Making Health Care Safer II: An Updated Critical Analysis of the Evidence for Patient Safety Practices.

< Prev Next >

Show details

Contents

Search this book

Chapter 10 Prevention of Central Line-Associated Bloodstream Infections: Brief Update Review

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Introduction

Go to:

Central venous catheters (CVCs) are intravascular access devices that terminate within the great vessels of the neck (superior or inferior vena cava, brachiocephalic veins, subclavian vein or internal jugular vein), or a site proximal to the heart. CVCs are vital for the care of hospitalized and critically ill patients, as they provide reliable venous access for clinical activities such as blood sampling, infusion of medications, and hemodynamic measurement. However, CVCs are also the leading cause of healthcare-associated bloodstream infections (BSIs) and are frequently implicated in life-threatening illnesses.[1,2] Infections associated with CVCs are categorized in the literature as either "central-line associated bloodstream infection" (CLABSI), or "catheter-related bloodstream infection" (CRBSI), based on whether surveillance or ascertainment of infection is the desired goal. For instance, the Centers for Disease Control and Preventions' (CDC) National Healthcare Safety Network (NHSN) uses the CLABSI definition for surveillance purposes, defining the term as a laboratory confirmed BSI in any patient with a CVC present either at the time of, or within a 48-hour period before the detection of infection.[3,4] Thus, the CDC-NSHN definition overestimates the true incidence of CRBSI, as some BSIs may be due to infection at other sites (e.g., pneumonia or urinary tract infection) or at sites that are difficult to detect (e.g., translocation from the gastrointestinal tract or mucositis following chemotherapy). In contrast, CRBSI is a more precise and rigorous definition that requires either (a) isolation of the same organism from the catheter and the peripheral blood, (b) simultaneous quantitative blood cultures with a ratio of 5:1 or higher of those from the indwelling CVC compared with peripheral blood, or (c) a differential time to positivity of CVC-derived versus (vs.) peripheral blood culture positivity of more than 2 hours.[5] The CRBSI definition is thus largely used within the context of clinical care and research, whereas the term, CLABSI, is implemented for epidemiologic surveillance.[6] For the purposes of this review, we use the term CLABSI to encompass both of these operational definitions.

Of the approximately 249,000 BSIs that occur in U.S. hospitals each year, 80,000 (32.2%) occur in intensive care unit (ICU) settings.[2] Because CVCs are more frequently used in ICUs than in other areas of the hospital, and the strongest predictor of developing a BSI is the presence of a CVC, the epidemiology of CLABSI has traditionally focused on the critically ill. With over 15 million catheter days in ICUs annually, the potential impact of CLABSI is substantial in this population alone.[6,7] However, in a survey of major medical centers, CVC use was identified in 24.4 percent of patients outside the ICU.[8] Thus, millions of patients both in and out of ICU settings are potentially at risk of developing CLABSI. Although the frequency of CLABSI outside the ICU is largely unknown, Weber and colleagues found that the incidence of CLABSI decreased when patients transitioned from ICUs to step-down units or non-ICU floors.[9] Data from the CDC-NHSN also suggest lower CLABSI rates in patients on hospital wards compared with those in an ICU setting.[10] Furthermore, recent evidence suggests that the incidence of CLABSI in ICUs is significantly lesser than reported in 2001, likely due to a number of efforts aimed at preventing this infection.[11] These efforts notwithstanding, the increasing use of CVCs such as peripherally inserted central catheters (PICCs) outside of ICUs may reflect an important shift in the epidemiology of CLABSI to non-ICU settings.[12] This change is highly relevant, as lack of a uniform patient-care team and absence of comprehensive surveillance efforts in non-ICU settings represent substantial

Views
PubReader
Print View
Cite this Page
PDF version of this title (9.6M)

In this Page
Introduction
What Practices Are Associated With CLABSI Prevention?
How Has CLABSI Prevention Been Implemented?
What Have We Learned About CLABSI Prevention?
Conclusions and Comment
References

Other titles in these collections
AHRQ Evidence Reports
Health Services/Technology Assessment Texts (HSTAT)

Related information
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PubMed

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Turn Off Clear
Prevention of Central Line-Associated Bloodstream Infections: Brief Update Revie...
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obstacles to addressing CLABSI in these areas.

