Effectiveness of Minocycline and Rifampin vs Chlorhexidine and Silver Sulfadiazine-Impregnated Central Venous Catheters in Preventing Central Line-Associated Bloodstream Infection in a High-Volume Academic Intensive Care Unit: A Before and after Trial

Stephanie Bonne, MD, FACS, John E Mazuski, MD, PhD, FACS, Carie Sona, RN, Marilyn Schallom, RN, Walter Boyle, MD, Timothy G Buchman, PhD, MD, FACS, Grant V Bochicchio, MD, MPH, FACS, Craig M Coopersmith, MD, FACS, Douglas JE Schuerer, MD, FACS

BACKGROUND: Use of chlorhexidine and silver sulfadiazine-impregnated (CSS) central venous catheters (CVCs) has not been shown to decrease the catheter-related bloodstream infection rate in an ICU. The purpose of this study was to determine if use of minocycline and rifampin-impregnated (MR) CVCs would decrease central line-associated bloodstream infection (CLABSI) rates compared with those observed with use of CSS-impregnated CVCs.

STUDY DESIGN: A total of 7,181 patients were admitted to a 24-bed university hospital surgical ICU: 2,551 between March 2004 and August 2005 (period 1) and 4,630 between April 2006 and July 2008 (period 2). All patients requiring CVC placement in period 1 had a CSS catheter inserted, and in period 2 all patients had MR CVCs placed.

RESULTS: Twenty-two CLABSIs occurred during 7,732 catheter days (2.7 per 1,000 catheter days) in the 18-month period when CSS lines were used. After the introduction of MR CVCs, 21 catheter-related bloodstream infections occurred during 15,722 catheter days (1.4 per 1,000 catheter days). This represents a significant ($p < 0.05$) decrease in the CLABSI rate after introduction of MR CVCs. Mean length of time to infection developing after catheterization (8.6 days for CSS vs 6.1 days for MR) was also different ($p = 0.04$). The presence of MR did not alter the microbiologic profile of catheter-related infections, and it did not increase the incidence of resistant organisms.

CONCLUSIONS: The CLABSI rate decreased more with the use of MR CVCs compared with CSS CVCs in an ICU where the CLABSI rate was already low. The types of organisms causing infection were similar. With continued use of MR-impregnated CVCs in our ICU in the subsequent 5 years, we have seen sustained low rates of CLABSIs. (J Am Coll Surg 2015;221:739–747. © 2015 by the American College of Surgeons)

The CDC estimated that a total of 18,000 central line-associated blood stream infections (CLABSIs) occurred in ICUs in the United States in 2009.[1] An additional estimated 28,000 infections occurred in inpatient wards. Although this represents a 58% reduction from 2001 levels,[2] the CLABSI rate is still well above zero. Current (2014) CDC data estimate that 41,000 CLABSIs occur annually in US hospitals.[3] With the National Healthcare

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From the Departments of Surgery (Bonne, Mazuski, Bochicchio, Schuerer) and Anesthesiology (Boyle), Washington University School of Medicine, Barnes-Jewish Hospital (Sona, Schallom), St Louis, MO, and Department of Surgery, Emory University School of Medicine, Atlanta, GA (Buchman, Coopersmith). Correspondence address: Stephanie Bonne, MD, FACS, Department of Surgery, Washington University School of Medicine, 660 S Euclid, Box 8109, St Louis, MO 63122. email: bonnes@wudosis.wustl.edu

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Abbreviations and Acronyms

CLABSI	= central line-associated blood stream infection
CSS	= chlorhexidine and silver sulfadiazine
CVC	= central venous catheter
MR	= minocycline and rifampin
NHSN	= National Healthcare Safety Network
SICU	= surgical ICU

Safety Network (NHSN) declaration of CLABSI as a "never" event, hospitals and practitioners are under increasing pressure to decrease their CLABSI rates to zero. Additionally, although the mortality of CLABSI is variable in the literature, with estimates ranging from 0 to 35%,[4-9] the development of CLABSI places patients in danger of adverse events. These infections also increase length of stay in both ICUs and hospitals, placing an additional financial burden on the health care system.[5,7-13] Estimates of cost per line range from $12,000 to $56,000 per infection.[10-13]

