Infection prevention practices in adult intensive care units in a large community hospital system after implementing strategies to reduce health care-associated, methicillin-resistant *Staphylococcus aureus* infections

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Background: A range of strategies and approaches have been developed for preventing health care-associated infections. Understanding the variation in practices among facilities is necessary to improve compliance with existing programs and aid the implementation of new interventions.**

Methods: In 2009, HCA Inc administered an electronic survey to measure compliance with evidence-based infection prevention practices as well as identify variation in products or methods, such as use of special approach technology for central vascular catheters and ventilator care. Responding adult intensive care units (ICUs) were those considering participation in a clinical trial to reduce health care-associated infections.

Results: Responses from 99 ICUs in 55 hospitals indicated that many evidenced-based practices were used consistently, including methicillin-resistant *Staphylococcus aureus* (MRSA) screening and use of contact precautions for MRSA-positive patients. Other practices exhibited wide variability including discontinuation of precautions and use of antimicrobial technology or chlorhexidine patches for central vascular catheters. MRSA decolonization was not a predominant practice in ICUs.

Conclusion: In this large, community-based health care system, there was substantial variation in the products and methods to reduce health care-associated infections. Despite system-wide emphasis on basic practices as a precursor to adding special approach technologies, this survey showed that these technologies were commonplace, including in facilities where improvement in basic practices was needed.

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Health care-associated infections (HAIs) are an ongoing problem in US health care facilities. For example, infections because of methicillin-resistant *Staphylococcus aureus* (MRSA) are especially prevalent, accounting for 75% of intensive care unit (ICU) *S aureus* infections and 60% of non-ICU *S aureus* infections.1 This has a tremendous impact on patients, with invasive MRSA causing an estimated 19,000 deaths and 278,000 hospitalizations in 2005.2 In addition, there are approximately 250,000 catheter-related bloodstream infections because of all microorganisms per year, with 80,000 infections occurring in ICUs.3 Complications of catheter-related bloodstream infections include prolonged ICU and hospital stays and increased morbidity and mortality with an estimated 30,000 deaths per year.3,4

As a result, there has been considerable pressure to reduce HAIs. Common practices include the implementation of strategies aimed at a particular organism, such as MRSA. MRSA prevention strategies range from “active screening”—actively culturing the anterior nares
of patients on admission to ICUs—to the implementation of contact precautions for all MRSA-positive patients and to the use of various topical or systemic antimicrobial agents to “decolonize” MRSA-positive carriers and thereby prevent subsequent MRSA infection. Whereas strategies that specifically target a particular organism like MRSA are widely accepted, many now question whether universal strategies that impact all pathogens may be more effective, such as the use of universal chlorhexidine gluconate (CHG) bathing in place of usual soap and water baths for all patients. This is particularly relevant because of rising numbers of other antibiotic-resistant pathogens, such as multidrug-resistant gram-negative bacilli, as well as the limits to hospital resources dedicated to infection control and prevention. In addition, there is the ever-present interest in special products, such as impregnated central lines and antiseptic patches, which promise to help reduce infections but are more costly than traditional products.

Evidence supports all of these approaches, from active screening to decolonization to universal pathogen control, as potential strategies for reducing HAIs. However, there is still a lack of baseline information of current practices. There have been few surveys of infection prevention practices and compliance with recommendations, and these studies have shown a high amount of variation in compliance based on local practices. Additional study to understand the variation that exists in current practices will be necessary to both evaluate current recommendations and inform comparative effectiveness studies that will guide future HAI prevention practices. National pressure to adopt a single strategy is mounting, and thus an assessment of current practices would greatly inform the field.

This paper presents a survey of the practices present in subset of ICUs in a large, national hospital system. Most of these ICUs are within community hospitals, which provide the majority of hospital care in the United States. This survey of practices in these ICUs provides valuable insight into the adherence to evidence-based practices as well as the variation in products and processes used. The information from this survey provides a snapshot of current practices that will ultimately guide investigation into the clinical effectiveness of strategies to reduce HAIs because of MRSA or other organisms.

METHODS

Setting

HCA Inc is one of the largest health care systems in the United States. HCA-affiliated facilities (collectively referred to as HCA) currently include 166 hospitals, 116 outpatient surgery and endoscopy centers, and over 400 physician practices in 23 states and England. HCA facilities provide nearly 5% of major hospital care, a total of 35 hospitals did not participate because of pre-established use of CHG cloths in the ICU.

