The Effect of an Education Program on the Incidence of Central Venous Catheter-Associated Bloodstream Infection in a Medical ICU*

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Objective: To determine whether an education initiative could decrease the rate of catheter-associated bloodstream infection.

Design: Preintervention and postintervention observational study.

Setting: The 19-bed medical ICU in a 1,400-bed university-affiliated urban teaching hospital.

Patients: Between January 2000 and December 2003, all patients admitted to the medical ICU were surveyed prospectively for the development of catheter-associated bloodstream infection.

Intervention: A mandatory education program directed toward ICU nurses and physicians was developed by a multidisciplinary task force to highlight correct practices for the prevention of catheter-associated bloodstream infection. The program consisted of a 10-page self-study module on risk factors and practice modifications involved in catheter-related bloodstream infections and in-services at scheduled staff meetings. Each participant was required to complete a pretest before reviewing the study module and an identical test after completion of the study module. Fact sheets and posters reinforcing the information in the study module were also posted throughout the ICU.

Measurements and main results: Seventy-four episodes of catheter-associated bloodstream infection occurred in 7,879 catheter-days (9.4 per 1,000 catheter-days) in the 24 months before the introduction of the education program. Following implementation of the intervention, the rate of catheter-associated bloodstream infection decreased to 41 episodes in 7,455 catheter-days (5.5 per 1,000 catheter-days) \(p = 0.019\). The estimated cost savings secondary to the decreased rate of catheter-associated bloodstream infection for the 24 months following introduction of the education program was between $103,500 and $1,573,000.

Conclusions: An intervention focused on the education of health-care providers on the prevention of catheter-associated bloodstream infections may lead to a dramatic decrease in the incidence of bloodstream infections. Education programs may lead to a substantial decrease in medical-care costs and patient morbidity attributed to central venous catheterization when implemented as part of mandatory training.

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Key words: bacteremia; catheter-associated; hospital; infection; outcomes

Abbreviation: CDC = Centers for Disease Control and Prevention

Central venous catheters are commonly employed in the management of critically ill patients. Primary bloodstream infections resulting from central venous catheterization are a common cause of excess morbidity, mortality, and medical-care costs in the ICU setting. The National Nosocomial Infections Surveillance system for the Centers for Disease Control and Prevention (CDC) reports a catheter-associated bloodstream infection rate of 5.7 per 1,000 catheter-days.

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per 1,000 catheter days.\textsuperscript{8} Mortality attributable to catheter-associated bloodstream infections has been estimated to be as high as 35%, and length of hospital stay is consistently increased in published reports among infected patients.\textsuperscript{4,9–16} The excess hospital costs associated with an episode of catheter-associated bloodstream infections has been estimated to range from $3,700 to $56,167.\textsuperscript{4,13,15}

Although the optimal approach to reducing hospital-associated infections is unclear, several recent studies\textsuperscript{8,15} indicate that educating health-care workers on evidence-based approaches for the prevention of these infections can decrease their rates. The CDC recommends the utilization of health-care worker education as an important element in programs aimed at the prevention of hospital-acquired infections.\textsuperscript{19} Successful education-based interventions for bloodstream infections have focused on community hospitals, teaching hospitals, and physicians-in-training.\textsuperscript{8,15} Therefore, we carried out a clinical investigation to determine whether an education program could decrease the rate of catheter-associated bloodstream infection in the medical ICU of a teaching hospital.

\section*{Materials and Methods}

\subsection*{Study Location and Patients}

This study was conducted in a medical ICU at a university-affiliated, urban teaching hospital: Barnes-Jewish Hospital (1,400 beds). The medical ICU (10 beds) is a closed unit with a multidisciplinary team providing patient care under the direction of attending physicians who are board certified in critical care medicine. Nurse staffing is maintained at a ratio of two patients per nurse, and central venous catheters are usually inserted by resident physicians. During a 4-year period (January 2000 to December 2003), all patients admitted to the medical ICU were prospectively followed up by members of the hospital infection control team and surveyed for the occurrence of central venous catheter-associated bloodstream infection. The intravenous catheters (eg, central venous catheters, dialysis catheters, pulmonary artery catheters) employed throughout the hospital during this study period were standard catheters without antimicrobial or antiseptic coatings. Arterial catheters were not surveyed as part of this investigation. This study was approved by the Washington University School of Medicine Human Subjects Committee.

