insertion, site assessment, dressing change requirements, documentation requirements, appropriate flushing procedures, tubing replacement, and central catheter removal and/or replacement requirements. As part of this policy, in October 2000, all physicians or physician extenders who insert central catheters were required to complete a Web-based training module and successfully complete a ten-question test before they were allowed to insert a central venous catheter in our institution. The Web-based training module (www.hopkins-heic.org) was designed to increase provider awareness of evidence-based infection control practices, including appropriate use of hand hygiene, chlorhexidine skin preparation, full-barrier precautions during central venous catheter insertion, subclavian vein placement as the preferred site, maintaining a sterile field while inserting the catheter, and the care of central catheters once inserted. In 2002, proof of completion of the module was required before physician received credentials. In addition, HEIC staff provided 16 lectures for nurses and five for doctors to reinforce these evidence-based practices. CR-BSI rates were posted in the SICU for providers to see. The vascular access device policy was revised in September of 2002 to incorporate changes from the CDC, Society of Critical Care Medicine, Society of Healthcare Epidemiologists of America, and Infectious Disease Society of America prevention of catheter infection guidelines (9).

Intervention 2: Creating a Central Catheter Insertion Cart (Introduced: June 1999)

We identified that a potential barrier to compliance with the evidence-based practices was that physicians in the study SICU had to go to eight different places to collect the equipment needed to comply with the CDC guidelines. We hypothesized that we could improve compliance by decreasing the number of steps required. To test our hypothesis, we created a central catheter insertion cart that contained the equipment and supplies needed and, thereby, reduced the number of steps required for compliance from eight to one. Our central catheter insertion cart has four drawers with partitions to organize the contents, and the cart can be rolled to the patient's room. To ensure that the central catheter cart is stocked at all times, our support associate stocks the cart every 4 hrs from the ICU supply room and signs off on the checklist located on top of the cart. At our institution, support associates are indirect care providers with a high school diploma, or equivalent degree, who assist nursing staff with a variety of environmental, nutritional, clinical, and transportation services.

Intervention 3: Asking Providers Daily Whether Catheters Can Be Removed (Introduced: June 2001)

One of the most effective strategies for preventing CR-BSIs is to eliminate, or at least reduce, exposure to central venous catheters. The decision regarding the need for a catheter is complex and, therefore, difficult to standardize into a practice guideline. Nonetheless, to reduce exposure to central venous catheters, the ICU team in the study ICU asked daily during patient rounds whether any catheters or tubes could be removed. To ensure that this question was asked, we added it to the rounding form, called the daily goals form, which is used to develop daily care plans for patients in our SICU (13, 14).

Intervention 4: Implementing a Checklist to Be Completed by the Bedside Nurse (Introduced: November 2001)

To help ensure compliance with the evidence-based guidelines for central catheter insertion, we developed a standardized checklist to be completed by the bedside nurse during central venous catheter insertion in the study SICU (Appendix). We pilot tested the checklist in the SICU for 1 wk and interviewed ten SICU nurses, using a convenience sample, regarding the clarity of the form, burden of data collection, and the need for modification. Based on this feedback, we modified the form and provided in-services to the study SICU nursing staff.

We then implemented the checklist in two phases. During the first phase, we asked SICU nursing staff for 2 wks to observe the physicians during catheter placement and to complete the checklist for each procedure. Physicians were not aware that they were being observed during the first phase. We audited the percentage of central venous catheter insertions that had the checklist completed. We also interviewed ten SICU nurses who had completed the checklist to evaluate their perceptions of the form, the burden, and the average time to complete the form.

Intervention 5: Empowering Nurses to Stop Procedures if Guidelines Were Not Followed (Introduced: December 2001)

During the second phase, we modified the checklist and asked nursing staff to continue to observe the physician during central venous catheter placement. In this phase, we informed the residents that the checklist was being implemented and we empowered SICU nurses to stop the procedure, except in an emergency, if they observed a violation in compliance with the evidence-based guidelines. The nursing staff indicated if the procedure was stopped on the modified checklist. To decrease the burden of data collection, we did not collect data on the nature of the violation. Finally, we discussed with both residents and nurses that the nurse should page the SICU attending physician if the resident, after the nurse identifies a violation, fails to correct the violation.