Survey methods

An electronic survey of adult ICUs was administered to assess the consistency of practices surrounding the prevention of HAIs. The survey was requested of hospitals that indicated interest in participating in a clinical trial to reduce HAIs because of MRSA, excluding those facilities that did not have an ICU, were specialty care/psychiatric facilities, or were dedicated children’s hospitals (n = 13). In addition, those ICUs in which routine CHG bathing was standard practice for more than one third of patients were excluded from the survey as an initial screen because this intervention was in direct conflict with the proposed clinical trial. Whereas this threshold would include mixed medical/surgical populations where CHG bathing for cardiovascular surgery is the standard of care, a total of 35 hospitals did not participate because of pre-established use of CHG cloths in the ICU.

This survey was designed with several parts: (1) hospital and ICU characteristics, including type, number of admissions, and average length of stay; (2) self-assessment of average compliance with basic infection prevention processes; (3) MRSA prevention strategies in use, including screening, isolation, and decolonization; (4) environmental cleaning practices; and (5) use of special approach technology for prevention of central line and ventilator-associated infections.

Survey questions were sent in September 2009 to infection preventionists and ICU nursing directors, who jointly responded for each adult ICU location using an electronic SurveyMonkey based tool (SurveyMonkey, Palo Alto, CA). Survey results were downloaded into Microsoft Excel (Microsoft Corp, Redmond, WA) for tabulation after validating responses for nonstandard and free text responses.

RESULTS

Respondent hospital and ICU characteristics

Survey responses were obtained from 99 adult ICUs in 55 hospitals. The majority of these hospitals were community based; 5% were major medical teaching hospitals. Hospitals were located across 16 states with an average licensed bed size of 288 (range, 67–875; median, 257) and an average daily census of 163 (range, 13–537; median, 157). Average annual admission was 12,023 (range, 1,459–37,478; median, 12,005). Bed size and geographic distribution are presented in Table 1. The geographic distribution reflects both the wide geographic range as well as a large number of HCA facilities in Florida and Texas. Classification of the 99 adult ICUs are presented in Table 1. Annual admissions for these ICUs averaged 1,695 (range, 161–4,689; median, 1,299).

Self-assessment of compliance with infection prevention practices

The median self-reported compliance rate across ICUs for basic infection control practices was 90% (range, 50%-100%) for hand hygiene, 90% for central line-associated bloodstream infections (CLABSI) practice bundles (range, 30%-100%), and 90% for ventilator bundles (range, 30%–100%). Compliance less than 80% was reported in 22% (22) of ICUs for hand hygiene, 15% (15) of ICUs for CLABSI practice bundles, and 16% (16) of ICUs for ventilator bundles. Validation of compliance was not performed.

Patient bathing occurred daily in 98% of ICUs, with 7.9% using CHG bathing products. Oral care of ventilated patients occurred once daily in 18% of ICUs, twice daily in 5%, every 4 hours in 22% and every 2 hours in 35%. Of all ICUs, 6.5% used CHG-based oral care; the others used a variety of other oral care products that did not include CHG.
MRSA prevention strategies

Compliance with contact precaution practices for MRSA is provided in Table 2. Active surveillance precautions for MRSA colonization occurred for 100% of ICU direct admissions or transfers because of implementation of the HCA MRSA “ABC” initiative. Nares screens for active surveillance were taken within 24 hours of admission. The prevalence of MRSA in adult ICUs averaged 22% (range, 6.9%-43.9%) based on analysis of microbiology testing for colonization and infection. 

Body sites screened for MRSA were predominantly bilateral nares (85%) or unilateral nares (15%). Other sites also assessed for MRSA colonization included wounds (12%), axillae (2%), and groin (1%). In addition to nares screen at ICU admission, 3% of ICUs routinely repeated screens for patients with at least a 14-day stay. Nares are the most common site to detect MRSA carriage. Screening other body sites and repeat screening are recommended for enhanced control efforts where colonized patients would not be identified by nares testing alone.8