The economic burden of CLABSI is substantial. A recent analysis estimated that each CLABSI episode independently increases length of hospitalization from 7 to 21 days, and adds an attributable cost of about $37,000 (2002 dollars) per patient.[13] The annual national cost of caring for patients who develop CLABSI is estimated to range from $0.67 to $2.68 billion.[13-15] Similar trends exist in European nations, where the incremental expenditure related to CLABSI is estimated at €9,154 (€18,241 [$24,558 in 2012 dollars vs. €9,087 [$12233]) per patient.[16] Given this clinical and economic cost, investigators, policy-makers, and regulatory agencies in the U.S. and abroad have devoted great efforts to curtail CLABSI over the past decade.[17-19]

CLABSIs are potentially preventable through the use of evidence-based practices.[20] The original "Making Health Care Safer" report examined the prevalence, strategies, and costs associated with CLABSI prevention, and found that certain practices (e.g., the use of maximal sterile precautions) were associated with both a decrease in CLABSI risk and reduced cost, whereas others (e.g., intravenous antimicrobial prophylaxis) added expense without clear benefit.[21,22] In this review, we provide an update to the original report by highlighting the most clinically and cost effective strategies associated with CLABSI prevention. To compile this report, we performed a systematic review of the literature and searched multiple databases to identify relevant studies published between 2000 and 2012 using terms such as "Bacteremia," "Catheterization, Central Venous," and "central line-associated bloodstream infection." Our search strategy yielded a total of 1,087 unique manuscripts of which 337 articles were relevant for this report.

What Practices Are Associated With CLABSI Prevention?

Go to:

One of the most important advances in the science of CLABSI prevention has been the identification of individual risk factors associated with this condition. These include (a) lengthy hospitalization before venous catheterization; (b) prolonged duration of catheterization; (c) heavy microbial colonization at the insertion site; (d) heavy microbial colonization of the catheter hub; (e) femoral or internal jugular vein insertion (rather than subclavian vein); (f) operator-inexperience or lack of implementation of best practices during CVC insertion; (g) presence of neutropenia; (h) total parenteral nutrition provided through the catheter; (i) inadequate care/maintenance of the CVC after insertion; and (j) type of CVC.[23-30] Strategies to prevent CLABSI have evolved from targeting these variables.

The CD's Healthcare Infection Control Practices Advisory Committee (HICPAC) recently updated their guidelines to summarize the evidence behind a number of practices associated with CLABSI reduction.[20] As with prior iterations, the update provides levels of recommendation for each clinical practice based on the theoretical rationale, scientific data, applicability and impact of the intervention. Based on the level of evidence in their support, recommendations are divided into five categories, ranging from practices that are strongly recommended and supported by well-designed experimental, clinical, or epidemiologic studies to those that are of unclear value owing to insufficient evidence or lack of consensus regarding efficacy (Table 1). From a conceptual standpoint, these practices can be classified as (a) interventions that may be implemented at the time of CVC insertion; (b) practices best utilized after placement of a CVC; and (c) institutional initiatives to reduce CLABSI.

Table 1, Chapter 10

Categories and recommendations for CLABSI reduction practices from the Healthcare Infection Control Practices Advisory Committee of the Centers for Disease Control and Prevention.

Measures To Prevent CLABSI at Time of Central Venous Catheter Insertion

Hand hygiene before catheter insertion. Hand hygiene is an important practice in the prevention of CLABSI.[31] Hand decontamination with either antiseptic-containing soaps or alcohol-based gels/foams has consistently been shown to reduce CLABSI rates.[32-34] A key strategy in promoting hand hygiene involves educating staff who insert CVCs on the importance of this practice. In a before-and-after study assessing the impact of an educational initiative on hand hygiene, the incidence of CLABSI decreased from 3.9 per 1,000 catheter days to 1.0 per 1,000 catheter days ($P < 0.001$) following education on this topic in an ICU setting.[35] As the most common cause of

CLABSI is entry of skin pathogens during CVC insertion and maintenance, ensuring best practice during catheter placement and handling is crucial for CLABSI prevention (Category IB).[20,36]

