The Bundle "Plus": The Effect of a Multidisciplinary Team Approach to Eradicate Central Line-Associated Bloodstream Infections

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BACKGROUND: Central line–associated bloodstream infections (CLABSIs) have decreased significantly over the last decade. Further reductions in CLABSI rates should be possible. We describe a multidisciplinary approach to the reduction of CLABSIs.

METHODS: This was an observational study of critically ill patients requiring central venous catheters in 8 intensive care units in a tertiary medical center. We implemented a catheter bundle that included hand hygiene, education of providers, chlorhexidine skin preparation, use of maximum barrier precautions, a dedicated line cart, checklist, avoidance of the femoral vein for catheter insertion, chlorhexidine-impregnated dressings, use of anti-infective catheters, and daily consideration of the need for the catheter. Additional measures included root cause analyses of all CLABSIs, creation of a best practice atlas for internal jugular catheters, and enhanced education on blood culture collection. Data were analyzed using the Poisson test and regression.

RESULTS: CLABSI, catheter use, and microbiology were tracked from 2004 to 2012. There was a 92% reduction in CLABSIs (95% lower confidence limit: 67.4% reduction, $P < 0.0001$). Central venous catheter use decreased significantly from 2008 to 2012 ($P = 0.032$, −151 catheters per year, 95% confidence limits: −277 to −25), whereas peripherally inserted central catheter use increased ($P = 0.005$, 89 catheters per year, 95% confidence limits: 50 to 127). There was no apparent association between unit-specific Acute Physiology And Chronic Health Evaluation III/IV scores and CLABSI. Three units have not had a CLABSI in more than a year. The most common organism isolated was coagulase-negative staphylococcus. Since the implementation of minocycline/rifampin catheters, no cases of methicillin-resistant *Staphylococcus aureus* CLABSI have occurred.

CONCLUSIONS: The implementation of a standard catheter bundle combined with chlorhexidine dressings, minocycline/rifampin catheters, and other behavioral changes was associated with a sustained reduction in CLABSIs. (Anesth Analg 2013;XXX:00–00)

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Central venous catheters (CVCs) are essential for the care of many critically ill patients. However, serious complications can occur with their use. One such complication is central line–associated bloodstream infection (CLABSI). While the attributable mortality associated with these infections is likely quite low, the economic costs and morbidity can be substantial.

In 2000, the estimated number of CLABSI in intensive care units (ICUs) in the United States per year was 80,000. Since that time, both behavioral and technological interventions have resulted in reduced CLABSI rates. Based on reporting to the National Healthcare Safety Network (NHSN), the Centers for Disease Control and Prevention (CDC) has estimated that 25,000 fewer CLABSIs occurred in 2009 in U.S. ICUs than that occurred in 2001.[1] Hand hygiene, education programs[2–4] and use of maximum barrier precautions,[5] catheter bundles,[6] and checklists[7] are some of the behavioral changes that have resulted in reductions in CLABSI. Technological advances include aqueous or alcoholic chlorhexidine solutions for skin preparation,[8,9] chlorhexidine patches for catheter site care,[10] and antiseptic or antibiotic-impregnated catheters.[11–13]

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Although these aforementioned studies showed significant reductions in the incidence of CLABSIs, continued improvement should be possible. In this study, we describe a multidisciplinary approach toward reducing CLABSI rates in the ICUs at UMass Memorial Medical Center, Worcester, MA, that has led to a 92% reduction in these infections.