Control ICU

The only intervention in the control ICU during the study period was the institutional educational intervention to increase provider awareness of evidence-based infection control practices for inserting and maintaining central catheters.

Analysis and Interpretation

We calculated the rate of adherence to evidence-based practices during a 2-wk observation period when the checklist was implemented and the percent of central venous catheter insertions that required nursing intervention for a violation in compliance for 1 month. The rates of CR-BSIs were calculated by dividing the number of infections identified by a risk-adjusted denominator—1,000 catheter days (3, 15). We obtained the denominators from an administrative database, which was validated by the infection control practitioners. Catheter days are calculated by counting every patient with a central catheter at midnight. Only one catheter per patient is included. We followed the rate of CR-BSIs per 1,000 catheter days from January 1,1998, through December 31, 2002, using a control chart (16). A Poisson regression model with a spline was used to model the change in infection rates over time in the control and intervention groups. A knot was included at the first quarter of 1999, i.e., the point at which the intervention was introduced into the SICU. The regression model included six covariates, allowing the intervention and control groups to each have its own intercepts, slopes before the knot, and slopes after the knot. To assess the effect of the intervention, we tested whether the slopes after the knot were equivalent. The group-specific parameters (e.g., slopes) were compared using Student's *t*-tests, with a two-sided α level of 0.05.

Estimated Savings

Estimates of attributable morbidity, mortality, and costs of care for CR-BSIs vary. To estimate the number of CR-BSIs that we may have prevented and the potential savings as a result of our improvement, we used mean published estimates (ranges): 18% (0% to 35%) mortality and extra costs of $45,254 ($34,508–$56,000) per CR-BSI. These estimates are consistent with those cited by the 2002 Guidelines for the Prevention of Intravascular Catheter-Related Infections (9).

RESULTS

During the 2-wk observation period before we implemented the checklist, nursing completed the checklist for 26 procedures: eight (31%) for new central venous access and 18 (69%) for catheter exchanges over a wire. None of the procedures were emergent. Overall, we found that physicians were compliant in all of the evidence-based infection control guidelines during 62% of the observed procedures (Table 1). The SICU nurses interviewed recommended a few minor changes to improve the clarity of the central catheter insertion checklist.

The SICU leadership then empowered nurses to stop the procedure if they observed a violation in compliance with the evidence-based guidelines. During the first month, nursing completed the checklist for 38 procedures: eight (24%) for new central venous access, 30 (79%) for catheter exchanges over a wire, and three (8%) were emergent. A nursing intervention was required in 32% (12/38) of central venous catheter insertions. All providers interviewed reported that the format of the central catheter insertion checklist was easy to understand and could be completed in <3 mins. The SICU nurses also indicated that they found the form helpful in that they were more comfortable intervening if they observed a violation, because they felt that an expectation had been set and as a result, they were less likely to have an uncomfortable encounter with the physician inserting the central venous catheter.

During the study period, 22,785 patient days and 19,905 catheter days were included in the study SICU. In the control ICU, 21,964 patient days and 17,383 catheter days were included.

The CR-BSI rate in the study ICU was 11.3/1,000 catheter days in the first quarter of 1998 and 0/1,000 catheter days in the fourth quarter of 2002. The CR-BSI rate in the control group was 5.7/1,000 catheter days in the first quarter of 1998 and 1.6/1,000 catheter days in the fourth quarter of 2002. The fitted Poisson regression model is shown in Figure 1. Before quarter 5, the slope in the intervention arm equaled 0.046 ($p = .48$) and the slope in the control arm equaled 0.08 ($p = .41$). There were no significant differences found when comparing the intercepts ($p = .11$) and the slopes before quarter 5 ($p = .80$).

