THREE YEARS EXPERIENCE IN IMPLEMENTING HICPAC RECOMMENDATIONS FOR THE REDUCTION OF CENTRAL VENOUS CATHETER-RELATED BLOODSTREAM INFECTIONS

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MODIFIED ABSTRACT

Three Years Experience in Implementing HICPAC Recommendations for the Reduction of Central Venous Catheter-Related Bloodstream Infections. Garcia R.*, Jendresky L., Landesman S., Maher A., Nicolas F. Brookdale University Medical Center (BUMC), Brooklyn, NY.

BACKGROUND: An estimated 250,000 Central Venous Catheter (CVC)-Related Bloodstream infections (CR-BSI) occur each year in the United States resulting in extensive mortality, excess length of stay, and cost increases.

OBJECTIVES: To determine the effectiveness of implementing various scientifically supported interventions in reducing the incidence of CR-BSI.

METHODS: Infection Control Professionals (ICPs) conducted surveillance for CR-BSI between Jan 1999-Dec 2002 using definitions published by the Centers for Disease Control and Prevention (CDC). Interventions included the following: Establishment of an education and awareness program, conversion of silver-chlorhexidine (CHG) to silver-platinum catheters, use of a barrier kit containing sterile gloves, gown and mask, and using a 2% CHG-70% alcohol skin prep.

RESULTS: Rate of CR-BSI during Jan-Dec 1999 was 15.0 cases/1000 catheter days (CD) (pre-intervention period; period of use of silver-CHG catheters). Focused education for nurses and physicians during 2000 resulted in a 57.3% reduction in the rate to 6.4 (rates rose in the later 7 months although below 1999 mean rate levels). In Jan `01, conversion to silver-platinum catheters (Jan `01-Sep `01) resulted in a 48.4% reduction from prior mean to 3.3. A slight increase in the rate to 4.2 was observed after requiring the use of maximal sterile barriers (Oct `01-Dec `01). A further decrease to 1.6 (equal to a rate reduction of 61.9% from prior mean) was attained by the use of a 2% CHG-70% isopropyl alcohol skin prep (Jan `02-Mar `03). Overall, the rate of CR-BSI was reduced by 89.3%.

CONCLUSION: Four key interventions resulted in the overall avoidance of 237 CR-BSI cases over 39 months. These interventions are addressed in the 2002 HICPAC guideline on prevention of CR-BSI. Using cited cost per infection figures of $34,508 to $56,000, the annual savings is estimated to range between $2,519,084 to $4,088,000.

BACKGROUND

It is estimated that >150 million intravascular devices are purchased by healthcare facilities each year for the administration of IV fluids, medications, blood products, and parenteral nutrition[1]. One particular device, the central venous catheter (CVC), has become increasingly common (>5 million used per year) due to its flexibility in allowing simultaneous fluid and medication administrations as well as hemodynamic monitoring of critically ill patients. Such devices account for 15 million CVC days in ICUs each year[2]. Despite the extensive medical benefits provided, the use of CVCs is associated with a significant number of BSIs. It is estimated that 75% of all catheter-related bloodstream infections that occur in hospitals are associated with the use of CVCs[3-5]. When non-ICU patients are included, the total number of CR-BSI occurring per year in U.S. hospitals may exceed 250,000[5]. Up to 35% of patients who develop CR-BSI, expire as a result of developing such infections[3].

The need to reduce the occurrence of CR-BSI has become a major issue in both the quality improvement and patient safety arenas. The federal agency responsible for coordinating efforts in research and promotion of patient safety, the Agency for Healthcare Research and Quality (AHRQ) has developed evidence-based safety practices that are applicable to a wide range of healthcare facilities[6]. Working from the premise that a patient safety practice is "…*a type of practice or structure whose application reduces the probability of adverse events resulting from exposure to the health care system across a range of diseases and procedures*", AHRQ reviewed 73 patient safety practices and rated

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BACKGROUND

them based on their potential impact on reducing negative outcomes and strength of scientific evidence. Using maximal sterile barriers and antimicrobial-coated catheters were found to have the greatest strength of evidence at a low cost and complexity of implementation. Although the use of chlorhexidine as a skin antiseptic was rated lower, the cost for implementation was also concluded to be low.

The findings by the AHRQ were subsequently used by the National Quality Forum to create the first set of national voluntary standards for measuring the quality of care provided to patients (the NQF is a non-profit public benefit group created in 1999 as a response to the need to establish a national strategy for healthcare quality measurement and reporting and is supported by more than 170 organizations who represent all sectors of the healthcare industry, including consumers, employers, insurers, healthcare providers, and policy groups). Infections associated with the use of CVCs are included among the first 31 recommended measures to be monitored[7].