METHODS

In 2004, a Critical Care Operations Committee (CCOC) was formed at UMass Memorial Medical Center with the intent of providing standardized care to our critically ill patients by developing clinical practice guidelines based on the best published medical evidence.[14] This committee is multidisciplinary and includes physicians, nurses, pharmacists, occupational and physical therapists, hospital administrators, and patient representatives. In addition, in 2006, the institution implemented a uniform electronic medical record system (Visicu eCare Manager; Visicu Inc., Baltimore, MD) for all 7 adult ICUs. One of the first issues that the CCOC considered was reducing the rate of CLABSIs with the subsequent creation of a dedicated subcommittee to address this concern. Interventions that were incorporated into the initiative over time included an education program (that also emphasized hand hygiene), use of a dedicated catheter cart that has all of the necessary supplies, catheter insertion using maximum barrier precautions, preprocedural time out, use of a checklist during catheter insertion, empowering the bedside nurse to stop the procedure if elements in the checklist were not followed, incorporation of chlorhexidine solutions for skin preparation and chlorhexidine sponges for catheter dressings, tracking of high-risk catheters (i.e., those that were inserted during emergencies or in the femoral vein) via the eCare Manager system, treating a CLABSI as a critical event and holding a root cause analysis (RCA) after each one to discern the cause, creation of a best practice atlas of dressings for internal jugular catheters to decrease the risk of the weight of catheter lumens peeling the dressing off patients' necks, use of the subclavian vein as the preferred site for catheter insertion, documentation of the catheter insertion with a standardized procedure note, and daily assessment as to the need for the CVCs. In addition, reduction of CLABSI rates in individual units became a pay-for-performance (P4P) measure for senior ICU leadership in 2005 and for ICU medical directors and nurse managers beginning in 2007. While we are not able to report absolute numbers for reasons of confidentiality, the framework to calculate P4P for ICU medical directors is as follows: A set amount (stipend) is paid to the medical directors for their administrative time (not a percent of their salary), and their annual bonus is a percent of that amount. As for the bonus structure, they have 3 goals for the year and prevention of CLABSI is one of them. There are target and "stretch" variables for each goal. If the individual misses the target for the 3 goals combined, 10% of the stipend as bonus is lost; if the target is made for the 3 goals combined, the bonus will increase by 10%; and if the stretch for the 3 goals combined is made, the bonus will increase to 20% of the stipend.

Catheter days were tracked through the eCare Manager system for the adult ICUs and by Infection Control for the pediatric ICU. Definitions of CLABSI were those as published by the CDC (Appendix Tables 1–3). The definition for laboratory-confirmed bloodstream infection was revised on January 1, 2008, and no longer includes 2b or 3b criteria: "common skin contaminant is cultured from at least one blood culture from a patient with an intravascular line, and the physician institutes appropriate antimicrobial therapy." Data were presented to the CCOC on at least a quarterly basis and to the individual ICUs on a monthly basis by means of an electronic newsletter. In addition, the data could be viewed on the CCOC intranet Web site. Beginning in July 2008, CLABSI rates in ICUs in Massachusetts became a publicly reported health care–associated infection measure for the state through reporting to the CDC/NHSN network. In 2011, the UMass Memorial Medical Center Infection Control Department's CLABSI surveillance program for the July 1, 2009, to June 30, 2010, time period was audited by the Betsy Lehman Center of the Massachusetts Department of Public Health.

This study was exempt from review by the University of Massachusetts Medical School Committee for the Protection of Human Subjects in Research.

Statistical Analysis

The number of catheterizations per year was modeled using general linear mixed models,[15] with first and second order slopes fit for each type of catheter to detect linear trends and changes to those trends; hospital units were modeled as random effects and calendar year as a fixed effect. Linear mixed models were fit using the Mixed procedure from the SAS statistical software package[16,17] (SAS Institute Inc, Cary, NC) using restricted estimation by maximum likelihood. Model terms were evaluated using P values from type III tests of fixed effects and Wald tests of model parameters: significant parameters would have to be >2 SEs from 0. The assumed covariance structure was compound symmetry.

Differences in infection rates were evaluated with a Poisson test.[18] The trend in catheter blood infection rates was modeled using Poisson regression.[19] The association between yearly CLABSI rates and Acute Physiology And Chronic Health Evaluation (APACHE) III/IV scores was tested using Spearman rank correlation.

The distributional assumptions of methods used were evaluated using the "Lilliefors adaptation" of the Kolmogorov–Smirnov goodness of fit test for normality (Appendix Table 2)[20] and by visual inspection of frequency histograms, both performed on residuals from models fit to the appropriate design. The Lilliefors adaptation of the Kolmogorov–Smirnov goodness of fit test for normality is a test of the goodness of fit of empirical model residuals against the normal distribution with mean parameter zero and a variance estimated using the standard deviation squared of the model residuals. Poisson regression was performed using the LogXact software package (Cytel Inc, Cambridge, MA).[21]

Log CLABSI rates were modeled using general linear models with year and year squared as continuous fixed effects and units as random effects. To evaluate the effect of interventions that were made in any given year, dummy variables were added one at a time for each year (e.g., for the 2009 variable, prior years were coded as 0 and 2009

and later as 1.0). A 1-degree of freedom F test was used to evaluate the improvement in the model by inclusion of each dummy variable. For significant intervention year effects, an interaction with the continuous year was fit to identify a break point in the slope.