Exposure to central venous catheters (CVC) is high in ICU patients, with use rates ranging from 0.36 CVC days per total number of patient days in coronary care units to 0.83 CVC days per total number of patient days in cardiothoracic ICUs. Surgical and medical ICUs have rates of 0.63 and 0.52, respectively.[2] Multiple studies have shown that most, if not all, CLABSIs are preventable, and extensive guidelines have been developed to guide best practice for CVC placement.[14] Successful strategies to reduce CLABSIs include implementation of educational programs directed toward the entire multidisciplinary ICU team.[15-18] These programs typically stress adherence to best practice behaviors known to prevent CLABSIs, including the use of full barrier precautions,[19] skin preparation at the insertion site,[20] appropriate hand hygiene,[21,22] and specifying the anatomic site of CVC placement (subclavian preferred to internal jugular preferred to femoral).[23,24] The introduction of checklists and central line "bundles," along with educational programs, have additionally been shown to improve outcomes and increase adherence to best practices, including decreasing CLABSIs.[25,26] Although the decrease in CLABSIs varies depending on which intervention is being studied, comprehensive prevention programs can result in almost complete elimination of CLABSIs from a surgical ICU (SICU).[27,28]

Another tool to prevent CLABSIs is the use of antiseptic or antimicrobial-impregnated catheters. To date, there have been >20 randomized trials, as well as several meta-analyses and cost to benefit analyses on the efficacy of either chlorhexidine and silver sulfadiazine (CSS) CVCs or minocycline and rifampin (MR) CVCs.[29-33] The majority of these demonstrate substantial decreases in CLABSI rates without the development of resistant organisms, regardless of which catheter was used.[31,32] Of note, placement of antiseptic-impregnated catheters has been shown to be effective in decreasing CLABSIs if evidence-based practices are adhered to, but infection rates are still higher than desired.[33] The accumulated weight of these studies has resulted in recommendations from the CDC,[1] the Agency for Healthcare Research and Quality,[34] and from thought leaders in the field[35-37] to use antiseptic or antimicrobial-impregnated catheters, although their efficacy has not been universally accepted.

Although antiseptic or antimicrobial-impregnated catheters are approximately $15 to $20 more expensive (pricing varies by institution) than standard CVCs, cost to benefit analyses favor their use due to the attributable cost of an infection being much greater than the cost of a catheter. There has been substantial interest in determining at-risk populations that would most benefit from the use of these catheters. The CDC recommends that an antiseptic or antimicrobial-impregnated CVCs be placed "in adults whose catheter is expected to remain in place >5 days if, after implementing a comprehensive strategy to reduce rates of CLABSI, the CLABSI rate remains above the goal set by the individual institution based on benchmark rates and local factors."[14] The comprehensive strategy is defined as an educational program directed toward those who insert and maintain CVCs, as well as use of both maximal barrier precautions and 2% chlorhexidine as skin preparation solution for CVC insertion.

Previously, we instituted educational and behavioral interventions designed to prevent CLABSIs.[15,17] These resulted in infection rates that were one-third the national average, as determined by the NHSN at the time of their publication. To determine if there was additional efficacy in using CSS CVCs despite our low CLABSI rates, we studied the effect of inserting these catheters in all patients in our SICU during an 18-month period. These data showed that CSS CVCs were only effective in specific patient populations, but did not statistically decrease the rate of CLABSI in the SICU.[38] In an attempt to study the potential benefit of antibiotic-impregnated catheters, we changed our practice pattern to use MR CVCs on all patients in the SICU and studied the efficacy of these catheters compared with CSS CVCs.

These results could be consistent with the CDC recommendation to use these catheters in settings where the CLABSI rates remain elevated after other interventions were made. However, there are actually few other data currently available on the efficacy of antiseptic or

antimicrobial-impregnated catheters in ICUs that have successfully instituted the comprehensive strategy outlined by the CDC, and whether or not different types of catheters might have different efficacy in this setting. The purpose of this study was to address the use of antiseptic- or antibiotic-impregnated catheters (specifically looking at MR CVCs) in an ICU with low infection rates after implementation of a successful educational program to prevent CLABSI.