OBJECTIVES

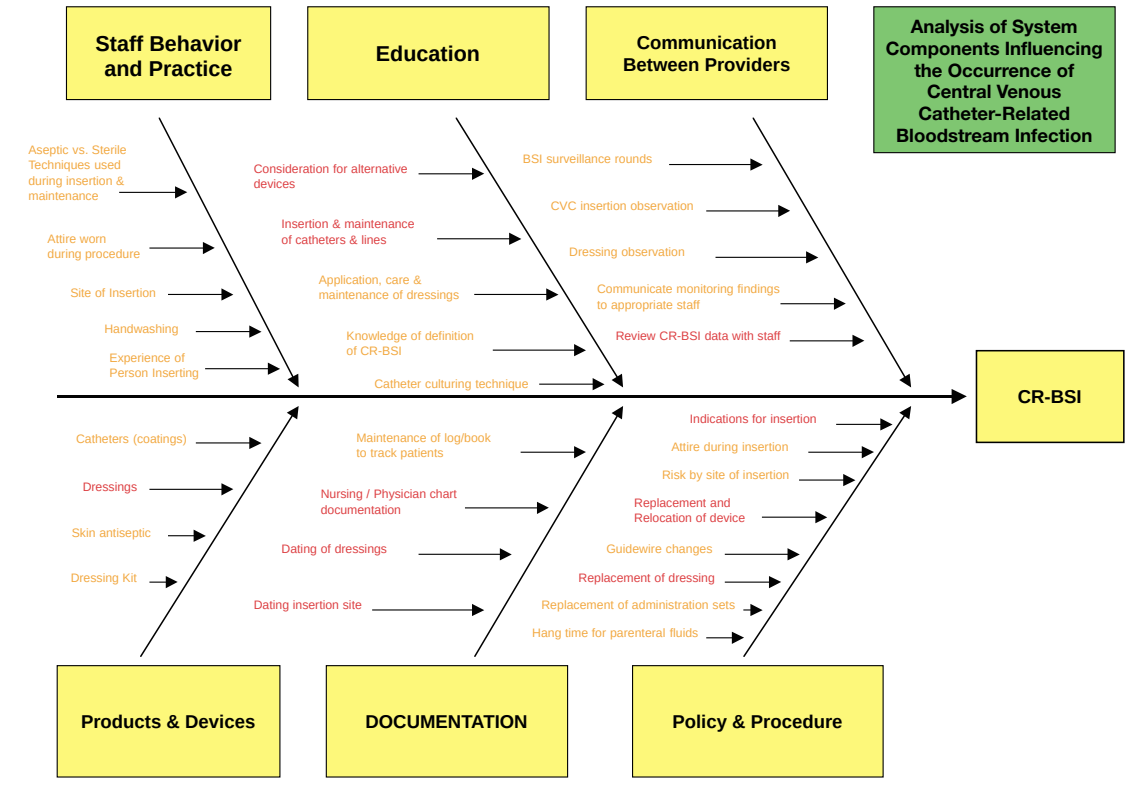
To determine the effectiveness of implementing various scientifically supported interventions in reducing the incidence of CR-BSI. Interventions to be taken were based on information in the medical literature and as contained in the guidelines on the prevention of CR-BSI as published by the CDC[8,9].

METHODS

Nosocomial house-wide bacteremia data which implicated CVCs as the likely source of an increasing number of nosocomial infection cases became the impetus for re-assigning infection control resources to conducting focused surveillance for CR-BSI starting in January 1999. One ICP was assigned to conduct daily surveillance of all adult patients with a CVC insertion in both ICU and non-ICU settings. Data collected included patient name, medical record number, location, date of insertion, date of removal, physician inserting device, blood and central line tip culture results, and information regarding the condition of the site dressing. Patients with CVCs were identified by interviewing nursing and physician staff, by the review of an established documentation form kept on all nursing stations, and by direct observation. Central line tips were collected in an aseptic manner on all patients suspected of a CR-BSI and cultured using the recommended semi-quantitative method. Definition of a CR-BSI was that as published by the CDC[9].

Infection Control organized a series of meetings with key representatives from medicine and surgery, nursing staff from both medical and critical care units, anesthesiology, the emergency room, materials management, and performance improvement. Information needed to identify factors influencing the occurrence of CR-BSI

FIGURE ONE



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METHODS

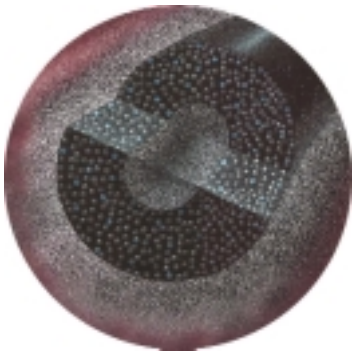
were gathered through this working group, through assessment sessions conducted by ICPs (consisting of interviews of nurses, medical and surgical attendings and residents, and anesthesiology personnel), and via observations conducted during catheter insertion and maintenance procedures. This process, along with other information derived from literature sources, resulted in the development of a VAP fishbone diagram which highlighted the healthcare groups, practices, and devices which impact the outcome of CR-BSI (Fig. 1).