Contact precautions are enhanced strategies intended to prevent transmission of infectious agents, which are spread by direct or indirect contact with the patient or the patient’s environment. Recommendations for health care personnel caring for patients on contact precautions are to wear a gown and gloves for all interactions that may involve contact with the patient or potentially contaminated areas in the patient’s environment.5 As reported in Table 2, 86% of responding ICUs standardized the wearing of gloves upon entry to the patient’s room, and 76% standardized the wearing of gowns upon room entry. The remainder permitted barrier protection selection based on anticipated contact with the patient or their immediate environment. Masks are not recommended as a routine precaution strategy to prevent transmission but are recommended for splash-generating procedures, respiratory exposure, and to prevent transmission from heavily colonized sources such as burns. Approximately one third of facilities implemented routine mask use as a standard of practice to minimize exposure of health care personnel in ICUs based on MRSA-positive status, patient symptoms, and tasks performed (Table 2). Although private rooms are preferred, cohorting MRSA-colonized patients is acceptable.5,13 Discontinuing contact precautions remains an unresolved issue,5,18 and 68% reported having a policy for discontinuing contact precautions.

In accordance with current recommendations against routine decolonization,5,18 only 5% of surveyed ICUs regularly decolonized all MRSA-positive patients. Forty percent of ICUs performed targeted decolonization, mostly in MRSA-positive patients prior to cardiovascular surgery in accordance with current recommendations.5,19,20 When presurgical decolonization was performed, it mainly consisted of mupirocin in cardiovascular surgery patients and was observed with high compliance (range, 80%-100%). Variation in the consistency of decolonization among patients within a single ICU was dependent on the unit-based ICU surgical population (ie, dedicated surgical cardiothoracic ICU or a mixed unit where a subportion of patient were surgical cardiothoracic). In addition, for ICU patients undergoing a surgical procedure, 45% of surgical ICUs routinely gave CHG preoperative baths to 80% to 100% of surgical patients, and 21% of surgical ICUs gave CHG preoperative baths to 10% to 50% of surgical patients.

Although 65% of protocols for MRSA-positive patient were initiated by physician preference, there was variation in decolonization regimens used and duration of therapy because of the patient population in a particular ICU. When decolonization was performed, the most common regimen was mupirocin alone for 3 to 7 days (regimen reported by 43% of ICUs). CHG bathing for 1 to 10 days plus mupirocin for 3 to 7 days was the regimen reported by 35% of ICUs. Finally, CHG bathing for 10 days plus 10 days mupirocin plus oral antibiotics was the regimen reported by 5% of ICUs.

Table 1
Respondent hospital and ICU characteristics

| Number of facilities | Percent of facilities |
|----------------------|-----------------------|
| Total hospitals responding | 55                     |
| Hospital bed size | | |
| 6-24 | 0 | 0 |
| 25-49 | 0 | 0 |
| 50-99 | 4 | 7 |
| 100-199 | 14 | 25 |
| 200-299 | 15 | 27 |
| 300-399 | 12 | 22 |
| 400-499 | 5 | 9 |
| 500-699 | 5 | 9 |
| Hospital geographic region (AHA)* | | |
| Mid-Atlantic/NE | 1 | 2 |
| S Atlantic | 28 | 51 |
| E North Central | 0 | 0 |
| E South Central | 4 | 7 |
| W North Central | 5 | 9 |
| W South Central | 12 | 22 |
| Mountain | 3 | 5 |
| Pacific | 2 | 4 |
| Total ICUs responding | 99 |

Table 2
MRSA isolation precautions and use of antimicrobial products in adult ICUs

| Practices | % Performing practice |
|-----------|-----------------------|
| MRSA contact precautions practice | | |
| Active surveillance screening on admission to ICU | 100 |
| Contact precautions if MRSA | 99 |
| Private room whenever possible | 94 |
| Cohort patients with same MDRO | 34 |
| Glove use | | |
| Gloves to enter room | 86 |
| Gloves only if patient contact anticipated | 14 |
| Gown use | | |
| Gown to enter | 76 |
| Gown only if patient contact anticipated | 24 |
| Masks used for all MRSA+ patients | 29 |
| Masks used in patients with respiratory symptoms | 32 |
| Use of disposable patient care equipment | 87 |
| Have a policy for discontinuing precautions | 68 |
| Use of antimicrobial products | | |
| Antimicrobial CVC dressings | | |
| Biopatch CHG dressing | 34 |
| 3M Tegaderm with CHG | 15 |
| Algipex (silver) dressing | 32 |
| Total use of antimicrobial CVC dressing | 81 |
| Antimicrobial CVC | | |
| CHG-silver coated CVC | 44 |
| Minocycline/rifampin CVC | 7 |
| Silver/platinum CVC | 10 |
| Antimicrobial heparin coated CVC | 8 |
| Total use of antimicrobial CVCs | 69 |
| Use of both antimicrobial catheter and CVC dressing | 20 |