\subsection*{Changes in ICU Policies During the Study Period}

Patient-care policies and protocols in the medical ICUs remained unchanged during the study period except for the prevention of ventilator-associated pneumonia. A new policy for the prevention of ventilator-associated pneumonia was introduced in October 2000 and maintained throughout the duration of the study.\textsuperscript{17}

\subsection*{Study Design and Data Collection}

A prospective cohort study design was employed with the main outcome measure being central venous catheter-associated bloodstream infection. The education program (described subsequently) was developed by a multidisciplinary task force in 1998 by infection control practitioners representing nine hospitals in the Barnes-Jewish-Christian Health System.\textsuperscript{7} The local plan for implementation of this education program was developed during monthly meetings of the medical ICU infection control committee beginning in July 2001. The medical ICU committee was made up of the unit infection control nurses (J.E.Z., J.L.M.), the medical directors of the hospital infection control group (Y.J.F., D.K.W.), physician representation from the unit (M.H.K., A.C.), the unit clinical nurse specialist (D.P.), and members of the nursing staff. The 2000 and 2001 calendar years served as the baseline period for the incidence of catheter-associated bloodstream infection. For all study patients, the following data were prospectively recorded by one of the investigators: occurrence of primary bacteremia, the number of catheter days prior to the onset of bacteremia, the presence of a femoral catheter, and the species of microorganism associated with bloodstream infection.

\section*{Definitions}

Bloodstream infections were classified as primary or secondary based on CDC National Nosocomial Infections Surveillance definitions.\textsuperscript{20} Primary bloodstream infection (bacteremia) was defined employing either of the following two criteria: (1) isolation of a recognized pathogen from blood culture (\textit{Staphylococcus aureus}, Enterococcus species, Candida species) not related to infection at another site; and (2) fever $\geq$ 38.0°C, chills, or hypotension, and either of the following: common skin contaminant (eg, diphtheroids, Bacillus species, Propionibacterium species, Craigiea-negative staphylococci, or micrococci) isolated from two blood cultures drawn on separate occasions, within 24 h, unrelated to infection at another site; or common skin contaminant isolated from a blood culture from a patient with an intravascular device and the physician institutes appropriate antimicrobial therapy.

Catheter-associated bloodstream infection was defined as primary bacteremia in the presence of a central venous catheter. Secondary bacteremia was defined as bloodstream infection that develops as a result of a documented infection with the same microorganism at another body site.

\section*{Intervention/Education Program}

The monthly ICU infection control meetings between July 2001 and December 2001 were aimed at accomplishing the following objectives: to educate the leadership of the unit on the problem of catheter-associated bloodstream infection, to review in detail the optimal practices for catheter insertion and maintenance in the unit, to describe the components of the education program and their local implementation, to foster team building, to develop a strategy for the education of resident and attending physicians, and to have a feedback mechanism for potential problems encountered during the implementation phase of the study. Additional meetings were held by members of the ICU infection control committee to revise the policies and procedures for central venous catheter insertion and site maintenance. Flow charts for all aspects of care related to central venous catheters were developed and approved by the ICU infection control committee.