All-inclusive catheter-carts or kits. A study by Young and colleagues found that a systems-based intervention featuring a catheter kit (that contained a large sterile drape and 2% chlorhexidine gluconate) led to a significant reduction in CLABSI rates (11.3 per 1,000 CVC-days vs. 3.7 per 1000 CVCs, P<0.01) in a medical-surgical ICU.[37] This approach has been expanded upon by a number of other investigators to include not only a kit of essential items, but a mobile cart that contains all of the equipment needed to insert CVCs.[38,39] The use of an all-inclusive cart or catheter kit minimizes interruptions related to non-availability of necessary equipment and thus lends itself to CLABSI reduction by ensuring maintenance of a sterile field during catheter insertion. Furthermore, the use of carts encourages a consistent approach to CVC insertion by standardizing catheter types, guide-wires, needles, and other essential supplies. Although the use of catheter-carts and kits is not specifically endorsed by the recent HICPAC guidelines,[20] they are pragmatic, relatively low-cost innovations that have been associated with lower CLABSI rates.

Maximal sterile barrier precautions. Several studies have demonstrated that the use of maximal barrier precautions including a cap, mask, sterile gown, gloves, and a sterile full-body drape when inserting CVCs reduces CLABSI.[6,37,40,41] Current HICPAC guidelines thus recommend that maximal sterile barriers are used during insertion of all CVCs (Category IB).[20] The cost-effectiveness of this practice in preventing CLABSI has been established, as the expense of sterile barriers is dwarfed by the additional expense of CLABSI and its subsequent care, even in resource-poor environments.[42] Despite this evidence, a study of 10 ICUs in major academic medical centers published in 2006 reported that fewer than 30 percent had systematically adopted maximal sterile barrier precautions.[43] However, a more recent national survey of infection preventionists, which examined the use of evidence-based practices (including maximal sterile barriers) in Federal and non-Federal hospitals between 2005 and 2009, found that the reported use of this practice is on the rise.[44] This more recent finding highlights the fundamental role of translating evidence into practice regarding CLABSI prevention.

Chlorhexidine for skin antisepsis. In a systematic review and meta-analysis of 8 trials involving 4,143 unique catheter insertions, skin antisepsis with chlorhexidine was found to be associated with a 50 percent reduction in the subsequent risk of CLABSI compared with povidone iodine.[45] A formal economic evaluation by the same authors projected that although costlier initially, the use of chlorhexidine over povidone iodine for insertion site disinfection and CVC care would lead to a 1.6 percent decrease in the incidence of CLABSI, a 0.23 percent decrease in the incidence of death, and a savings of $113 per catheter.[46] Existing HICPAC guidelines endorse the use of chlorhexidine gluconate for skin antisepsis prior to CVC insertion (Category IA).[20]

Antimicrobial catheters. The utility of catheters impregnated with a variety of substances including chlorhexidine-silver sulfadiazine, minocycline-rifampin, benzalkonium chloride, and silver have been evaluated in more than 20 randomized controlled studies and four recent systematic reviews and meta-analyses.[47-51] Meta-conclusions from these reviews remain limited, due to heterogeneity arising from differences in the population, design, and conduct of the pooled studies. For example, in a study involving a pediatric burn population, Weber and colleagues found significant reductions in CLABSI with the use of minocycline and rifampin antimicrobial coated catheters over non-coated catheters.[52] However, a prospective, double-blinded, randomized study in adults failed to show a reduction in CLABSI with a second-generation CVC coated with chlorhexidine and silver sulfadiazine.[53] Due to the initial acquisition cost, variation in benefit according to patient populations, and potential concern for inducing antimicrobial resistance, routine use of antimicrobial CVCs is not recommended.[20,54] However, in facilities where high-rates of CLABSI persist despite deployment and compliance with comprehensive CLABSI prevention efforts, the use of antimicrobial CVCs is considered reasonable by current HICPAC guidelines (Category IA).[20]