Our improvement in performance was sustained. Between January 2003 and April 2004, there were two CR-BSIs in the study SICU or 0.54/1,000 catheter days, and we have not had a CR-BSI in >9 months. The educational intervention, central catheter insertion cart, daily goals form, and checklist are now routinely used in our SICU. As a result of this improvement, we estimate that in our SICU alone, we may have prevented up to 43 CR-BSIs, eight (0–15) deaths, and $1,945,922 ($1,483,844–$2,408,000) in additional costs per year.

Table 1. Baseline surgical intensive care unit compliance with evidence-based infection control guidelines

Guideline	n (%)
Cleaned hands	16 (62)
Sterilized procedure site	26 (100)
Draped patient in sterile fashion	22 (85)
Used hat, mask, and sterile gown	24 (92)
Used sterile gloves	26 (100)
Applied sterile dressing	26 (100)
Compliance with all guidelines	16 (62)

DISCUSSION

In many healthcare settings, evidence-based clinical practice guidelines have been developed but bridging the gap between best evidence and best practice has been a struggle (11). In our SICU, we used five simple and inexpensive interventions to increase compliance with evidence-based infection control practices and dramatically decreased the rate of CR-BSIs in our SICU, whereas the rates in a control ICU were unchanged. Our improvements likely translate into significant reductions in patient morbidity, mortality, and costs of care in our SICU.

There is debate whether CR-BSIs can be eliminated or whether ICUs should strive to achieve a benchmark, such as the National Nosocomial Infections Surveillance 50th percentile for similar patient populations. Although we, and others, believed that zero CR-BSIs should be the goal, we were unsure if we could achieve that performance. In this study, we demonstrated that it is possible to nearly eliminate CR-BSIs; therefore, we should not accept National Nosocomial Infections Surveillance mean values as a measure of success, but rather, we should shift our focus on zero harm. Given the significant morbidity, mortality, and costs associated the CR-BSIs, broad application of this intervention may improve clinical and economic outcomes for hospitalized patients.

There were several important lessons from this initiative that can be incorporated into future efforts to improve ICU care. First, we reduced our rate of CR-BSIs using relatively simple and inexpensive interventions, as opposed to implementing more expensive interventions, such as antibiotic/antiseptic catheters. For interventions to work in the busy world of clinical practice, they should be simple to implement. By changing systems rather than exhorting providers to

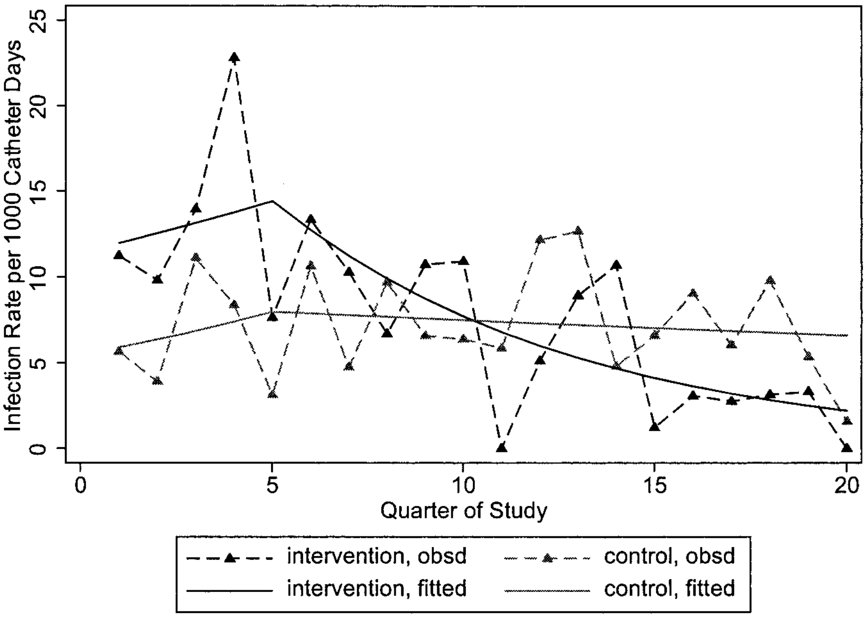

Figure 1. Catheter-related bloodstream infection rates in the surgical intensive care unit (ICU) and control ICU (1998–2002). The rate of catheter-related bloodstream infections per 1,000 catheter days observed in the intervention (*intervention, obsd*) and control (*control, obsd*) groups. A Poisson regression model with a spline was used to model the change in infection rates over time in the intervention (*intervention, fitted*) and control (*control, fitted*) groups. There were no significant differences found when comparing the intercepts ($p = .11$) and the slopes before the knot at quarter 5 ($p = .80$). After quarter 5, the slope in the intervention arm equaled -0.12 ($p < .001$) and the slope in the control arm equaled -0.013 ($p = .56$). *VAD*, vascular access device; *obsd*, observed.