The education program was implemented in January of 2002 consisting of 45-min lectures, posters, and fact sheets distributed at each patient computer terminal located directly outside of the patient room, and the administration of the education module. The education module was administered to all nurses working in the medical ICU by the end of January 2002. Newly hired nurses
during the study period were required to complete the education module as part of their job orientation. Physicians (interns, residents, fellows, attending physicians) completed the module during the first 3 days of their ICU rotation. The tests and self-study modules were based on the guidelines of the Hospital Infection Control Practices Advisory Committee published in 1996 and updated in 2002.\textsuperscript{11,12} The 10-page self-study module was reviewed after completing a 20-question pretest; the same questions were answered as a posttest at the end of the module for reinforcement of the topic and group discussion. An individual score of 85\% correct was required on the posttest; otherwise, the self-study module and posttest were repeated until a passing score was achieved. Topics covered in the pretest, posttest, and self-study module included the epidemiology of catheter-associated bloodstream infection, aseptic technique, the use of maximal barrier precautions during central vein catheter insertion, the preference for the subclavian vein as a central vein insertion site, routine central vein catheter care, proper technique for obtaining blood cultures, and guidelines for changing IV tubing and the administration sets (Tables 1, 2).

In addition to the education program, a promotional campaign was launched to achieve success with the educational program beginning in January 2002. This campaign involved regular administration of lapel buttons to a staff member promoting the education program, fact sheets, and posters displayed throughout the ICU describing the program, and photographic guidelines available at each bedside computer station illustrating the correct procedure for the insertion of central venous catheters and their subsequent maintenance to include dressing of the insertion site. Additionally, a monthly update of the catheter-associated bloodstream infection rates was posted in the ICU in multiple locations for purposes of feedback to the unit staff. This was presented graphically similar to Figure 1 as the monthly data became available.

Table 1—Major Sections of the Self-Study Module for the Prevention of Catheter-Associated Bacteremia

<table>
<thead>
<tr>
<th>Section</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>I. Goal of the self-study module: To provide information and prevention strategies for catheter-associated bloodstream infection.</td>
<td></td>
</tr>
<tr>
<td>II. What are the risk factors? (Includes discussion of the following): 1. Prolonged hospitalization: before central vein catheter insertion. 2. Prolonged duration of catheterization. 3. Heavy growth of bacteria at the insertion site and the catheter hub. 4. Catheters inserted in the femoral vein and internal jugular vein.</td>
<td></td>
</tr>
<tr>
<td>IV. How do you define catheter-associated bloodstream infection? 1. Presence of vascular catheter within the last 48 h. 2. Must meet one of the following: a. Recognized pathogen isolated from blood culture and pathogen not related to infection at another site. b. Temperature at least 38.0°C (100.4°F) or hypotension, and common skin contaminant* isolated from two blood culture samples drawn on separate occasions, within 24 h, and organism is not related to infection at another site.</td>
<td></td>
</tr>
<tr>
<td>V. How do I decrease the risk of catheter-associated bloodstream infection? (See Table 2).</td>
<td></td>
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</table>

*Common skin contaminants include coagulase-negative staphylococci, Corynebacterium (diphtheroids), Bacillus species, Micrococcus, Propionibacterium species.

Table 2—Hospital Policy for the Prevention of Catheter-Associated Bloodstream Infection Described in the Study Module and Presented in the Preintervention and Postintervention Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Description</th>
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<tbody>
<tr>
<td>1. Wash hands thoroughly or use an alcohol-based waterless disinfectant before and after patient contact.</td>
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<tr>
<td>2. Disinfect hands and wear sterile gloves when touching or changing the dressing on the catheter.</td>
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<tr>
<td>3. Femoral catheters should be avoided. When placed in an emergency situation, the femoral catheter should be discontinued as soon as feasible.</td>
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<tr>
<td>4. The person placing the catheter must wear sterile gown, sterile gloves, a mask, and a cap.</td>
<td></td>
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<tr>
<td>5. Excessive hair around insertion site can be removed with scissors or clippers only.</td>
<td></td>
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<tr>
<td>6. The insertion site and area of at least 15 cm in diameter around the site shall be cleansed with the appropriate skin antiseptic.</td>
<td></td>
</tr>
<tr>
<td>7. Drape the insertion site using a sterile drape.</td>
<td></td>
</tr>
<tr>
<td>8. Use sterile technique to apply transparent dressing to insertion site.</td>
<td></td>
</tr>
<tr>
<td>9. Do not apply antimicrobial ointment to the insertion site unless the central venous catheter is a dialysis catheter.</td>
<td></td>
</tr>
<tr>
<td>10. Avoid changing catheters over a guide wire.</td>
<td></td>
</tr>
<tr>
<td>11. Change transparent membrane dressing no more than every 7 d or when dressing becomes damp, loosened, or soiled.</td>
<td></td>
</tr>
<tr>
<td>12. Follow hospital protocol for changing IV fluid administration sets and cleaning of injection ports with appropriate antiseptic prior to accessing.</td>
<td></td>
</tr>
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Blood Culture Technique