RESULTS

Table 1 specifies the interventions and when they were enacted. The CLABSI rate in fiscal year (FY) 2004 was 5.86 per 1000 catheter-days and over time the rate was reduced to 0.33 per 1000 catheter-days by FY 2012 ($P < 0.0001$ by Poisson test). There was a significant consistent downward trend (0.39-fold decrease per year) in the rate of infections ($P < 0.0001$ by Poisson regression, 95% confidence limits: 0.32 to 0.47). Figure 1 shows the numbers of infections and rates per year over that time span.

Table 1. Key Milestones and Interventions

Year	Milestone and intervention
2004	Critical Care Operations Committee (CCOC) started 9/13
2005	• Bloodstream infection (BSI) clinical practice guideline (CPG) program recommendations made to the CCOC 2/16 • Standardize education on central venous catheter (CVC) insertions. • Use of maximum barrier precautions during CVC insertions • Use of chlorhexidine skin prep • Use of chlorhexidine sponge for dressing • Empower nurses to monitor catheter placement and stop the procedure when deemed appropriate • Complete a quality assurance (QA) checklist during CVC insertion • Documentation of insertion via a standardized procedure note • Assess need for central or arterial catheters on a daily basis • Avoid femoral catheters whenever possible; the preferred site is the subclavian
2006	• BSI CPG approved • eLearning module active 4/4 • Quality rounds focus on central line–associated bloodstream infections (CLABSIs)
2007	• Standardized use of antibiotic or antiseptic catheters in catheter cart 2/28 • Tracking of high-risk catheters by location, placement, and duration 5/07 • Positive blood cultures reviewed by electronic intensive care unit (eICU) midlevel or MD staff daily 9/07
2008	• BSI eLearning module activated for MD staff, residents, midlevels, and fellows 4/08 • UMass Memorial Medical Center begins public reporting of CLABSIs to the Massachusetts Department of Public Health 7/08 • eICU BSI tool developed 4/08 • Root cause analysis for each CLABSI 4/08 • Atlas of pictures on standardized central line dressing 8/08 • Interventional radiology implemented peripherally inserted central catheters (PICCs) improvement process
2009	• Reporting of blood culture contamination rates at the CCOC 1/09 • Enhanced staff education on blood culture collection technique • Implement a reporting system on staff completion of eLearning training program 3/09 • Use of only minocycline/rifampin (MR) catheters 6/09 • Transparent occlusive dressing with chlorhexidine (CHG) replaces CHG sponge dressing
2010	• CPG initiated in the emergency department (ED) 9/10 • Quality rounds in the ED 10/10 • ED procedure note revised 12/10
2011	• MR catheters used in ED 2/3 • BSI bundle compliance may be obtained via electronic procedure note 4/21

MD = medical director.

Figure 2 shows the CVCs, peripherally inserted central catheters (PICCs), and total catheter usage (including dialysis catheters and pulmonary artery catheters) from 2008 to 2012. Complete data before 2008 are not available. The number of CVCs inserted over that time period decreased significantly ($P = 0.0315$ by Poisson regression, –151 catheters per year, 95% confidence limits: –277 to –25), whereas the number of PICCs inserted increased significantly ($P = 0.0053$, 89 catheters per year, 95% confidence limits: 50 to 127). There was no change in the total catheter usage ($P = 0.170$, 95% confidence limits: –197 to 55).

Table 2 shows yearly CLABSI rates and APACHE III/IV scores for individual units. There was no apparent relationship between unit-specific APACHE III/IV scores and CLABSI rates.

The days since last CLABSI in the ICUs ranged from 68 to 784 days, while the longest CLABSI-free duration ranged from 329 to 1562 days (Appendix Table 3).

Table 3 delineates the microbiology of CLABSI. Coagulase-negative staphylococci were the most common cause of CLABSI followed by enterococci (including vancomycin-resistant enterococci), Gram-negative bacilli, and *Candida* species. Since 2009, no cases of CLABSI due to methicillin-resistant *Staphylococcus aureus* (MRSA) have occurred.