comply with guidelines, we can help ensure that patients receive effective therapies. For example, it was difficult to write a detailed guideline regarding the need for a central venous catheter; there are too many decisions to account for. It is unlikely that detailed guidelines would be practical for complex decisions, such as ICU admission and discharge, extubation, and use of catheters (17). Rather, we simply asked physicians to consider daily whether central catheters could be removed, highlighting the risk of catheters yet allowing physicians to use their clinical judgment.

Second, because each step in a process has an independent probability of failure, care processes that require more steps are more likely to fail than processes that require fewer steps (12). As a result, efforts to improve safety whether in health care or other industries focus on reducing or eliminating steps in a process (18). We found that providers had to go to eight different places within our SICU to gather the supplies needed to comply with the evidence-based infection control practices. As a result, providers often omitted steps, especially when busy. By introducing a central catheter cart, we reduced the complexity by decreasing the number of steps in the process. Given the complexity of ICU care, this concept has broad applicability.

Third, creating independent redundancies, through the use of a checklist, is an effective technique to ensure that patients receive the care processes they should receive. Checklists are used extensively in aviation (18) to create independent redundancies for key steps in a process. With the central catheter insertion checklist, nurses serve as an independent, redundant check to help ensure physician adherence. When the improvement team first introduced the CR-BSI checklist, staff expressed concern. Barriers identified included the following: a) the nurses perception that their job was not to police residents; and b) the residents perception that credibility and authority would be challenged if they were critiqued or corrected by nursing staff. The SICU leadership met with both groups of providers and emphasized our focus on patient safety and teamwork. When presented in this light, residents and nurses understood that they need to work together to ensure patient safety. In addition, HEIC required leaders from hospital administration to support the initiative and provide the SICU with the additional resources required.

Fourth, we must have a culture that supports patient safety. Although efforts to improve interpersonal communication have resulted in improved aviation safety (18, 19), health care lags behind where the culture is still hierarchical (20). Although we did not formally train staff in interpersonal or communication skills, successful implementation of the checklist requires these skills and provides a means to learn teamwork skills experientially. We are observing that the teamwork skills developed through the use of the checklist are spilling over to other areas. In addition, our results highlight the importance of collaboration between hospital level services, such as HEIC, and ICU clinical services.

We recognize several limitations of our study. First, the pre- and post-study design may not have accounted for other confounding factors that may have decreased our CR-BSI rate, independent of our interventions. For example, we did not collect standardized measures of patient acuity to allow comparison of patient severity of illness or patient demographic characteristics over time or to determine whether patients in the study ICU were sicker than patients in the control ICU. The members of our improvement team, which include the SICU codirectors and active SICU nursing staff, are not aware of other changes in practice or changes in our surgical patient population during the study period. In the absence of a new patient product-line, risk adjusted severity of illness tends to change little over time (21) and, therefore, is unlikely to jeopardize the validity of our results.

Second, we do not know the nurses' rate of adherence with completing the checklist following the observation period. Our ICUs do not routinely collect data for the number of central venous catheter insertions or the number of guidewire exchanges. Nonetheless, on average nurses complete 20–30 checklists every 2 wks and there is a relatively constant 15% to 25% violation rate in our SICU, likely reflecting the fact that our residents rotate through our ICU. In addition, we did not collect data about the nature of infection control practice violations following the observation period, whether the catheter was inserted in the operating room or ICU, the duration of catheterization, or antibiotic use during the study period. Although this informa-

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tion would be helpful in guiding future improvement efforts, we accomplished the goal: reducing the CR-BSI rate. Furthermore, the ongoing need for reinforcement of best practice is supported by these findings.