METHODS

Study location and patient population

Barnes-Jewish Hospital is a 1,305-bed tertiary care, university-affiliated teaching hospital. All patients admitted to the SICU between March 1, 2004 and August 31, 2005, and subsequently between April 1, 2006 and July 31, 2008, were included in the study. The SICU is a 24-bed unit that admits all noncardiothoracic and non-neurosurgical critically ill surgical and trauma patients in the hospital, as well as selected medical patients. Mean length of stay was constant throughout the study at 4.0 (±0.8) days, as were nursing and physician staffing ratios. Throughout the study, all patients admitted to the SICU were followed prospectively by an infection-control team and surveyed for bloodstream infections. Data in this study were collected after completion of our published educational and behavioral interventions to prevent CLABSI in the SICU,[15,17] and after the completion of our study showing no decrease in rates of CLABSI with second-generation CSS CVCs over traditional, nonimpregnated catheters.[37]

Demographic data for patients in the study was retrieved from the Project IMPACT database (Cerner). All positive blood cultures were classified as primary or secondary based on CDC definitions. A CLABSI was identified when a pathogen was isolated from blood culture not considered to be the manifestation of an infection at another site or in a patient with fever >38.5°C, chills, or hypotension. Common skin contaminant, such as coagulase-negative staphylococci, were considered pathogens if they were isolated from two blood cultures drawn on separate occasions and were unrelated to infection at another site, or if the attending physician chose to provide a therapeutic course of antimicrobial therapy based on a single positive blood culture. Secondary bacteremias were not included in this analysis. Central line-associated related bloodstream infections were reported when they were identified in first-time central line or subsequent central line placements.

Updates on CLABSI rates were reported monthly at the SICU's quality-improvement conference and were compared with earlier rates within the SICU before the universal implementation of MR CVCs. Data collections and surveillance protocols remained the same across the two study periods. However, aggregate results using the MR CVCs were neither reported nor compared with rates obtained when the CSS CVCs were being used until completion of the trial.

The study was approved by the IRB of the Human Research Protection Office of Washington University School of Medicine. A requirement for informed consent from the patients was waived.

Study design

In the preintervention group, or period 1, all patients requiring a central line in the ICU had a second-generation CCS CVC placed (Arrowgard Blue Plus; Arrow International). All patients admitted to the SICU in the postintervention group, or period 2, who required CVC insertion had MR CVCs (Cook Medical, Cook Group) placed. These catheters are polyurethane catheters that are manufactured with both external coating and internal impregnation of the antibiotic agents. The decision to use catheters exclusively was based on a decision that any CVC placed in the SICU was likely to stay in place for 5 days and therefore met the CDC criteria for placing antimicrobial or antiseptic-impregnated catheters. Mandatory educational modules on how to prevent CLABSI continued on a regular basis throughout the study for both physicians and nurses in the SICU.

A pre-hoc decision was made that the primary end point would be CLABSI rates for CVCs placed in the SICU, with a secondary end point being CLABSI rates for all CVCs identified in the surgical ICU regardless of where they were placed. The rationale behind this decision was to eliminate the confounding effect of nonimpregnated CVCs placed by individuals in the operating room, emergency department, hospital wards, interventional radiology suite, or at another hospital for the primary analysis. The same primary end point was used in a previous study from this ICU.[38] All CVCs placed in the SICU throughout the study were inserted by supervised residents, fellows and nurse practitioners, or attending physicians.

Statistical analysis

Data were analyzed using the statistical software program GraphPad Prism software, version 4.0 (GraphPad Software). Infection rates and contingency tables (ie, when comparing insertion site between CSS and MR groups) were analyzed using chi-square test. Demographic and microbiology comparisons between pre- and postintervention groups