Blood samples were obtained from two peripheral sites by nurses and hospital-trained phlebotomists. Before collecting the blood sample, the skin was disinfected with 70\% isopropyl alcohol followed by 2\% iodine tincture. The antecubital fossa was the preferred sampling site using a sterile needle and syringe. When only one peripheral site was available and the patient had a central vein catheter in place, the second blood culture sample was obtained from the central vein catheter.\textsuperscript{23} The blood samples from central vein catheters were obtained from needless caps that were disinfected with 70\% isopropyl alcohol, allowed to dry, and wiped with a povidone-iodine pad for 30 s. The excess povidone-iodine was wiped off with sterile gauze prior to obtaining the sample. Three milliliters of blood were aspirated and discarded from both the central vein catheter and peripheral venipuncture. A new syringe was used to aspirate an additional 20 mL of blood. A blood volume of 10 mL was injected into each of two blood culture bottles. Injection of ≤ 5 mL of blood into a blood culture bottle was not permitted to avoid false-negative results.\textsuperscript{24} All blood samples were inoculated into aerobic media and processed using the BacT/ALERT Blood Culture system (Becton Dickinson; Sparks, MD).
Catheter-Associated Bloodstream Infections

![Graph showing monthly rate per 1,000 catheter-days of catheter-associated bloodstream infection from January 2000 through December 2003. The mean catheter-associated bloodstream infection rate for the baseline period (2000) and 2001) and the time period following introduction of the education program (2002 and 2003) are shown (broken line).]

**Figure 1.** Monthly rate per 1,000 catheter-days of catheter-associated bloodstream infection from January 2000 through December 2003. The mean catheter-associated bloodstream infection rate for the baseline period (2000) and 2001) and the time period following introduction of the education program (2002 and 2003) are shown (broken line).

**Cost Analysis**

Numerous studies have attempted to quantify the cost of catheter-associated bloodstream infection. The lowest of these estimates published in the last 12 years comes from Amow et al., who estimated the cost to be $3,700 per infection using 1991 dollars, examining central venous catheters, arterial lines, and peripheral IV catheters in both floor and ICU patients. More recent analyses with cost data using 1994 and 1998 dollars published in the past 5 years in ICU patients have calculated a cost of $56,167 and $45,999 per episode of infection.

**Statistical Analysis**

Statistical analysis was performed by using SPSS for Windows (Version 10.0; SPSS; Chicago, IL). A Fisher Exact Test and χ² test were used for comparing categorical variables where appropriate. Wilcoxon rank-sum test was performed for comparison of the monthly rates of catheter-associated bloodstream infection in the preintervention period to the postintervention period; p < 0.05 was considered significant on two-tailed testing. The incidence rate of catheter-associated bloodstream infection per 1,000 catheter-days was calculated, and a risk difference of catheter-associated bloodstream infection in the postintervention periods vs the preintervention period was determined with 95% confidence intervals.