AHA, American Hospital Association.*AHA-defined regions: New England: CT, MA, ME, NH, RI, VT; Mid-Atlantic: NJ, NY, PA; South Atlantic/associated territories: DC, DE, FL, GA, MD, NC, SC, VA, WV, Puerto Rico, Virgin Islands; East North Central: IL, IN, MI, OH, WI; East South Central: AL, KY, MS, TN; West North Central: IA, KS, MN, MO, ND, NE, SD; West South Central: AR, LA, OK, TX; Mountain: AZ, CO, ID, MT, NM, NV, UT, WY; Pacific/associated territories: AK, CA, HI, OR, WA, American Samoa, Guam, Marshall Islands, Northern Mariana Islands. All states within a given region may not be represented in data.
The majority of surveyed adult ICUs (90%) routinely used a quaternary ammonium-based product for terminal cleaning at discharge. Diluted bleach and phenolic-based disinfectants were utilized by the remainder. In addition, 32 (32%) of ICUs reported special practices for isolation precaution rooms at terminal cleaning. Among these, 91% reported changing privacy curtains, and 71% discarded unused disposable supplies.

Use of special products and technology

For skin antisepsis prior to central line insertion, 88 (90%) ICUs used a CHG plus alcohol product ≥ 90% of the time, 6 (6%) primarily used CHG plus alcohol 70% to 80% of the time, and 5 (4%) routinely used an antiseptic other than a CHG base. Antiseptic solutions were available in prepackaged vendor kits or individually picked supplies.

The use of special approach technologies are reported in Table 2. Most ICUs (81%) used an antimicrobial dressing, and 69% reported use of an antimicrobial impregnated central line. One in 5 ICUs (20%) used both. The percent purchase volume of antimicrobial-impregnated central venous catheters (CVCs) from 67% in 2005 to 79% in 2009 for HCA company wide. Of note, peripherally inserted central catheters with impregnated antimicrobial agents were not available at the time of this survey.

Use of antimicrobial products was substantial even in ICUs that reported needing improvement in basic practices (Table 3). Among ICUs reporting less than 80% compliance with hand hygiene, 77% (17) routinely used antimicrobial CVC dressings, and 59% (13) routinely used antimicrobial catheters. Similarly, among ICUs reporting less than 80% compliance with CLABSI bundles, 80% (12) routinely used antimicrobial CVC dressings, and 73% (11) routinely used antimicrobial catheters. Use of special products did not appear to be different among groups reporting high versus low compliance with basic practices.

DISCUSSION

Evidenced-based protocols have been shown to reduce HAIs, resulting in an elimination of as many as 65% to 70% of cases of CLABSIs and catheter-associated urinary tract infections (CAUTIs), and up to 55% of cases of VAPs and SSIs. Consequently, there have been increased demands for evidence-based infection control practices to both improve patient care and meet external pressures from state requirements and the Centers for Medicare and Medicaid Services, yet there are few data regarding how well these programs have been incorporated into local workflows or the variety that exists among various facilities. To understand better these issues, we surveyed 55 hospitals regarding the use of previously established infection control programs in the ICU. We found that there was variability in infection prevention and control measures and that the use of special approaches and technologies was not always subsequent to the full implementation of basic evidence-based practices.

Implementation of evidence-based practices has been shown to reduce HAIs, and, therefore, consistent use of these basic practices (Table 2) should precede the deployment of technology solutions. This is in agreement with the Society for Healthcare Epidemiology of America Compendium guidance that recommends special approaches and technology only if CLABSI rates remain unacceptably high despite implementation of basic practices. This survey revealed variation in compliance with infection prevention practices. Compliance with active surveillance, hand hygiene, and use of gloves and gowns was consistent; however, there remains room for improvement. The observed variation appeared to be a product of local practices and culture and may have contributed to the high reliance on special approach technologies.