Between October 2007 and November 2012, 140 event reviews (RCA) were performed by the critical event review committee composed of a multidisciplinary panel of clinicians and infection control staff including the hospital epidemiologist. The most common categories identified in these meetings along with subsequent interventions are listed in Table 4. For the timeline of implementation of interventions listed, please refer to Table 1.

DISCUSSION

Similar to other published reports, the primary finding of our study is that a multimodal approach to the insertion and care of CVCs was associated with a significant reduction in rates of CLABSI. In several of our ICUs, no CLABSIs occurred for >2-year time periods. Our findings differ in several important ways from previous reports. Other investigations included a single ICU that did not use antiseptic catheters[3,6] or collaborative cohort studies that included a large number of different ICUs (community hospitals versus tertiary medical centers).[7] In addition to the elements of the Pronovost et al. study,[7] we included use of chlorhexidine sponges, antibiotic-impregnated catheters, clinical quality rounds where the issue of CLABSI was discussed with nursing and medical staff, and the treatment of CLABSIs as a sentinel event. Furthermore, we included decreases in CLABSI into the P4P structure for ICU and institutional leadership.

As with any bundled intervention aimed at improvement of processes of care and improved patient outcomes, the relative contribution of the individual elements of our approach is unclear. Multivariate modeling of log CLABSI

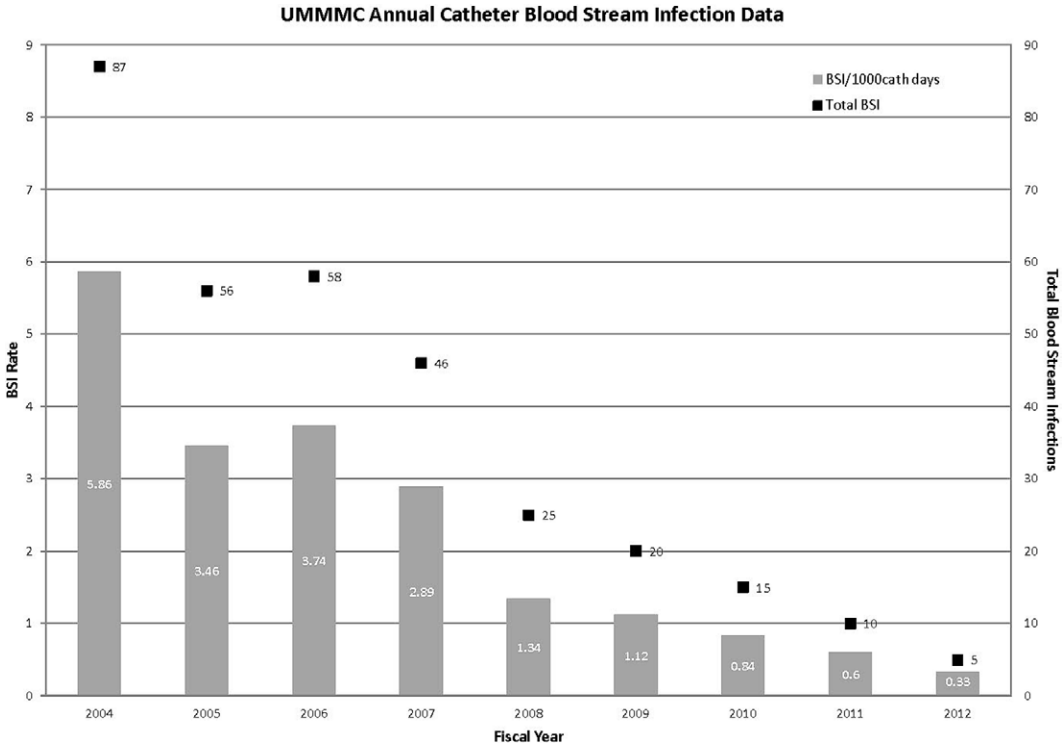

Figure 1. Central line–associated bloodstream infections (CLABSIs) rate and yearly CLABSI numbers as a function of time. There was a significant reduction in the rate over time (approximately 0.4-fold per year). UMMMC = UMass Memorial Medical Center.