Third, we did not evaluate other evidence-based interventions for reducing CR-BSIs. For example, we discussed the use of antimicrobial-coated catheters and decided to first ensure that we were compliant with simple and inexpensive interventions known to reduce CR-BSI rates before escalating to more expensive interventions. Our strategy is consistent with current guidelines that recommend antimicrobial-coated catheters in adults when the CR-BSI rate remains above the goal set by the individual institution based on benchmark rates after standard procedures have been implemented and then balanced against the concern for emergence of resistant pathogens (9). In addition, some of our interventions may have been more effective than others, and we may have been able to achieve our results without all five interventions or if we implemented the interventions in a different sequence.

Fourth, we evaluated interventions in a surgical ICU at an academic medical center, potentially limiting the ability to generalize. Nonetheless, our interventions were effective and were not burdensome or expensive and, therefore, can be widely applied. Although we did not quantify the impact of our interventions on nursing time in our ICU, the overwhelming impression among nursing staff and the nurse manager (KE) is that the ongoing burden is minimal and the checklist can be completed in <2 mins. In fact, several ICU nurses indicated that the central catheter cart saved them time because they did not have to go to multiple locations to gather supplies. In addition, these interventions have been subsequently implemented in the control ICU with similar results and at other institutions as part of collaborative projects sponsored by VHA, Inc., and the Institute for Healthcare Improvement.

Finally, we assumed that each patient has only one central catheter, and as a result, we may have underestimated our CR-BSI rate, the number of CR-BSIs prevented, and the potential savings. For example, a patient may have two or more central catheters on a single day but would be counted as having one catheter day. In addition, we were not able to account for patients who developed more than one CR-BSI in our statistical analysis. However, the rate of autocorrelation among patients was low (113 patients developed 126 CR-BSIs in the study ICU, and 140 patients developed 167 CR-BSIs in the control ICU) and, therefore, would not be expected to impact upon our results (16). In addition, we do not have the patient level data required to exclude duplicate patients from the denominator (catheter days). Nevertheless, we re-ran our analysis excluding duplicate CR-BSIs from the numerator, and the statistical inference was unchanged.

CONCLUSIONS

Catheter-related bloodstream infections are a preventable cause of morbidity and mortality in critically ill patients. Although debate continues about the extent to which CR-BSIs are preventable, our study demonstrates that they can be nearly eliminated. Our improvement model combined traditional infection control strategies with improvement models designed to ensure provider adherence with evidence-based guidelines. We included interventions that enhanced provider awareness, reduced complexity, created independent redundancies, and empowered nurses to enforce adherence to evidence-based infection control practices to nearly eliminate CR-BSIs in our SICU. These interventions can be implemented in other ICUs and in many acute care sites to reduce nosocomial complications, length of stay, and costs of hospital care.

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APPENDIX 1: Central Line Insertion Checklist

Catheter-related Blood Stream Infection
Care Team Checklist

Purpose: To work as a team to decrease patient harm from catheter-related blood stream infections
When: During **all** central venous or central arterial line insertions or re-wires
By whom: Bedside nurse

1. Today's date ______ / ______ / ________ (month / day / year)

2. Procedure: ☐ New line ☐ Rewire

3. Is the procedure: ☐ Elective ☐ Emergent

4.

	Yes	No	Don't know
Before the procedure, did the housestaff:			
Wash hands (chlorhexidine or soap) immediately prior	☐	☐	☐
Sterilize procedure site	☐	☐	☐
Drape entire patient in a sterile fashion	☐	☐	☐
During the procedure, did the housestaff:			
Use sterile gloves	☐	☐	☐
Use hat, mask and sterile gown	☐	☐	☐
Maintain a sterile field	☐	☐	☐
Did all personnel assisting with procedure follow the above precautions	☐	☐	☐
After the procedure:			
Was a sterile dressing applied to the site	☐	☐	☐

Please return completed form to the designated location in your ICU.