The process was also beneficial in identifying various needs: the need for staff to understand the nature and severity of the problem; a uniform education program for nurses and physicians; a certification process for first-year resident physicians; selection of insertion site to reduce infection risk; standards for aseptic practice during catheter insertion and replacement; standardization of sterile attire and compliance with its use; standardization of skin antisepsis. A master plan was developed by the Infection Control Department (ICD) and subsequently approved by the Infection Committee Control (ICC) and Performance Improvement. At the core of the plan were four key strategies:

Education. Targeted medical residents (92% captured), surgical residents (98%), anesthesiologists (100%), and all nurses involved in the maintenance of the insertion site (89%). Topics covered included the morbidity, mortality, and costs associated with the occurrence of CR-BSI; hospital rates vs. national benchmarks; indications for use of a CVC; risk of infection by insertion site; procedure and timing of handwashing; proper sterile attire to be used during catheter insertion; aseptic techniques during initial catheter insertion and replacement (conducted by an experienced surgical attending); the nature and mechanism of infection prevention when using antimicrobial catheters; proper placement and maintenance of dressings including the recommended regimen for the application of skin antiseptic; review of the revised process for physician certification (first-year residents are required to successfully complete five insertions under supervision prior to solo attempts). Physician education also was conducted during new resident orientation sessions and monthly for residents covering critical care areas. (Implementation: January 2000)

Replacement of Silver-Chlorhexidine CVCs to Catheters Composed of Silver-Platinum Material (Vantex®, Edwards Lifesciences LLC, Irvine, CA). During 1997-1999, all patients requiring CVC access used a silver-chlorhexidine catheter. Significantly high rates observed during 1999 with these catheters resulted in the recommendation of the working group and the ICC to seek alternative antimicrobial devices. A novel antimicrobial catheter combining polyurethane with silver, carbon and platinum was considered (Fig 2). Studies published in the literature appeared to indicate effectiveness in reducing infection (see Discussion section). Cost of the insertion kit with a silver-platinum catheter was approximately 20% less expensive than comparable kits using silver-chlorhexidine catheters. Based on the clinical and financial information, a decision was made to convert to silver-platinum catheters for all adult patients requiring CVC devices. All CVCs during the four years were triple-lumen models. (Implementation: January 2001)

FIGURE TWO



Universal Line Insertion Kits (Tri-State Hospital Supply Corporation, Howell, MI). Observation sessions conducted by ICPs at BUMC revealed that physicians did not uniformly adhere to a policy of wearing of maximal sterile attire during insertion. Physicians were observed either not wearing any gown, did not wear a sterile gown (due to unavailability on specific units), did not wear a mask, and used various items as patient drapes which were inadequate in size and configuration (obtained from the catheter kit or from other supply). A select group of senior medical and surgical residents were gathered in order to solicit information on an ideal kit for use when inserting not only CVCs, but peripherally inserted central catheters (PICCs), arterial, and swan-ganz lines. It was decided that a custom kit to

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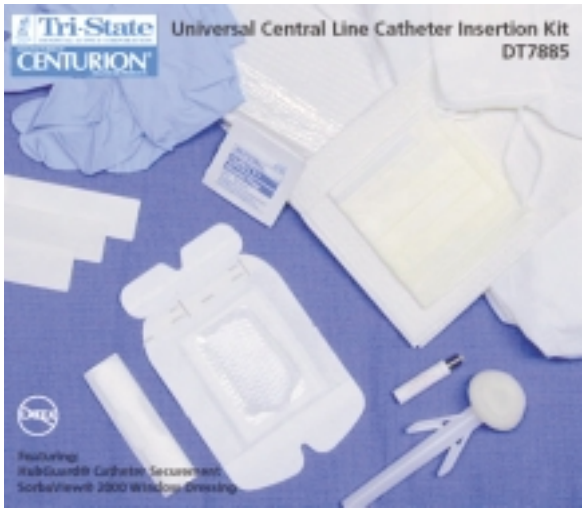
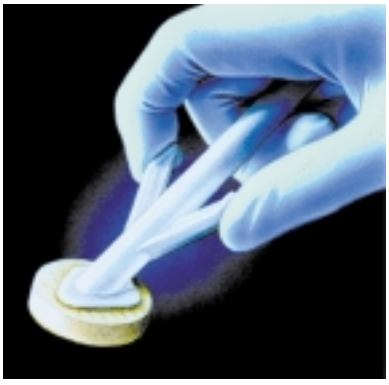
include a 36" x 60" sterile drape, sterile gown (folded in a manner to avoid contamination when donning), a mask, sterile gloves, and enclosed wound dressing kit (Sorbaview® transparent dressing, tape strips, 70% isopropyl alcohol-2% chlorhexidine antiseptic applicator, gauze, small drape) would be needed (Fig. 3). Central Supply ensured distribution to all patient care units, including the operating and emergency departments. The vendor conducted Inservice on the use of the kit and the practice of using maximal sterile barriers was incorporated in all subsequent educational sessions. (Implementation: September 2001)