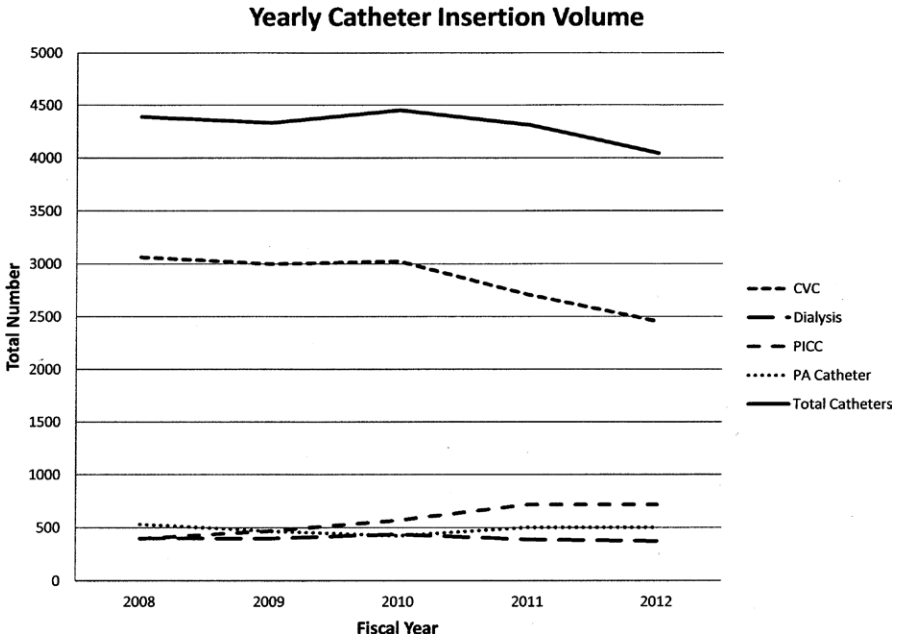

Figure 2. Catheter usage as a function of fiscal year. The number of central venous catheters (CVCs) inserted decreased significantly from 2008 to 2012, whereas the number of peripherally inserted central catheters (PICCs) inserted increased significantly over the same time period There was no change in hemodialysis, pulmonary artery (PA), or total catheter usage.

rates showed a significant reduction in CLABSI rate over the 9-year time period but did not demonstrate a break point (change in slope) in any particular year. Thus, we could neither demonstrate which intervention or group of interventions was responsible for the reduction in the CLABSI rate nor infer causality from any data in the study. The rationale for adding elements to our bundle was the expanding evidence base on the subject since the original publication by Berenholtz et al.,[6] such as the use of chlorhexidine sponges to cover the catheter insertion site. Initially published in abstract form,[22] further evidence supporting the effectiveness of chlorhexidine sponges (or dressings) in decreasing catheter colonization and potentially CLABSIs was added in 2006 in a review and meta-analysis[23] and subsequently in a randomized controlled trial.[10]

While financial incentives are common in the marketplace and increasingly used in all aspects of health care to promote positive behavior with respect to improved

Table 2. Unit-Specific CLABSI Rates and APACHE III/IV Scores

	Neurotrauma		General/transplant		Cardiothoracic		Medical 1		Medical 2		Pediatrics		Medical 3		Medical surgical	
Fiscal year	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV	CLABSI rate	APACHE III/IV
2008	0.94	51	0.92	62	0.39	52	0.91	72	1.43	73	1.53		2.54	65	1.87	49
2009	1.08	51	0.99	65	0.39	52	0.59	70	2.81	72	0.0		0.38	67	0.62	60
2010	1.14	54	0.83	67	0.0	52	0.91	68	1.47	69	0.0		0.77	64	0.66	55
2011	1.01	55	0.4	63	0.45	52	0.63	68	1.08	68	0.0		0.43	62	0.0	57
2012	0.0	56	0.0	59	0.97	55	0.41	65	0.0	66	1.98		0.0	62	0.95	55

CLABSI = central line–associated bloodstream infection; APACHE = Acute Physiology And Chronic Health Evaluation.

patient outcomes, evidence regarding the magnitude of the effect is lacking. If not done correctly, some economists argue that P4P does not necessarily boost performance, and in some cases may even have a negative impact.[24] The Cochrane group has reviewed the evidence in support of P4P in the field of primary care medicine and recently concluded that there is insufficient evidence to support the use of financial incentives to improve the quality of primary health care.[25]