The subclavian vein as the insertion point of choice. The site of CVC placement may influence the risk of CLABSI, owing to the differing density of bacterial skin colonization at each entry site. In a multicenter study of 289 patients randomized to undergo venous catheterization using either the femoral or subclavian site, CVC placement in the femoral area was associated with a substantially greater risk of CLABSI than was subclavian insertion (20 versus 3.7 per 1,000 catheter days).[55] In a recent Dutch multicenter study involving 3,750 CVCs and 29,003 CVC days, insertion into the femoral and jugular vein was independently associated with an increase in the risk of subsequent CLABSI.[56] In a study directly comparing the subclavian to the internal jugular and femoral sites,

the subclavian site was associated with the lowest risk of infection (0.97 versus 2.99 and 8.34 per 1,000 catheter days, respectively).[24] For this reason, whenever medically feasible, the subclavian vein is the preferred site for venous catheterization in the current HICPAC guidelines (Category IB).[6,20,57-59] However, this recommendation remains the subject of ongoing debate, as some rigorous studies have found that the risk of CLABSI from femoral vein CVC insertion is not greater than that associated with insertion into the subclavian or internal jugular veins.[60-62]

Measures To Prevent CLABSI After Central Venous Catheter Insertion

Following the insertion of a CVC, several practices may decrease the risk of developing CLABSI. These "maintenance" practices are important aspects of CLABSI prevention, especially in CVCs that remain in place for an extended period of time.

Disinfect hubs, needleless connectors, and injection ports prior to CVC use. Contamination of the catheter hub due to non-sterile access technique is a recognized path for developing CLABSI. Minimizing contamination by wiping the catheter hub with an appropriate antiseptic specifically recommended by the device manufacturer, or swabbing the membranous septum of a CVC with 70% alcohol have been shown to reduce both risk of catheter contamination and incidence of CLABSI.[63-65] The practice of disinfecting access sites prior to CVC use, colloquially dubbed "scrub the hub," is linked to decreases in both bacterial colonization at access sites and rates of incident CLABSI.[66-68] Educational efforts targeting providers responsible for CVC care (such as bedside nurses) are an important component in ensuring dissemination and compliance with this practice.[69] Although current HICPAC guidelines emphasize minimizing the risk of contamination by scrubbing the hub with an appropriate antiseptic (Category IA),[20] several *in vitro* studies have demonstrated that even with strict attention to decontamination, pathogenic organisms can persist in crevices or inside CVC access valves and/or require prolonged duration of contact with an antimicrobial to significantly decrease the level of colonization of CVC valves.[69-72] In response, innovative technologies such as those that incorporate antimicrobial compounds in the matrix of the CVC access valve, or devices that bathe the valve with antimicrobials are being developed and tested.[70,72-74] In the absence of significant clinical experience with these novel devices, recommendations regarding their widespread use are not possible.

Remove nonessential CVCs. Each day with a CVC increases the risk of developing CLABSI.[75,76] Prompt removal of CVCs that are no longer warranted is thus an important practice to reduce CLABSI. This action necessitates both awareness of CVC presence and an ongoing risk-benefit assessment of continued central venous access. In a study tracking temporary CVC use in hospitalized patients, Chernetsky-Tejedor and colleagues reported that patients who underwent PICC placement for venous access paradoxically also had 5.4 concurrent days with a peripheral intravenous line (P<0.001), and had more days in which the only justification for the CVC was intravenous administration of antimicrobial agents (8.5 versus 1.6 days; P=0.0013). The authors therefore concluded that a substantial proportion of CVC-days might have been unjustified in this cohort.[65] In a recent survey conducted in a European hospital, neither the bedside nurse nor the treating physician knew why a CVC was in place for 8.3 percent of non-ICU patients.[77] Importantly and relatedly, routine replacement of CVCs at pre-determined time intervals has not been shown to reduce the risk of CLABSI and is not recommended based on the available evidence (Category IA).[20]