FIGURE THREE



Use of 2% Chlorhexidine as the Standard Skin Antiseptic (ChloraPrep®, Medi-Flex, Inc., Overland Park, KS). Skin organisms, particularly Staphylococcusaureus and coagulase-negative Staphylococci, have been known for many years as the predominant pathogens causing both wound infections and those related to the use of intravascular catheters[10-13]. Maki and colleagues reported in 1988 that colonization of the skin at the insertion site was the predominant source for both local site infection and bacteremia[14]. Addressing the issue of adequately degerming the skin prior to catheter insertion becomes a central issue in projects aimed at reducing adverse events such as CR-BSI. Prior to January 2001, the hospital used a 10% tincture of iodine solution as its base antiseptic product. Careful examination of the literature indicated that in trials conducted to compare the efficacy of 2% chlorhexidine (CHG) to 10% povidone iodine (PI), 2% CHG exhibited a much greater ability to reduce colonization and bacteremia. In a large study involving 668 patients with central and arterial lines, Maki and researchers showed that BSI occurred seven-times as much as when using a 2% CHG skin prep[15]. CHG has also been shown to have greater antimicrobial residual effect than literature indicated that in trials conducted to compare the efficacy of 2% chlorhexidine (CHG) to 10% povidone iodine (PI), 2% CHG exhibited a much greater ability to reduce colonization and bacteremia. In a large study involving 668 patients with central and arterial lines, Maki and researchers showed that BSI occurred seven-times as much as when using a 2% CHG skin prep[15]. CHG has also been shown to have greater antimicrobial residual effect than 10% PI, a characteristic of great importance since the period between CVC dressing changes may be as long as 4-5 days[16]. Based on this information, and the approval by the FDA of ChloraPrep® as a skin antiseptic (Fig. 4), the Infection Control and the Products Evaluation & Standardization Committees approved the product for use. Bottles, swabs, and other applicators containing povidone-iodine were removed from all patient units and kits and replaced with 2% chlorhexidine. Educational sessions on the use and application of the product were conducted for the majority of staff. (Implementation: January 2002)

FIGURE FOUR



RESULTS

A total of 3,079 patients with 31,445 catheter days (average duration of catheterization equaled 10.2) were included in this study. CR-BSI rates by month for the four-year study period are shown in Figure 5. The period of January-December 1999 is considered in this study to be the pre-intervention period. Silver-chlorhexidine CVCs had been used in the institution for all adult patients since 1997 and was the only major intervention used during the pre-intervention period. During 1999, the mean rate of CR-BSI was 15.0 cases per 1000 catheter days (CD). Focused education for nurses and physicians during 2000 resulted in a 57.3% reduction in the mean rate to 6.4. However, educational efforts alone did not result in a sustained low rate; the occurrence of CR-BSI rates rose in the later 7 months of 2000, although still below 1999 mean rate levels. Conversion to silver-platinum central line catheters (Jan '01-Sep '01) resulted in a 48.4% reduction from the 2000 mean rate to 3.3 BSIs per 1000 CD. An increase in the rate to 4.2 BSIs per 1000 CD was observed after instituting new kits containing barriers (Oct '01-Dec '01). The mean rate for the 15-month period in which 2% chlorhexidine was used for prepping skin prior to catheter insertion was calculated to be 1.6 cases per 1000 CD, an approximate 62% reduction from the prior mean of 4.2. The four interventions resulted in an overall CR-BSI rate reduction of 89.3%. The overall effect of each of the four interventions is summarized in Table 1.

During the 39 month period of intervention, there were an estimated 237 cases of CR-BSI avoided (Table 2). This figure was derived by calculating the difference in cases between the expected number of BSIs (approximately 8 per month if no interventions had been taken) and the actual number of BSIs identified. Surveillance data collected in 2003 indicates that the number of CR-BSI cases occurring per month has been reduced to 0.3 or one case per quarter.

When the CDs were categorized as to location, it was determined that for the 51-month period, 52.7% of all the CDs occurred in non-ICU patient units (16,579 days) and 47.3% (14,875 days) were attributed to the adult ICUs. Rates for each type of unit are shown in Figure 6.