Whereas technology may appear to be a quick solution to the problem of HAIs, it should be considered a special approach and implemented only after assuring consistent, high compliance with basic, evidence-based practices. We found that antimicrobial catheters and CVC dressings were highly used regardless of compliance level with basic practices. Further research would be valuable to understand the reasons behind the use of these antimicrobial products to understand whether guidance is being followed. For example, among ICUs with lower compliance with basic practices, we do not know whether antimicrobial technologies were adopted in lieu of improving basic practices in response to elevated CLABSI rates. Similarly, we do not know whether ICUs with high compliance with basic practices adopted antimicrobial technologies preventatively or in response to elevated rates. Discussion with individual hospitals revealed that local pressure from management—because of reduced reimbursement for HAIs and increased public reporting—drove some facilities to adopt technology before assessing compliance with basic practices. External pressures, from reporting requirements to intense marketing campaigns, in combination with the inherent challenges associated with changing behaviors and culture, has increased the interest in special approach technologies. Accordingly, there is an overall need to emphasize adherence to evidence-based practices and the appropriate use of technology.

The ICUs participating in this survey were encouraged to utilize programs previously shown to be associated with high compliance with basic practices, including guidance from experts in infection prevention, education, ownership and execution by clinicians at the local level, using “bundles” of care, data-driven tools to assess impact and to provide feedback to clinicians, and improvement of the safety culture. Although support for these processes exists in the surveyed ICUs, additional efforts will be necessary to further increase compliance and reduce variation. This will be promoted through the development of reliable processes in combination with effective tools for teamwork and communication to achieve a culture of safety. The goal is for the integration of patient safety
and teamwork with evidenced-based interventions to reduce variation and achieve sustained improvement.

The major limitation of this survey is the self-reported nature of the survey data. Compliance with evidence-based practices was not validated. However, a parallel tracking of hand sanitizer and disposable gown orders—indirect indicators for hand hygiene and barrier precautions, respectively—showed dramatic increases in these process measures related to reported compliance with evidence-based practices. In addition, the use of chlorhexidine bathing and MRSA decolonization may be underestimated because this survey was undertaken by hospitals responding to a request for participation in a trial that required minimal use of these agents. The use of CHG based products is a considered a special approach and was known to be a study exclusion criteria which resulted in a lower practice prevalence.

CONCLUSION

The move toward public reporting mandates and changes in reimbursement, such as value-based purchasing, has dramatically increased hospital and public awareness to around HAI prevention. Rigorous adherence to evidenced-based interventions and appropriate use of technology can significantly impact HAI rates, but compliance with these measures varies greatly among facilities. Therefore, the quest to eliminate HAIs will require the development of effective strategies and action plans that can be implemented at the facility level while taking into account local resources and culture.

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References

1. Hidron AI, Edwards JR, Patel J, Horan TC, Sievert DM, Pollack DA, et al. NHSN annual update: antimicrobial-resistant pathogens associated with healthcare-associated infections: annual summary of data reported to the National Healthcare Safety Network at the Centers for Disease Control and Prevention, 2006-2007. Infect Control Hosp Epidemiol 2008;29:965-1011.

2. Klein E, Smith DL, Laxminarayan R. Hospitalizations and deaths caused by methicillin-resistant Staphylococcus aureus, United States, 1999-2005. Emerg Infect Dis 2007;13:1840-6.

3. Kleven RS, Edwards JR, Richards CL Jr, Horan TC, Gaynes RP, Pollack DA, et al. Estimating health care-associated infections and deaths in US hospitals, 2002. Public Health Rep 2007;122:160-6.

4. Blot SI, Depuydt P, Annemans L, Benoit D, Hoste E, De Weele J, et al. Estimated health care-associated infections and deaths in US hospitals, 2002. Public Health Rep 2007;122:160-6.

5. Siegel JD, Rhinehart E, Jackson M, Chiarello L. 2007 Guideline for isolation precautions: preventing transmission of infectious agents in health care settings. Am J Infect Control 2007;35:365-164.

6. Bleasdale SC, Trick WE, Gonzalez IM, Lyles RD, Hayden MK, Weinstein RA. Effectiveness of chlorhexidine bathing to reduce catheter-associated bloodstream infections in medical intensive care unit patients. Arch Intern Med 2007;167:2073-9.

7. Popovich KJ, Hota B, Hayes R, Weinstein RA, Hayden MK. Effectiveness of routine patient cleansing with chlorhexidine gluconate for infection prevention in the medical intensive care unit. Infect Control Hosp Epidemiol 2009;30:959-63.

8. Evans HL, Delli TH, Chan J, Nathans AB, Maier RV, Cuschieri J. Effect of chlorhexidine whole-body bathing on hospital-acquired infections among trauma patients. Arch Surg 2010;145:240-6.