Table 1. Demographics of All Patients with a Central Venous Catheter in Place

Variable	March 2004 to August 2005	April 2006 to July 2008
Patients admitted, n	2,551	4,630
Patients with CVC, n	1,949	3,727
Where CVC placed, %		
In SICU	50.1	43.8
Outside SICU (OR, ED, radiology, ward, other)	49.9	56.2
Age, y, mean	59.3	57.5
CVC duration, d, mean	3.4	3.3
APACHE II score	18.2	17.9
ICU length of stay, d, mean	8.9	8.0
Hospital length of stay of patients, d, mean	23.3	21.4
Duration of CVC, %		
<7 days	82.7	84.4
7 to 10 days	11.8	11.1
>10 days	5.4	4.6
Insertion site, %		
Subclavian	40.0	43.0
Internal jugular	52.0	48.3
Femoral	8.0	8.7

CVC, central venous catheter; ED, emergency department; OR, operating room; SICU, surgical ICU.

were performed using the Mann-Whitney test. A p value <0.05 was considered statistically significant.

RESULTS

Patients

There were 7,181 patients admitted to the SICU during the 46 months of the study. This includes 2,551 patients, of which 1,949 had CVCs in 18 months from March 2004 through August 2005, when CSS CVCs were standard in the ICU. There were 4,630, patients, of which 3,727 had CVCs in 28 months from April 2006 through July 2008, during which time all patients who had a CVC placed in the SICU had an MR CVC inserted. Demographics for all patients with a CVC in place were similar in the pre- and postintervention groups (Table 1). The majority of all CVCs were placed in the internal jugular vein, but this was predominantly due to CVCs placed in the operating room (nearly exclusively placed in the internal jugular) because the majority of CVCs inserted in the SICU were placed into the subclavian vein (data not shown). Patients who had a CVC inserted had higher severity of illness throughout the study than those who did not, because patients who had a CVC in place had higher mean APACHE II scores (18.2 vs 15.6) and had longer lengths of stay than those without CVCs (6.9 vs 4.3 days, data not shown).

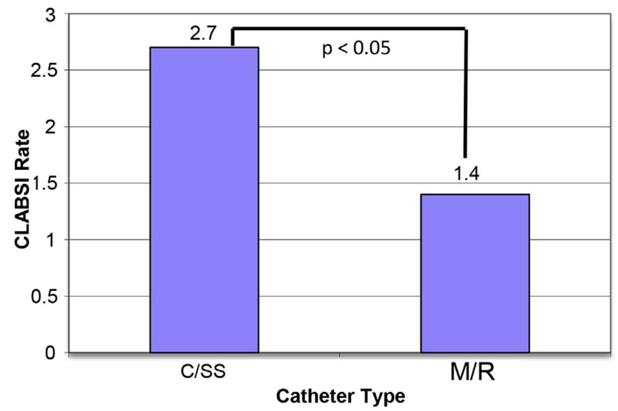

Figure 1. Central line-associated bloodstream infection (CLABSI) rate per 1,000 catheter days. C/SS, chlorhexidine and silver sulfadiazine-impregnated catheter; M/R, minocycline and rifampin-impregnated catheter.

Central line-associated blood stream infection in chlorhexidine and silver sulfadiazine central venous catheters placed in surgical intensive care units

In the first time period of the study, when CSS CVCs were being placed, there was a total of 7,732 catheter days. In this time, there were 16 CLABSIs identified, or 2.1 per 1,000 catheter days. During the second time period, when MR CVCs were placed, there were a total of 21 CLABSIs in 15,722 catheter days, or 1.4 per 1,000 catheter days ($p < 0.05$) (Fig. 1). The demographics of patients with CLABSI in CVCs placed in the SICU were similar regardless of whether the infection was in a CSS CVC or MR CVC (Table 2). Length of stay and anatomic site of catheter insertion were also similar between groups.

Microbiology of central line-associated blood stream infection in intensive care unit

No statistically significant differences in microbiology were noted in infection in CVCs placed in the SICU, regardless of whether the patient had a CSS CVC inserted or MR CVC, Gram-positive organisms predominated in both the pre- and postintervention groups (Fig. 2). In the CCS-impregnated catheters, 50% of the infections were due to Gram-positive microorganisms, with a predominance of *Staphylococcus sp.* and *Enterococcus sp.* Twenty-five percent were due to Gram-negative microorganisms and 25% were due to fungal microorganisms. In the MR catheters, 57% were due to Gram-positive, 19% were due to Gram-negative and 24% were due to fungal microorganisms (p = NS).