FIGURE FIVE

CVC-RELAYED BLOODSTREAM INFECTIONS, 1999-2003
BROOKDALE UNIVERSITY MEDICAL CENTER

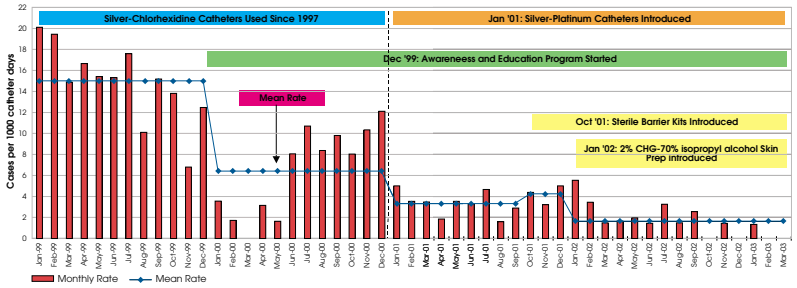


FIGURE SIX

CR-BSI RATES IN ADULT ICU AND NON-ICU PATIENT UNITS

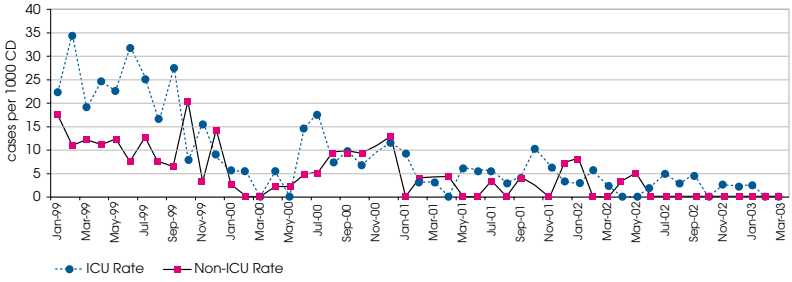


TABLE ONE

Intervention	Period	Months Between Interventions	Expected # of BSIs	Actual # of BSIs	# BSIs Avoided
(Baseline)	Jan 99-Dec 99	12	---	97	---
Education	Jan 00-Dec 00	12	97	47	50
Silver-platinum catheters	Jan 01-Sep 01	9	72	6	66
Maximal sterile barriers	Oct 01-Dec 01	3	24	8	18
2% chlorhexidine skin antiseptic	Jan 02-Mar 03	15	120	17	103
Totals:					**237**

 # BSIs Avoided = Expected # BSIs – Actual # BSIs

TABLE TWO

Intervention	Period	Months Between Interventions	# Patients	# CD	# BSI	Mean Rate	Percent Change from Prior Mean	Percent Change from Baseline
(Baseline or pre-intervention period)	Jan 99-Dec 99	12	642	6,457	97	15.0	---	---
Education	Jan 00-Dec 00	12	668	7,305	47	6.4	-57.3	-57.3
Silver-platinum catheters	Jan 01-Sep 01	9	628	5,438	6	3.3	-48.4	-78.0
Maximal sterile barriers	Oct 01-Dec 01	3	197	1,915	8	4.2	21.4	-72.0
2% chlorhexidine skin antiseptic	Jan 02-Mar 03	15	944	10,330	17	1.6	-61.9	-89.3
Totals:			**3,079**	**31,445**				

CD = catheter days; BSI = bloodstream infection

DISCUSSION

This study demonstrates that the implementation of well-supported interventions can have dramatic effects by reducing the rates of CR-BSI. The interventions used in this study as the foundation of a master plan to improve adverse infection outcomes related to CVC use have been addressed in two guidelines published by the CDC. Both guidelines were applicable due to the timeframes in which the study was conducted. The CDC statements relating to the four interventions used in this study are summarized in Table 3.

TABLE THREE

	CDC 1996 Guideline	CDC 2002 Guideline
Education	Conduct ongoing education and training of health care workers regarding indications for the use of and procedures for the insertion and maintenance of intravascular devices and appropriate infection control measures to prevent intravascular device-related infections. *Category IA*	Educate healthcare workers regarding the indication for intravascular catheter use, proper procedures for the insertion and maintenance of intravascular catheters, and appropriate infection-control measures to prevent intravascular catheter-related infections. *Category IA*
Antimicrobial Catheters	In adults, consider use of a silver-impregnated collagem cuff or an antimicrobial- or antiseptic-impregnated central venous catheter if, after full adherence to other catheter infection control measures (e.g., maximal barrier precautions), there is still an unacceptably high rate of infection. *Category II*	Use an antimicrobial or antiseptic-impregnated CVC in adults whose catheter is expected to remain in place >5 days if, after implementing a comprehensive strategy to reduce rates of CR-BSI, the CR-BSI rate remains above the goal set by the individual institution based on benchmark rates and local factors. *Category IB*
Maximal Sterile Barriers	Use sterile technique, including a sterile gown and gloves, a mask, and a large sterile drape (i.e., maximal sterile barrier precautions), for the insertion of central venous and arterial catheters. Use these precautions even if the catheter is inserted in the operating room. *Category IB*	Use aseptic technique including the use of a cap, mask, sterile gown, sterile gloves, and a large sterile sheet, for the insertion of CVCs (including PICCS) or guidewire exchange. *Category IA*
Skin Antiseptic	Cleanse the skin with an appropriate antiseptic, including 70% alcohol, 10% povidone-iodine, or 2% tincture of iodine, before catheter insertion. *Category IA*	Disinfect clean skin with an appropriate antiseptic before catheter insertion and during dressing changes. Although a 2% chlorhexidine-based preparation is preferred, tincture of iodine, an iodophor, or 70% alcohol can be used. *Category IA*

Category IA. Strongly recommended for all hospitals and strongly supported by well-designed experimental or epidemiologic studies.

Category IB. Strongly recommended for all hospitals and viewed as effective by experts in the field and a consensus of Hospital Infection Control Practices Advisory Committee (HICPAC), based on strong rationale and suggestive evidence, even though definitive scientific studies may not have been done.

Category II. Suggested for implementation in many hospitals. Recommendations may be supported by suggestive clinical or epidemiologic studies, a strong theoretical rationale, or definitive studies applicable to some, but not all, hospitals.

No recommendation; unresolved issue. Practices for which insufficient evidence or consensus regarding efficacy exist.