Similarly, an analysis by the World Health Organization is calling for more experimentation and rigorous evaluation of P4P to determine whether its use translates into greater efficiency and improved outcomes in health care.[26] When acute care hospitals are included in the analysis, however, the evidence in support of P4P appears to be somewhat stronger. In a review and meta-analysis of 128 studies both in the United States and abroad, P4P, when tied to specific performance measures, mostly served its purpose, and negative effects were rarely reported. Based on the available evidence, the authors made some specific recommendations, most of which we originally incorporated into the structure of our program. These recommendations include selection of P4P targets based on baseline data and room for improvement, involvement of stakeholders and communication of the program throughout development, implementation and evaluation, focus on quality improvement and achievement, and distribution of incentives at the individual level.[27]

Each episode of CLABSI in our ICUs prompted a full investigation in an RCA meeting attended by all key stakeholders. As an example, the event reviews in our ICUs identified the need for a photographic atlas demonstrating proper alternative applications of CVC dressings in the internal jugular vein position. Recent data demonstrate that disrupted and dirty dressings contribute to CLABSIs.[28] Another root cause demonstrated the need to have improved education on the technique of obtaining blood cultures, which was the most commonly cited issue. Despite an ongoing multifaceted educational effort, the frequency of problems involving obtaining blood cultures has not abated.

The use of CDC/NHSN surveillance definitions for tracking CLABSIs merits some discussion. As of January 2011, all hospitals have been required to report CLABSIs in ICUs to the CDC/NHSN using these definitions as part of the Medicare Pay-for-Reporting program. The definitions rely on a mixture of objective criteria (blood cultures) and subjective criteria (the determination whether a bacteremia is due to central venous catheterization or hematogenous spread from another source). Although useful as a quality control tool to benchmark against national data, there is potential for the introduction of reporting errors.

Specifically, there is potential for false negatives due to the lack of consideration of catheter cultures within the reporting criteria and the possibility that true CLABSI infections are ascribed to other sites. At the same time, there is potential for false-positive adjudication of CLABSI due to the reliance on a single positive blood culture for a definition for *Enterococcus* and *Candida* bloodstream infections. Indeed, on close review of each case during the event reviews (RCA), it was felt that for some of the cases that

Table 3. Yearly Microbiology of Central Line–Associated Bloodstream Infections

Pathogen	2005	2006	2007	2008	2009	2010	2011	2012
CNS	36 (52)	43 (68)	19 (37)	13 (45)	7 (37)	8 (50)	4 (36)	0
SA	7 (10)	1 (2)	2 (4)	0	0	1 (6.25)	0	1 (20)
MRSA	1 (1.5)	2 (3)	5 (10)	3 (10)	0	0	0	0
ENT	5 (7)	4 (6)	5 (10)	1 (4)	1 (5)	0	1 (9)	1 (20)
VRE	2 (3)	2 (3)	6 (12)	2 (7)	3 (16)	2 (12.5)	1 (9)	0
Streptococcus species	1 (1.5)	1 (2)	0	0	0	0	0	0
Candida species	9 (13)	7 (11)	8 (16)	6 (21)	3 (16)	4 (25)	4 (36)	0
Gram negatives	8 (12)	3 (5)	6 (12)	4 (14)	5 (26)	1 (6.25)	1 (9)	3 (60)

Data are presented as *n* (%).

CNS = coagulase-negative staphylococci; SA = *Staphylococcus aureus*; MRSA = methicillin-resistant *S aureus*; ENT = *Enterococcus* species; VRE = vancomycin-resistant *Enterococcus* species.

Table 4. Summary of Key Findings During Root Cause Analyses and Subsequent Interventions

Process identified	Number of events	Intervention
Blood culture draw technique (probable false-positive cultures due to faulty technique such as single blood culture, or draw via preexisting central venous catheter)	29	1. Improvement of online education tool. 2. Nursing staff education by Nurse Managers. 3. Reeducation of staff through quality rounds. 4. Periodic updates of Critical Care Operations Committee by hospital epidemiologist.
Line care	10	1. Distribution of illustrations on how to secure central dressing in internal jugular position to prevent the weight of the catheter from pulling off the dressing. 2. Reeducation of nursing staff on line care, with particular focus on adequate cleaning of claves for every line access.
High-risk catheter	7	1. Reeducation of staff through quality rounds. 2. Development of electronic tracking tool in eCare Manager, notification of bedside staff in real time.
Alternate infection investigation	6	1. Reminder to clinical teams involved in the case to evaluate patients for alternate sources of infection.
Miscellaneous		
Insertion technique	6	1. Development of online educational tool required to be completed by all LIPs who insert, or assist with, insertion of CVCs. 2. Reeducation of staff through quality rounds. 3. PICC/CVC inserted outside of UMMHC acute care areas, and catheters inserted at other institutions are all considered high-risk lines until insertion technique according to CDC guidelines can be verified.
Adherence to quality assurance checklist	4	
PICC in situ at time of ICU admission	4	