**RESULTS**

During the 24-month preintervention period (calendar years 2000 and 2001), a total of 74 episodes of catheter-associated bloodstream infection occurred during a total of 7,876 central vein catheter-days. This calculated to an infection rate of 9.4 per 1,000 catheter-days. During the postintervention period (calendar years 2002 and 2003), a total of 41 episodes of catheter-associated bloodstream infections were recorded of a total of 7,455 central vein catheter-days. This is equivalent to an infection rate of 5.5 per 1,000 catheter-days and represents a decrease of 41.5% (p = 0.019) compared with the preintervention period (Fig 1). The difference in catheter-associated bloodstream infection rates between the preintervention period and the postintervention period was 3.9 per 1000 catheter-days (95% confidence interval, 1.2 per 1,000 catheter-days to 6.6 per 1,000 catheter-days). The monthly percentage of central venous catheters placed in the femoral position statistically decreased between the preintervention period and the postintervention period (26.3 ± 5.8% vs 20.4 ± 6.6%, p = 0.002 [mean ± SD]).

The most common bacteria identified in both the preintervention and postintervention periods was coagulase-negative staphylococci (Table 3). The actual number of isolates decreased from 83 to 41, with a decrease in the percentage of fungal isolates and an increase in the percentage of Gram-negative bacterial isolates during the postintervention period.
Table 3—Microorganisms Isolated From Patients With Catheter-Associated Bloodstream Infection*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Preintervention, % (n = 83)</th>
<th>Postintervention, % (n = 41)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gram-positive bacteria</td>
<td>61 (73.5)</td>
<td>31 (75.6)</td>
</tr>
<tr>
<td>(p = 0.80)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coagulase-negative staphylococci</td>
<td>23</td>
<td>13</td>
</tr>
<tr>
<td>Vancomycin-resistant enterococci</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>Vancomycin-sensitive enterococci</td>
<td>18</td>
<td>2</td>
</tr>
<tr>
<td>Methicillin-resistant S. aureus</td>
<td>4</td>
<td>0</td>
</tr>
<tr>
<td>Methicillin-sensitive S. aureus</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Other</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Gram-negative bacteria</td>
<td>3 (3.6)</td>
<td>4 (9.8)</td>
</tr>
<tr>
<td>(p = 0.16)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yeast (p = 0.28)</td>
<td>19 (22.9)</td>
<td>6 (14.6)</td>
</tr>
<tr>
<td>Candida albicans</td>
<td>14</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>5</td>
<td>0</td>
</tr>
</tbody>
</table>

*Data are presented as No. (%) or %.

pared to the preintervention period (Table 3). The number of patients with multiple microorganisms isolated from blood cultures also decreased from nine to zero.

Cost Analysis

Assuming a continued infection rate of 9.4 per 1,000 catheter-days (the preintervention rate), 69 infections would have been expected to occur in the 7,455 catheter-days in the 24 months after the intervention. Multiplying the 28 infections prevented (69 expected vs 41 actual) by the range of published hospital costs attributable to a catheter-associated bloodstream infection, the calculated cost savings in the postintervention period were between $103,600 and $1,573,000.

DISCUSSION

Our study demonstrated that an education program directed at nurses and physicians working in the medical ICU setting may significantly reduce the incidence of catheter-associated bloodstream infection. The observed 41.5% decrease in the rate of bloodstream infection from 9.4 per 1,000 catheter-days to 5.5 per 1,000 catheter-days was associated with an estimated cost savings of between $103,600 and $1,573,000. This study demonstrates that an education-based intervention aimed at optimizing the process of care related to central venous catheters could be successfully implemented in a teaching hospital, where the majority of the central venous catheters are placed by physicians-in-training.

Our results support the findings of previous studies demonstrating significant reductions in the occurrence of hospital-associated infections with the implementation of education-based interventions. Coopersmith et al. achieved a 66% reduction in the incidence of catheter-associated bloodstream infection in the surgical ICU of their hospital. Similarly, Warren et al. applied a nearly identical program within two ICUs of a community hospital. Despite the hospital-wide use of antimicrobial-coated catheters, they found that catheter-associated bloodstream infections decreased from 4.9 per 1,000 catheter-days to 2.1 per 1,000 catheter-days, representing a 57.1% reduction in the occurrence of infection. These results support the recommendations of the 2002 Hospital Infection Control Practices Advisory Committee to use a comprehensive educational approach to improve the process of central venous catheter insertion and maintenance as an initial step to prevent infections, before the use of antimicrobial-coated catheters. Sherritz et al. also provided a 1-day course on infection control practices to medical students and physicians completing their first postgraduate year. This course, encompassing a number of hands-on training stations, reduced the rate of catheter-associated bloodstream infections by 29%.