Chlorhexidine cleansing. Daily bathing of patients with a chlorhexidine-based solution in ICU- or advanced care settings may lower CLABSI incidence. In a crossover study conducted in a medical ICU, daily washing with a 2% chlorhexidine-impregnated washcloth significantly reduced subsequent BSI compared with using soap and water (4.1 vs. 10.4 per 1,000 patient-days, P<0.05).[78] A study in a surgical ICU also found that daily bathing with a 2% chlorhexidine gluconate impregnated cloth led to significant reductions in CLABSI (12.07 vs. 3.17 CLABSIs per 1,000 days; 73.7% rate reduction, P= 0.04).[79] The benefits of chlorhexidine baths may also extend to high-risk patients outside of ICU settings. In a quasi-experimental before and after study of the effect of daily washing with 2% chlorhexidine solution on CLABSI incidence, Munoz-Price and colleagues reported a 99 percent reduction in the CLABSI rate in a long-term acute care facility.[80] However, a recent retrospective study involving patients in a surgical ICU suggested that the benefit from chlorhexidine bathing might not apply to all patients.[81] As the evidence base for this practice is limited and conflicting, current HICPAC guidelines cautiously endorse the use of chlorhexidine washes (either in solution form or as a chlorhexidine impregnated wash cloth), for daily skin

cleansing as a means to prevent CLABSI with a Category II recommendation.[20] However, the level of evidence for this recommendation may soon be upgraded, as a recent meta-analysis pooling 12 studies found significant reductions in CLABSI risk in studies that evaluated chlorhexidine cleansing in a medical ICU setting (OR 0.44, 95% confidence interval, 0.33 to 0.59).[82]

CVC dressing, chlorhexidine sponges and topical antibiotic use. The type of dressing and use of topical antibiotic ointments or creams at the catheter site may affect the risk of CLABSI. In a meta-analysis of seven studies comparing clear dressings to gauze for CVCs, transparent dressings were associated with greater risk of catheter tip colonization (Relative Risk [RR] 1.78, 95% confidence interval [CI] 1.30 to 2.30, P<0.05), but not CLABSI (RR 1.63, 95% CI 0.76 to 3.47).[83] Another meta-analysis of randomized controlled trials comparing gauze and tape to transparent dressings found no significant differences between dressing type and risk of CLABSI.[84] Thus, for CLABSI prevention, existing guidelines do not endorse one type of dressing over the other and leave the choice of CVC dressing to provider/patient preference and clinical scenario.[20]

The use of a chlorhexidine gluconate sponge over the site of CVC insertion has been associated with a decrease in the frequency and cost of CLABSI. In a study involving 1,636 patients with venous and arterial catheters, Timsit and colleagues reported that chlorhexidine gluconate sponge placement at the site of catheter insertion substantially reduced the incidence of CLABSI (1.4 to 0.6 per 1,000 catheter days, hazard ratio 0.39, P<0.03). However, severe contact dermatitis was observed in eight low birth-weight infants (5.3 per 1,000 catheter days), and the potential for this adverse effect remains an important limitation in the use of chlorhexidine gluconate sponges in this population.[85] In a recent economic evaluation, chlorhexidine-impregnated sponge use in patients with CLABSI was estimated to save $197 per patient using a 3-day dressing change strategy vs. $83 using a 7-day standard dressing change strategy.[86] In another cost-benefit analysis, a hypothetical 400-bed hospital inserting 3,078 CVCs annually would avoid a projected average of 35 CLABSIs, 145 local infections, and 281 ICU days with the systematic use of a chlorhexidine-impregnated foam dressing; potential annual hospital net savings were projected at over $895,000.[87] Owing to important differences in study design and outcomes involving primarily pediatric populations, current guidelines recommend the use of chlorhexidine-impregnated sponge dressings only in situations where the CLABSI rate is not decreasing despite adherence to other prevention measures (Category IB).[20]

The use of topical antibiotic ointment or creams at the insertion site (e.g. povidone iodine) is recommended only for patients with hemodialysis catheters, where its use has been associated with suppression of BSI.[88,89] Interestingly, a recent prospective, non-blinded crossover study found that chlorhexidine sponge dressings were not protective against BSI in patients with hemodialysis catheters.[90] Conversely, topical antibiotic dressings are not recommended for CLABSI prevention in non-dialysis patients as their use may paradoxically increase fungemia and antimicrobial resistance in this category of patients (Category IB).[20,91,92]