LIP = licensed independent practitioner; CVC = central venous catheter; PICC = peripherally inserted central catheter; ICU = intensive care unit; UMMHC = UMass Memorial Healthcare; CDC = Centers for Disease Control and Prevention.

met the CDC/NHSN case definition there was no evidence of true infection and instead the case was a false positive due to a contaminated blood culture. It is important to state though that for the purpose of statistical analysis, these cases were counted toward CLABSI, and therefore our true CLABSI rates may be even lower than what is reflected in our statistical analysis. Furthermore, the CDC changed the surveillance definitions in 2008: The agency removed the criterion that allowed a single positive blood culture caused by common skin commensals to represent an infection if appropriate antibiotic treatment was administered.[29] Whether this change in definition has had any impact on public reporting is unclear. However, it is likely that the possibility of hospitals "gaming" the reporting system has been reduced. In addition, several investigations have demonstrated that the accuracy of reporting data can be variable due to misinterpretation of components of the NHSN definitions, which may complicate interpretation of data, and interinstitutional comparisons.[30,31] In this regard, our hospital underwent an independent review of reported CLABSIs for 1 year (July 1, 2009–June 30, 2010) by the Massachusetts Department of Public Health.

Our CVC usage decreased steadily over time. This observation is most likely the result of better adherence to catheter removal when indicated (daily checklist) and to an increasing reliance on PICCs. Other studies have noted substantial or increasing reliance on PICCs.[32] Although the PICCs in our institution are uncoated, they are inserted in the interventional radiology suite where the same catheter bundle has been implemented. This practice has likely contributed to our reduction in CLABSIs.

There have been no cases of CLABSIs due to MRSA since 2009. It is tempting to associate this observation with the use of minocycline/rifampin (MR)–impregnated catheters. These devices became the only anti-infective catheter that was used in the emergency departments, ICUs, and the operating rooms since 2009. However, the efficacy of the MR catheter against MRSA is unclear. Hanna et al.[33] demonstrated a significant reduction in nosocomial and multidrug-resistant bacteremias when MR catheters were introduced in their institution. However, the biggest reductions were noted for coagulase-negative staphylococci and both vancomycin-sensitive and vancomycin-resistant enterococci. On the contrary, in a follow-up study, the same authors showed that routine use of the MR catheters did not promote bacterial resistance (*S aureus* and coagulase-negative staphylococci) to tetracycline or rifampin but in fact were associated with a stable or declining resistance

pattern.[34] Finally, recent in vitro data show that MR catheters are not particularly effective at preventing MRSA-induced biofilm formation.[35]

We believe our approach to CLABSI prevention to be one of the most comprehensive published to date, and while proven very effective over a 9-year time period, it raises the question of cost effectiveness. Rather than reporting gross expenses for each bundle item, we have chosen to calculate the cost associated with the use of the MR catheter, as well as the chlorhexidine dressing for the following reason: The guideline for prevention of intravascular catheter-related infections by the CDC[36] provides a framework for CVC insertion and maintenance, which is considered standard of care. Our organization would therefore incur the cost of any bundle item within this guideline, even in the absence of our more comprehensive approach. The only 2 items currently not recommended by the CDC (unless rates are unacceptably high) are anti-infective catheters and chlorhexidine catheter dressings. The cost for an uncoated CVC for UMass Memorial Health Care at present is $29.00, and for the MR-coated CVC is $69.00, while the cost for the chlorhexidine dressing is $5.97 each. In FY 2009, when the organization switched to chlorhexidine dressings, and MR catheters across all acute care areas, we had 20 CLABSIs in the organization (baseline), compared with only 5 CLABSIs in the last FY reported here (an absolute reduction of 15 cases). For the last FY, 2229 coated and 10 uncoated CVCs were used across all acute care areas, resulting in excess cost of $103,000 compared with using uncoated catheters alone without any chlorhexidine dressings. Assuming the CDC estimate of $16,500 for each episode of CLABSCI,[1] our approach would therefore result in an annual savings of approximately $145,000 ($247,500 in savings by virtue of preventing 15 cases of CLABSI, minus the gross expense for coated CVCs and chlorhexidine dressings of $103,135). Therefore, based on economic data published in the literature[37,38] and in light of the fact that we used our existing infrastructure (apart from the acquisition of line carts), our bundle "plus" approach is very likely cost effective. It is tempting to speculate that there is potential for further cost reduction if we are able to sustain the current low rates of CLABSI even if anti-infective coated catheters are eliminated from the bundle.