The infection control group at Barnes-Jewish Hospital has demonstrated the benefits of education-based programs on the reduction of other hospital-associated infections. An education program focused on the prevention of ventilator-associated pneumonia was associated with a 57.6% decrease in infections in five ICUs. Use of the same education program in a pediatric hospital and a community hospital was subsequently shown to have similar results. An education program aimed at encouraging the use of protective gowns and gloves prior to patient contact, for individuals with vancomycin-resistant enterococci colonization, was associated with a 53.6% reduction in patient colonization. An important common element of these education programs was the wide exposure of the education intervention to the appropriate staff caring for patients in the ICU setting. For example, the education programs focusing on the prevention of catheter-associated bloodstream infections were directed at physicians and nurses, while the intervention focused on the prevention of ventilator-associated pneumonia was directed toward nurses and respiratory therapists. This was purposefully done to impact the health-care providers most closely associated with the interventions described in the respective education programs. Taken together, these studies demonstrate that education-based infection
prevention programs can be successfully employed within different hospital settings.

Despite the decreased catheter-related infection rate and cost, a number of limitations are present in this study. First, it was performed within a single ICU and these results may not be applicable to other hospitals. That seems unlikely given the broad successful implementation of similar programs in a variety of hospital settings. Second, in our non-randomized study, the ICU staff was not blinded to either the presence of or the recipients of the education intervention. This raises the possibility of changes in behavior, other than the implementation of the study module that may have accounted for these results. For example, we did not record the duration of central venous catheterization. An unrecognized reduction in the duration of catheterization during the intervention period could account for some of our results. This seems unlikely given the similar number of catheter-days in both study groups. Third, our study design does not allow us to determine which components of the intervention accounted for the greatest reduction in the rate of catheter-associated bloodstream infections. The only specific variable we tracked in this study was the use of the femoral vein for placement of central venous catheters. Fourth, other sources of potential bias may have influenced our results. These would include unrecognized differences in ascertainment or reporting of catheter-associated bloodstream infections between the two study periods.

Another potential limitation of our study was that we did not evaluate outcomes other than bloodstream infection. As a result, we cannot determine whether this intervention influenced antibiotic utilization, length of hospital stay, mortality, or antibiotic-resistance patterns. We also cannot determine from our study design the long-term benefit of this education program. Nevertheless, the reduction in catheter-associated bloodstream infections over 2 years suggests that this intervention will continue to influence the occurrence of these infections in a beneficial manner. However, deterioration in the success of other process improvement interventions over time has been described. Therefore, we will be repeating the entire self-study module at 2-year intervals for administration to nursing staff and attending physician staff, and continue administering it to all new employees. Additionally, our postintervention femoral catheter utilization rate of 20.4% suggests that we have additional opportunity for improvement in catheter-associated bloodstream infection rates by further minimizing the use of the femoral site for venous catheterization. Despite these limitations, the end result of a reduction in the rate of catheter-associated bloodstream infection appears to be either directly or indirectly associated with implementation of this initiative. Therefore, the goal of the process improvement practice was accomplished despite the limitations in our study design and inability to identify the specific interventions accounting for it.

In summary, we have shown that a relatively simple education program may reduce central venous catheter-associated bloodstream infection. Infection rates declined by almost 50%, and potential savings were between $103,600 and $1,573 million during the 2-year intervention period. The consistent impact of education programs on the reduction of nosocomial infections suggests that their implementation should be routine in hospital areas caring for patients at risk for these infections. The importance of implementing education-based infection control programs is increasingly being recognized as a requirement for the optimal functioning of hospital floors and ICUs.

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