Successful outcomes involving education as a sole means of reducing CR-BSI has been reported[17-22]. Coopersmith and colleagues at the Barnes-Jewish Hospital in St. Louis developed a self-study module aimed primarily at nurses[17]. Pre- and post-tests were required of the participants in the ICU. Surveillance indicated a 66% decrease in the rate of infection with a corresponding avoidance of 48 cases of CR-BSI. Efforts at educating medical students involved in the care of CVCs have resulted in a 28% decrease in the bacteremia rate[18]. Education projects aimed at all healthcare workers involved in the process of insertion and care of CVCs has yielded even greater results, in one case an overall reduction of 67%[19]. The results of the education portion of this project, which was directed to all healthcare workers involved in the process, resulted in a comparable rate reduction of approximately 57%.

Silver-platinum catheters are designed to create an oligodynamic iontophoresis effect, a process whereby silver ions are released in a reaction created when the catheter contacts a fluid that is electrolytic, in this case blood[23]. The bactericidal effect of silver, in this product an action occurring from both the inner and outer surfaces of the catheter, against bacteria and fungi has been well researched[24]. There is evidence that suggests that the use of the silver-platinum CVC used in this study is effective in reducing both the proliferation of bacteria that occurs during colonization and of subsequent BSI. Studies conducted on silver-platinum CVCs in vitro reported reductions in gram-positive, gram-negative and yeast microorganisms of >3 logs[25]. The results of a large clinical trial indicated marked reductions in the rates of CR-BSI when using silver-platinum catheters vs. catheters made of polyurethane alone[26]. Pooled analysis of three small, randomized trials also suggests a beneficial effect when using these catheters (RR, 0.41)[27-29].

A meta-analysis involving 13 randomized, controlled studies has reported a mean rate of 3.1 BSIs per 1000 device days when using non-cuffed, antiseptic-coated CVCs[30]. The results of this study compare favorably with this reported figure; a mean rate of 3.3 BSIs per 1000 catheter days was achieved after the introduction of silver-platinum catheters. These findings, coupled with broad physician support regarding the technical aspects of insertion using this catheter and the kit components, plus the lower purchase cost of the device compared with the prior product, it appears to have been a reasonable and beneficial decision to convert to silver-platinum catheters.

Although the rate of infection increased after the introduction of a new barrier kit, there are several reasons as to why this may have occurred. First, the period of time (3 months) to conduct a valid assessment of this product probably was too short. Second, the transition between "old" and "new" product may have caused shortages of any available barriers. Third, the availability of the new kit did not guarantee its use. This was addressed at later sessions. Regardless of the results, the literature clearly indicates that the use of sterile barriers reduces both colonization at the insertion site and the occurrence of CR-BSI[31].

CHG has been used successfully as a topical antiseptic for decades in Europe and Canada. A review of several principal characteristics of CHG indicates that this antiseptic provides a significant

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DISCUSSION

advantage over other agents such as 10% povidone-iodine in providing optimal skin antisepsis: (1) a broad antimicrobial spectrum with good activity against gram-positives and somewhat less activity against gram-negatives[32]; (2) an intermediate level in its speed of antimicrobial effect, with good reductions in the levels of organisms after 15 seconds of contact[33]; (3) a prolonged bactericidal effect that may last for up to 6 days after application; its persistent effect may be the best among all antiseptics available[32]; and (4) unlike povidone-iodine, CHG has continued activity in the presence of blood and other organic matter[34,35]. The addition of 70% isopropyl alcohol to the formulation of the product used in this trial adds an agent with the greatest speed of action[36]. A meta-analysis of trials comparing the efficacy of chlorhexidine with povidone-iodine solution in preventing BSI in patients using either CVCs, peripheral venous, peripheral arterial, pulmonary arterial, peripherally inserted central venous, or hemodialysis catheters has been published[37]. Using extensive statistical analysis to select those studies that were randomized and controlled, were blinded, and which did not include publication bias, the authors included 8 studies for final review. Assessment for risk indicated a reduction in CR-BSI of 51% in those patients using CVCs and an overall reduction of 57% when the patients were prepped with a chlorhexidine alcohol solution. In the study at BUMC, the reduction from the prior mean rate was 62% after the introduction of a 70% isopropyl alcohol-2% chlorhexidine antiseptic. Chaiyakunapruk and colleagues also concluded that the absolute difference in cost between chlorhexidine and povidone-iodine is small (approximately $0.92 vs. $0.41 respectively for a quantity sufficient to prep a CVC insertion site) and would thus be likely to be cost-effective. Additional work by these authors reports a reduction in healthcare cost of $113 per catheter used ($224 for PI vs. $111 for CHG)[38].

It should be noted that three of four recommendations used in this study evolved to a category IA ranking in the 2002 CDC guideline. This highest of all categories indicates that the recommendation is strongly supported by scientific studies and should be in practice by all hospitals. Therefore, the selection of these interventions by BUMC for implementation appears to have been well justified.

Few studies have reported on CVC use outside of ICUs. Using point prevalence data on 2,265 patients gathered from six hospitals participating in the National Nosocomial Infection Surveillance System, the CDC discovered that 70% of all patients with CVCs were located outside of ICUs[39]. Our study indicates that intervention programs need to target practices performed in medical settings outside of ICUs.