Table 2. Demographics of Patients Who Developed Central Line-Associated Bloodstream Infection from Central Venous Catheters Placed in the Surgical Intensive Care Unit

Variable	CSS	MR
Age, y, mean ± SD	55.2 ± 20.0	57.5 ± 16.4
Male, n (%)	9 (56)	15 (62.5)
CVC duration before infection, d	8.6	6.1
Insertion site, n (%)		
Subclavian	8 (50.0)	10 (41.6)
Internal jugular	8 (50.0)	8 (33.3)
Femoral	0	3 (12.5)

CSS, chlorhexidine and silver sulfadiazine-impregnated catheter; CVC, central venous catheter; MR, minocycline and rifampin-impregnated catheter.

Time to development of infection in central venous catheters

During the initial study period, when CSS CVCs were used, the mean length of time a SICU-placed CVC was in before development of CLABSI was >8 days. This is substantially greater than the mean length of time the typical CVC remained in place, because <15% of all CVCs stayed in >7 days. During the subsequent study period, when MR CVCs were placed, catheters were in place for a shorter period of time before development of an infection (6.1 days; p = 0.04). However, the mean duration that CVC was in place (3.3 days; p = NS) was not significantly different, suggesting that earlier discontinuation of CVCs during the latter period did not account for the differences observed in the infection rates or their timing. For patients in whom an infection did eventually develop, the time to CLABSI development was 8.6 days in the CSS CVC group and 6.1 days in the MR CVC group (p = 0.04) (Fig. 3).

Central line-associated blood stream infection in all central venous catheters by placement location

In addition to CLABSIs in CVCs placed in the SICU, there were 6 CLABSIs in CVCs placed before patient arrival in the SICU in period 1 when CSS CVCs were being placed in the SICU, and 3 in period 2, when MR catheters were placed. There were 22 infections in the CSS group (2.7 per 1,000 catheter days). This includes 16 infections in CSS CVCs placed in the SICU and 6 standard catheters placed outside the SICU, which were not impregnated. In the MR group, there were a total of 21 central line-associated bloodstream infection in 15,722 catheter days, or 1.4 per 1,000 catheter days, including 3 lines placed outside the SICU that were not impregnated (Fig. 4). By comparison, CDC data for SICUs nationwide in 2009 show a rate of 1.9 per 1,000 catheter days in 2009. Throughout the study, CLABSI rates were lower in the SICU than CDC rates published for each year (data not shown).[2,39]

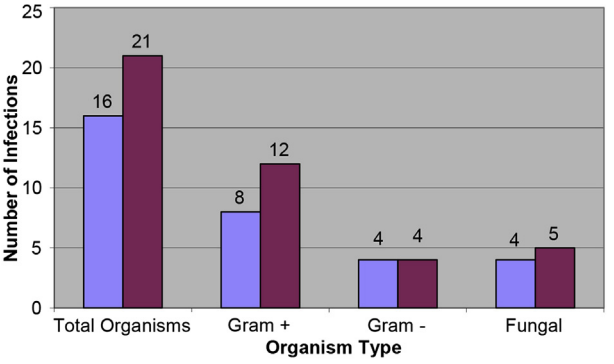

Figure 2. Microorganisms isolated from patients with central line-associated bloodstream infection from central venous catheters placed in the surgical ICU. Blue bar, chlorhexidine and silver sulfadiazine-impregnated; red bar, minocycline/rifampin-impregnated.

DISCUSSION

This study demonstrates that placing MR-coated catheters in all SICU patients requiring CVC insertion significantly decreased CLABSI rates below the already low rates obtained in an ICU using second-generation CSS-impregnated catheters. This was done in a SICU in which a comprehensive educational program and adherence to best practice behaviors program was already in place. To our knowledge, this is the only direct comparison of a second-generation antiseptic catheter vs antimicrobial-impregnated catheter.