9. Weber DJ, Hoffmann KK, Rutala WA, Pyatt DG. Control of healthcare-associated Staphylococcus aureus: survey of practices in North Carolina hospitals. Infect Control Hosp Epidemiol 2009;30:909-11.

10. Mansan FA, Ponziello J. Compliance with routine use of gowns by healthcare workers (HCWs) and non-HCW visitors on entry into the rooms of patients under contact precautions. Infect Control Hosp Epidemiol 2007;28:337-40.

11. Pettinger A, Nettlemann MD. Epidemiology of isolation precautions. Infect Control Hosp Epidemiol 1991;12:303-7.

12. Krein Sl, Kowalski CP, Hofer TP, Saint S. Preventing hospital-acquired infections: a national survey of practices reported by US hospitals in 2005 and 2009. J Gen Intern Med 2012;27:773-9.

13. Fast Facts on US Hospitals. American Hospital Association, 2010. Available from: http://www.aha.org/aha/resource-center/Statistics-and-Studies/fast-facts.html. Accessed May 18, 2011.

14. US Census Bureau. US census report. 2000. Available from: http://www.census.gov/main/www/cen2000.html. Accessed April 15, 2011.

15. Muto CA, Jernigan JA, Ostrosky WS, Richet HM, Jarvis WR, Boyce JM, et al. SHEA guideline for preventing nosocomial transmission of multidrug-resistant strains of Staphylococcus aureus and enterococci. Infect Control Hosp Epidemiol 2003;24:362-86.

16. Getting Started Kit: Reduce Methicillin-Resistant Staphylococcus aureus (MRSA) Infection How-to Guide. Cambridge (MA): 5 Million Lives Campaign, Institute for Healthcare Improvement. 2008. Available from: http://www.ihi.org/IHI/Programs/Campaign/MRSAInfection.htm. Accessed April 15, 2011.

17. Perlin JR, Septimus E, Englebright J, Hickok J, Moody J, Randall A, et al. A multipronged approach to reduce methicillin resistant Staphylococcus aureus infections in community hospitals. Society for Healthcare Epidemiology of America Annual Meeting; 2009, San Diego, CA. Presentation 39-207.

18. Yokoe DS, Merz EL, Anderson DJ, Arias KM, Burstin H, Calfee D, et al. A compendium of strategies to prevent healthcare-associated infections in acute care hospitals. Infect Control Hosp Epidemiol 2008;29(Suppl 1):S12-21.

19. Siegel JD, Rhinehart E, Jackson M, Chiarello L. Healthcare Infection Control Practices Advisory Committee. Management of multidrug-resistant organisms in healthcare settings, 2006. Atlanta (GA): Centers for Disease Control and Prevention; 2006. Available from: http://www.cdc.gov/ncidod/dhqp/pdf/ar/mdroGuideline2006.pdf. Accessed April 15, 2011.

20. Perl TM, Cullen JJ, Wenzel RP, Zimmerman MB, Pfaller MA, Sheppard D, et al. Intranasal mupirocin to prevent postoperative Staphylococcus aureus infections. N Engl J Med 2002;346:1871-7.

21. Umscheid CA, Mitchell MD, Doshi JA, Agarwal R, Williams K, Brennan PJ. A research framework for reducing preventable patient harm. Clin Infect Dis 2010;50:1569-75.

22. Pronovost PJ, Goeschel CA, Wachter RM. The wisdom and justice of not paying for preventable complications. JAMA 2008;299:2197-9.

23. Moody JA, Septimus EJ, Hickok J, Perlin JB. Sustained reduction in healthcare-associated infections in community hospitals. Society for Healthcare Epidemiology of America Annual Meeting; 2011, Dallas, TX. Presentation 32–259.

24. Pronovost P, Needham D, Berenholtz SM, Pronovost PJ, Cosgrove S, Berenholtz SM, et al. An intervention to decrease catheter-related bloodstream infections in the ICU. N Engl J Med 2006;355:2725-32.

25. Furuya EY, Dick A, Perencevich EN, Pogorzelska M, Goldmann D, Stone PW. Central line bundle implementation in US intensive care units and impact on bloodstream infections. PLoS ONE 2011;6:e15452.

26. Pronovost PJ, Cardo DM, Goeschel CA, Berenholtz SM, Saint S, Jernigan JA. A research framework for reducing preventable patient harm. Clin Infect Dis 2011;52:507-13.