COST SAVINGS

It is estimated that 73 (237/39 months x 12) cases of BSI were avoided per year during the 39-month period of intervention. Reported figures on attributable cost per infection are estimated at $34,508 to $56,000[40,41]. The cost savings per year in this study are therefore calculated to range from $2,519,084 to $4,088,000.

CONCLUSION

Patient safety not only has evolved to include the occurrence of nosocomial infection, but also errors of omission[42]. Interventional epidemiology advocates extensive assessment of processes in order to clarify "real world" practice, focus evidence-based interventions and implement those interventions with a heightened attention to detail. The study results reported here, with an overall reduction in the rate of nearly 90%, demonstrates the need to combine focused education with the use of novel technology in order to achieve maximum outcomes.

The authors gratefully acknowledge the critical contribution of the nursing, physician and materials management staff at BUMC in the success of this project.

REFERENCES

1. Maki DG, Mermel LA. Infections due to infusion therapy. In: Bennett JV, Brachman PS, eds. *Hospital Infections*. Philadelphia: Lippincott-Raven, 1998:689-724.

2. Mermel LA, Farr BM, Sherertz RJ, Raad II, O'Grady N, Harris JS, Craven DE. Guidelines for the Management of Intravascular Catheter-Related Infections. *CID* 2001;32:1249-72.

3. Pittet D, Tarara D, Wenzel R. Nosocomial bloodstream infection in critically ill patients: excess length of stay, extra costs, and attributable mortality. *JAMA* 1994;271:1598-601.

4. Rello J, Ochagavia A, Sabanes E, et al. Evaluation of outcome of intravenous catheter-related infections in critically ill patients. *Am J Respir Crit Care Med* 2000;162:1027-30.

5. Kluger D, Maki DG. The relative risk of intravenous device-related bloodstream infections with different types of intravenous devices in adults: a meta-analysis of 206 published studies (abstract). *Infect Control Hosp Epidemiol* 2000;21:95-6.

6. Making Health Care Safer: A Critical Analysis of Patient safety Practices. Agency for Healthcare Research and Quality, U.S. Department of health and Human Services. Evidence Report/Technology Assessment, No. 43, July 2001. (available at www.ahrq.gov)

7. National Quality Forum Endorses new Hospital Care National Performance Measures and a Comprehensive Framework for Hospital Care Performance Evaluation. The National Quality Forum. January 30, 2003. **(available at www.????)**

8. Guideline for the Prevention of Intravascular Device-Related Infections. Hospital Infection Control Practices Advisory Committee, Centers for Disease Control, Atlanta, GA, 1996.

9. Guidelines for the Prevention of Intravascular Catheter Related Infections. Centers for Disease Control, Atlanta, GA, 2002.

10. Schaberg DR, Culver DH, Gaynes RP. Major trends in the microbial etiology of nosocomial infection. *Am J Med* 1991;91(suppl 3B):72S-75S.

11. Armstrong CW, Mayhall G, Miller KB, et al. Prospective study of catheter replacement and other risk factors for infection of hyperalimentation catheters. *J Infect Dis* 1986;154:808-816.

12. Richet P, Hubert B, Nitemberg G, et al. Prospective multicenter study of vascular-catheter-related complications and risk factors for positive central-catheter cultures in intensive care unit patients. *J Clin Microbiol* 1990;28:2520-2525.

13. Bjornson HS, Colley R, Bower RH, et al. Association between microorganism growth at the catheter site and colonization of the catheter in patients receiving total parenteral nutrition. *Surgery* 1982;92:720-772.

14. Maki DG, Cobb L, Garman JK, et al. An attachable silver-impregnated cuff for prevention of infection with central venous catheters. A prospective randomized multi-center trial. *Am J Med* 1988;85:307-314

15. Maki DG, Ringer M, Alvarado CJ. Prospective randomized trial of povidone-iodine, alcohol, and chlorhexidene for the prevention of infection associated with central venous and arterial catheters. *Lancet* 1991;338:339-43.

16. Garcia R, Mulberry GK, Brady AR, Hibbard JS. Comparison of ChloraPrep" and Betadine" as preoperative skin preparation antiseptics. (abstract) Association for Infection Control and Epidemiology, 29th Annual Educational Conference and International Meeting, Nashville, TN, June 2002.

17. Coopersmith CM, Rebmann TL, Zack JE, et al. Effect of an education program on decreasing catheter-related bloodstream infections in the surgical intensive care unit.

18. Shertz RJ, Ely EW, Westbrook DM, et al. Education of physicians-in-training can decrease the risk for vascular catheter infection. *Ann Intern Med* 2000;132:641-48.

19. Eggimann P, Harbarth S, Constantin MN, et al. Impact of a prevention strategy targeted at vascular-access care on incidence of infections acquired in intensive care. *Lancet* 2000;355:1864-68.

20. Brennan PJ, Hoegg C, et al. Performance improvement in a medical intensive care unit (MICU) resulting from device based surveillance (DBS) from central venous catheter related bloodstream infections (CVC-BSI) (abstract). *Infect Control Hosp Epidemiol* 1997;18(5pt 2):20.