Existing literature supports the use of impregnated antiseptic or antimicrobial catheters to decrease the rate of CLABSIs in the ICU. The CDC currently has a 1A

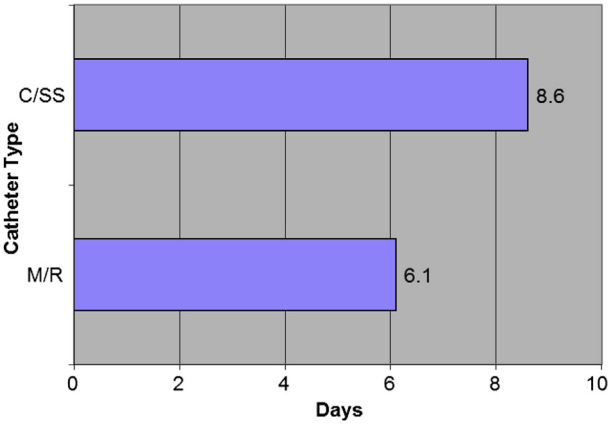

Figure 3. Days to line infection by catheter type. C/SS, chlorhexidine/silver sulfadiazine-impregnated; M/R, minocycline and rifampin-impregnated catheter.

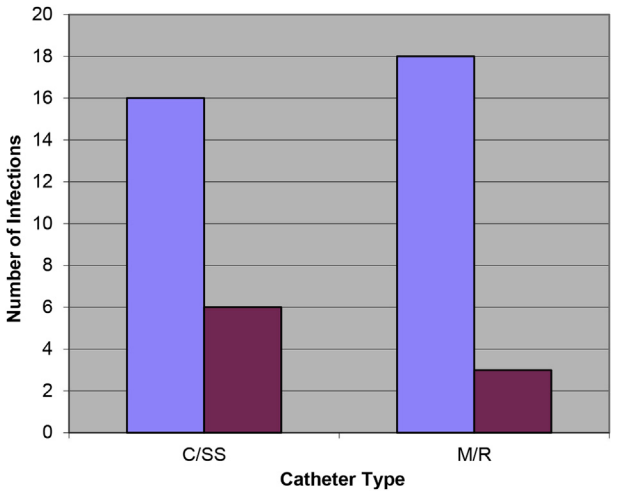

Figure 4. Infected line placement location. Blue bar, inside surgical ICU; Red bar, outside ICU. C/SS, chlorhexidine and silver sulfadiazine-impregnated catheter; M/R, minocycline and rifampin-impregnated catheter.

recommendation that either an antiseptic or antimicrobial CVC be placed when the catheter is likely to stay in place for >5 days and the ICU in which the CVC is to be placed has a record of higher than national average CLABSI rates after implementation of a comprehensive strategy to decrease CLABSI. However, the decision as to which catheter should be placed is left to the practitioner in the guidelines, with little available data comparing one catheter with another.[40]

In light of the fact that multiple ICUs have eliminated CLABSI, the goal CLABSI rate for the SICU at Barnes-Jewish Hospital should be zero. Despite the fact that our CLABSI rates have been less than mean NHSN and CDC levels since 1999, our CLABSI rates were, in fact, higher than the institutional goal. As such, strict implementation of the CDC guidelines would result in our using antiseptic or antibiotic-impregnated catheters (either CSS or MR) on all of our patients expected to have a catheter in place for >5 days. As NHSN rates of CLABSI and subsequently the CDC target rates of CLABSI drop year by year, an important question was whether antiseptic-impregnated or antimicrobial-impregnated catheters could decrease infection rates in an ICU if education and compliance with best practice led to CLABSI rates that were low, but not zero. Previously published results from our group comparing CSS CVCs with standard nonimpregnated catheters did not demonstrate a substantially lower rate of infection in these antiseptic-impregnated catheters.[39]

Based on these results here, however, the use of the MR CVCs does appear to be justified from the standpoint of efficacy alone. Previously, we reported that the CLABSI rate of CSS CVCs and traditional catheters were equivalent. Based on the current data, CLABSI rates should also be lower when MR CVCs are used rather than traditional catheters in our ICU setting. This conclusion is also supported by other studies.[41-43] In addition, when the cost of a CLABSI is considered, the use of MR CVCs becomes worth the small additional cost of the catheters. Actual cost savings would need to be considered on an institutional basis, as agreements about cost of materials vary by institution. However, regardless of specific cost at a given institution, the additional cost of catheters should be quite low compared with the overwhelming cost of treating a CLABSI.