This report has several weaknesses, which include the before and after design of this quality control initiative, as opposed to the more rigorous randomized controlled clinical trial design. Adherence to best practice patterns as required in the clinical practice guidelines was self-reported for all CVCs inserted outside the ICU setting and collected through a tool embedded in the electronic medical record for CVCs placed in the ICU. Since there have been no independent audits to determine the fidelity of the compliance data of the self-reporting process, we cannot confirm its accuracy and validity. However, given the sustained reduction in CLABSI rates over the 9-year period reported here, adherence to the elements of the bundle was likely high.

In summary, use of a multimodal approach to catheter care including chlorhexidine-impregnated dressings and anti-infective catheters was associated with a 92% decrease in CLABSI over a 9-year period.

Appendix Table 1. Current Centers of Disease Control and Prevention CLABSI Definitions

Criterion 1	Patient has a recognized pathogen cultured from 1 or more blood cultures, and the cultured organism is not related to an infection at another site.
Criterion 2	Patient has at least 1 of the following symptoms or signs: fever (>38°C), chills, or hypotension; and signs and symptoms and positive laboratory results are not related to an infection at another site; and common skin commensal is cultured from 2 or more blood cultures drawn on separate occasions.
Criterion 3	Patient ≤1 year of age has at least 1 of the following signs: fever (>38°C core), hypothermia (<36°C core), apnea, or bradycardia; and the signs and symptoms and positive laboratory results are not related to an infection at another site; and common skin commensal is cultured from 2 or more blood cultures drawn on separate occasions.
Previous CLABSI definitions	
Criterion 1	Patient has a recognized pathogen in the blood, and the pathogen is not related to an infection at another site.
Criterion 2	Patient has fever (>38°C), chills, or hypotension and any of the following: 1. A common skin contaminate is isolated from at least 2 blood cultures drawn on separate occasions and the organism is not related to infection. 2. A common skin contaminant is isolated from a blood culture in a patient with an intravascular device, and the physician institutes appropriate antimicrobial therapy. 3. A positive antigen test on blood and the organism is not related to infection at another site.
Criterion 3	Clinical sepsis was diagnosed when the patient had either fever, hypotension, or oliguria, and all of the following: 1. Blood not cultured or no microorganism isolated; 2. No apparent infection at another site; and 3. Physician institutes appropriate antimicrobial therapy for sepsis.

CLABSI = central line–associated bloodstream infection.

Appendix Table 2. One-Sample Kolmogorov–Smirnov Test

		Normal parameters[a,b]		Most extreme differences				
	n	Mean	SD	Absolute	Positive	Negative	Kolmogorov–Smirnov Z	Asymptotic significance (2-tailed)
Residual for central line days	69	0.0000	398.05279	0.075	0.074	−0.075	0.625	0.829
Residual for lnrateplus1	69	0.0000	0.43818	0.064	0.064	−0.037	0.533	0.939

[a]Test distribution is normal.
[b]Calculated from data.

Appendix Table 3. Days Since Last CLABSI and Longest Time Without a CLABSI for Individual Units

Unit	Days since last CLABSI	Longest period of time without a CLABSI
Neurotrauma	157	510
General surgery/transplant	212	729
Cardiothoracic	649	649
Medical 1	294	329
Medical 2	68	625
Pediatrics	347	1562
Medical 3	784	784
Medical surgical	225	910

CLABSI = central line–associated bloodstream infection.

DISCLOSURES

Name: J. Matthias Walz, MD.
Contribution: This author helped design and conduct the study, analyze the data, and write the manuscript.
Attestation: J. Matthias Walz has seen the original study data, reviewed the analysis of the data, approved the final manuscript, and is the author responsible for archiving the study files.
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