21. Armstrong P, Alferi N, Clowser M, et al. Central line-associated (CLA) surveillance and continuing quality improvement in an intensive acre unit (ICU) (abstract). *J Hosp Infect* 1998;40(Suppl A):8.1.8.

22. Vander Hyde K, Vanderelzen K, Chenoweth C. A "passive" education program aimed at improving knowledge about infections and reducing central venous catheter-related bloodstream infection rates. (abstract) Association for Infection Control and Epidemiology, 29th Annual Educational Conference and International Meeting, Nashville, TN, June 2002.

23. The Science of Oligon. Edwards Lifesciences LLC, 2000.

24. Russell AD, Hugo WB. Antimicrobial activity and action of silver. *Prog Med Chem* 1994;31:351-70.

25. Vantex Central Venous Catheter with Oligon Material. Evaluation of Antimicrobial Effectiveness. Edwards Lifesciences LLC, 2000.

26. Bong JJ, Kite P, Wilcox MH, et al. Reduction of the incidence of catheter-related sepsis (CRS) in high-risk patients by silver iontophretic central venous catheters (CVCs) (abstract 1918). In: 39th Interscience Conference on Antimicrobial Agents and Chemotherapy, San Diego, CA. *American Society for Microbiology*; 1999:649.

27. Parkhouse DAFH, Hocking GR, Shaikh LS. Advanced catheter related infection and line sepsis following the use of Vantex central venous catheters in the critically ill (abstract 54). *Crit Care Med* 2000;28(12 Suppl):A48.

28. Bong JJ, Kite P, Wilcox MH, McMahon MJ. Efficacy of silver iontrophetic central venous catheters in preventing catheter-related bloodstream infection amongst high-risk patients: a randomized controlled trial (abstract K-1425). In: Program and abstracts of the 41st Interscience Conference on Antimicrobial Agents and Chemotherapy (Chicago). Washington DC: American Society for Microbiology, 2001:425.

29. Ibanez-Nolla JJ, Corral ML, Nolla M, et al. A randomized study using Oligon Vantex central venous catheters (CVC) to reduce bacterial colonization (abstract K-1428). In: Program and abstracts of the 41st Interscience Conference on Antimicrobial Agents and Chemotherapy (Chicago). Washington DC: American Society for Microbiology, 2001:426.

30. Maki DG. A meta-analysis of the risk of intravascular device-related bloodstream infection based on 223 published prospective studies. (abstract) *4th CDC Decennial*, Atlanta, GA.

31. Raad II, Hohn DC, Gilbreath BJ, Suleiman N, et al. Prevention of central venous catheter-related infections by using maximal sterile barrier precautions during insertion. *ICHE* 1994;15:231-8.

32. Guideline for Hand Hygiene in Health-Care Settings. Recommendations of the healthcare Infection Control Practices Advisory Committee and the HICPAC/SHES/APIC/IDSA Hand Hygiene Task Force. Centers for Disease Control and Prevention. *MMWR* 2002;51 (RR-16):1-48.

33. Maki DG, Zitlz MA, Alvarado CJ. Evaluation of the antimicrobial efficacy of four agents for handwashing. *Curr Chemother Infect Dis* 1979;11:1089-90.

34. Larson E, Bobo L. Effective hand degerming in the presence of blood. *J Emerg Med* 1992;10:7-11.

35. Lowbury EJL, Lilly HA. The effect of blood on the disinfection of surgeons hands. *Br J Surg* 1974;61:19-21.

36. Groschel DHM, Pruett TL. Surgical antisepsis. In: Block SS, ed. Disinfection, sterilization and preservation. 4th ed. Philadelphia: Lea & Febiger, 1991:642-54.

37. Chaiyakunapruk N, Veenstra DL, Lipsky BA, Saint S. Chlorhexidine compared with povidone-iodine solution for vascular catheter-site care: a meta-analysis. *Ann Intern Med* 2002;136:792-801.

38. Chaiyakunapruk N, Veenstra DL, Lipsky BA, Sullivan SD, Saint S. The clinical and economic benefits of chlorhexidine compared to povidone-iodine for vascular catheter site care. (abstract #50808) 25th Annual meeting of the Society of General Internal Medicine, Atlanta, GA, May 2-4, 2002.

39. Prevalence of central line use in and outside the intensive care unit: results of a survey among hospitals in CDC's Prevention Epicenter Program. (abstract) Society for Healthcare Epidemiology of America, 12th Annual Meeting, Arlington, VA, April 2002.

40. Rello J, Ochagavia A, Sabanes E, et al. Evaluation of outcome of intravenous catheter-related infections in critically ill patients. *Respir Crit Care Med* 2000;162:1027-30.

41. Dimick JB, Pelz RK, Consumji R, et al. Increased resource use associated with catheter-related bloodstream infection in the surgical intensive care unit. *Arch Surg* 2001;136:229-34.

42. O'Grady NP, Gerberding JL, Weinstein RA, Masur H. Patient safety and the science of prevention: the time for implementing the Guidelines for the prevention of intravascular catheter-related bloodstream infections is now. *Crit Care Med* 2003;31:291-92.