The demographics of all patients with CVCs were strikingly similar throughout the 46 months of the study, as were the characteristics of patients whose catheters became infected, regardless of whether they were CSS CVCs or MR CVCs. There was a significant difference in the time to infection between the CSS CVCs and the MR CVCs. Of note, central lines were removed from the patient once a CLABSI was identified. At first look, the data on time to infection appear to favor the CSS CVCs because the time to infection was longer for these catheters. However, the overall duration of catheter use was not different between the two groups. In addition, even if the time to infection of MR CVCs is shorter, overall, there were still fewer patients with a CLABSI among patients having MR CVCs placed compared with those having CSS CVCs placed. Although the reason bloodstream infections became manifest slightly earlier with the MR CVCs remains elusive, it does not obviate the overall benefit observed with MR CVCs. Additionally, we do not advocate for routine line change at 7 days, based on these data. If overall line infection is short and the time to a line infection developing, if one is to develop, is <7 days, there should be no evidence-based reason for routine catheter changes.

One other finding with the use of both the CSS and MR CVCs was a nonsignificant trend toward increased fungemia. In the overall experience, there were 2 fungemias during 56 months before use of any antiseptic- or antibiotic-coated CVCs, 4 in the subsequent 18 months when the CSS catheters were used, and then 5 in the 28 months when the MR CVCs were used. Longer-term follow-up would be needed to determine if this constituted a clinically significant finding.

Although we believe this study answers an important, previously unanswered question about the direct comparison of antiseptic and antimicrobial catheters, it has a number of limitations. Because our previous educational program decreased CLABSI rates >2-fold, we already have a low CLABSI rate and, therefore, few patients with infections to study. Although our CLABSI rate was

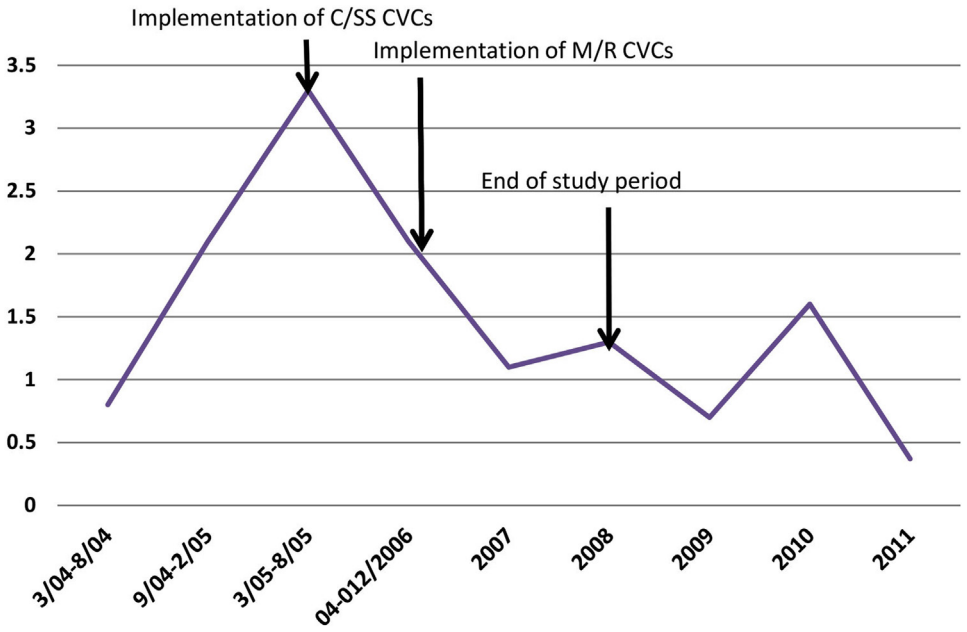

Figure 5. Five-year follow-up data. Purple line, rate of infection per 1,000 catheter days; C/SS CVCs, chlorhexidine and silver sulfadiazine-impregnated central venous catheters; M/R CVCs, minocycline and rifampin-impregnated central venous catheters.

downtrending after implementation of education programs, we still sought to bring our CLABSI rate closer to zero, as is the gold standard for a "never" event. Despite having a low number of total infections, we were still able to detect a 49% decrease in CLABSI with use of MR CVCs. Of note, we have had sustained low rates of CLABSI in our ICU in the subsequent period of time since the study period ended, which is tracked as part of our SICU quality-improvement process (Fig. 5). We conclude from these observations that education programs decrease CLABSI rates to a degree, but a multidisciplinary approach, including the use of antibiotic-impregnated catheters, brings rates closer to zero than education programming alone.

Other limitations exist with the pre- and poststudy design used. Compared with a prospective randomized trial, this type of study is susceptible to temporal bias due to unrecognized changes in patient populations or in ICU practices. In addition, it makes a blinded comparison impossible. However, the similarity of the patients in the 2 cohorts and the similar duration of CVC use suggest that a systematic bias due to changes in patient characteristics was not present. In addition, the stability of the CLABSI rate after study completion also argues against other interventions in the SICU contributing to the decreased rate of infection. Ultimately, with the overall low rate of CLABSI, a single-center randomized controlled trial would not be feasible, and even a multicenter trial would likely be impossible due to the need to enroll several thousand patients to detect a statistically significant difference without an appreciable type II error.

The study design called for all patients having CVCs placed in the SICU to have the MR CVC used. It was believed that there was a considerable chance that those catheters would be left in place for 5 days, to meet the CDC recommendation for antiseptic or antimicrobial-catheter placement. However, >80% of CVCs in the SICU remained in place for <7 days, and the mean duration of catheter use was 3.4 and 3.3 days in the 2 cohorts. Although this suggests the a priori assumption that catheters would be used for at least 5 days was not valid, this discrepancy might be more apparent than real. However, the data presented in Table 1 demonstrate that >80% of CVCs in the SICU were left in <7 days. This discrepancy is not as great as it might seem on the surface because the majority of CVCs in SICU patients were placed outside the SICU, and these were likely to be in a shorter period of time than catheters placed in the SICU. The short duration of use of CVCs placed outside of the SICU was also likely because of standard SICU protocols. Most CVCs placed in the emergency department, for instance, were removed within 24 to 48 hours. Central venous catheters placed in the operating room were frequently used for intraoperative monitoring or drug administration, and were many times removed within a day or 2 after the operation, if there was no longer an

indication for use, following the CDC guideline for daily assessment of need. In contrast, CVCs were usually placed in the SICU because of clinical necessity, such as a need for longer-term access for administration of medications, such as parenteral nutrition or vasoactive medications, or for ongoing monitoring of central venous pressures of oxygen saturations. This increases the likelihood that a CVC placed in the SICU would be left in place for >5 days. An unknown number of CVCs placed in the SICU during this study were likely removed within 5 days. However, from the standpoint of facilitating a standard approach by multiple different providers, using a single catheter was believed to be far more feasible than relying on a more complicated protocol asking individuals to speculate on the duration of catheter use to choose the desired one.

CONCLUSIONS

This study has important implications for ICUs, which have successfully decreased CLABSI rates to less than the NHSN and CDC means, but have been unable to bring their rates to zero. Given the choice between CSS CVCs or MR catheters, practitioners should consider stocking and using MR CVCs to further decrease catheter-related bloodstream infections, when a standard education program is already in place and CDC guidelines are being followed. In the subset of ICUs that have CLABSI rates less than NHSN and CDC, our data indicate that use of MR CVCs instead of CSS CVCs will result in decreased rates of CLABSI. Additional studies are needed in different ICU and non-ICU settings to continue to compare the different catheters available on the market to determine the generalizability of these findings.

Author Contributions

Study conception and design: Sona, Boyle, Buchman, Coopersmith, Schuerer

Acquisition of data: Sona, Schallom, Boyle, Schuerer

Analysis and interpretation of data: Bonne, Mazuski, Bochicchio, Schuerer

Drafting of manuscript: Bonne, Sona, Schallom, Schuerer

Critical revision: Bonne, Mazuski, Schuerer

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