Antibiotic/anti-infective "locks" in high-risk patients. A catheter lock refers to the instillation of supra-physiologic doses of an intravenous antibiotic or anti-infective solution into a catheter lumen between periods of CVC access. Several studies have examined both the utility of specific antibiotic or anti-infective agents (e.g. vancomycin, cephalosporins, taurolidine, EDTA, ethanol) and the targeted use of antibiotic locks in high-risk patient populations. In a systematic review and meta-analysis, vancomycin-based antibiotic locks in patients deemed high-risk for CLABSI (planned, long-term central venous catheter duration or those with a history of prior CLABSI) significantly decreased the risk of this outcome (RR 0.34, P=0.04).[93] A more recent systematic review also reported reductions in the risk of subsequent CLABSI using this approach as an adjunctive treatment, specifically in patients with poor venous access where catheter salvage was key.[94] In view of concerns regarding the potential for inducing antibiotic resistance, several novel compounds have been tested as anti-infective locks. For example, a recent study found a solution containing minocycline and EDTA to be highly efficacious in preventing CLABSI in patients with hemodialysis catheters.[95] In patients receiving prolonged home parenteral nutrition via a CVC, the antineoplastic compound taurolidine was found to reduce the risk of CLABSI when used as a catheter lock in a before and after study.[96] Even though several studies have found reductions in CLABSI incidence in specific populations, generalizations beyond these groups are difficult and not appropriate.[97-100] Thus, due to important differences in study design, type of catheter, agent used, and patient population, the use of antibiotic locks should be limited to those who are at high baseline risk for CLABSI (Category II).[20]

Systemic antibiotic prophylaxis. Routine systemic antibiotic prophylaxis during or after CVC insertion to reduce the risk of CLABSI is not recommended (Category IB).[20] A recent Cochrane meta-analysis involving patients with cancer found no convincing evidence that prophylactic peptidoglycan administration prior to CVC insertion was associated with reduced CLABSI incidence.[101] A recent study examining the effect of prophylactic cefazolin on CLABSI following port placement similarly found no benefit associated with antibiotic treatment.[102]

Institutional Initiatives To Reduce CLABSI

Educational interventions. Educational programs that emphasize appropriate indications for CVC placement and programs that review proper procedures for catheter insertion and maintenance have both been shown to reduce the incidence of CLABSI in various settings.[103-107] Although teaching CVC insertion using simulation techniques is a growing phenomenon, a recent systematic review found that this practice was associated with less frequent mechanical complications, but not CLABSI.[108] Reporting and monitoring for infections through a structured infection control program is a critical component of CLABSI prevention. Consequently, education and training regarding how to implement and assess infection control measures and periodic reassessment of this knowledge has also been shown to reduce CLABSI.[20,35,109] Despite these important studies, a recent survey found that knowledge regarding which practices are most associated with CLABSI prevention remains variable.[110] Educational initiatives thus represent an important area of opportunity for institutions and health systems interested in controlling CLABSI (Category IA).[20]

Use of catheter checklists or "bundles." A standardized approach to CVC placement that utilizes a set of evidence-based practices represents an important innovation in CLABSI prevention. In the Michigan Keystone ICU study, Pronovost and colleagues enrolled 103 ICUs in 67 hospitals to test whether an intervention consisting of five evidence-based practices implemented at the time of CVC insertion could reduce CLABSI. Notably, these five practices were selected because they each had strong evidence supporting their efficacy in CLABSI reduction and the lowest barriers to implementation. These five practices were hand hygiene prior to insertion; use of maximal sterile barrier precautions; chlorhexidine for skin antisepsis; avoidance of the femoral site of insertion; and prompt removal of catheters when no longer indicated. Following implementation of this intervention, the mean rate of CLABSI dropped from 7.7 per 1,000 catheter days at baseline to 1.4 per 1,000 catheter days at 16 months across participating sites.[33] The use of these five interventions in unison has been called the "checklist" or "the bundle." The use of the bundle and variations thereof has been associated with a sustained decrease in the incidence of CLABSI, not only within the U.S., but internationally as well.[38,111-116] The bundle has also been found to be cost-effective both in the U. S. and abroad, leading to its widespread acceptance as a key strategy with which to reduce CLABSI.[20,117] The HICPAC guidelines categorize the use of bundled interventions during CVC insertion as performance improvement initiatives and recommends this practice to reduce CLABSI (Category IB).[20]

Specialized CVC insertion teams. Data from several studies suggest that CVC placement by specialized teams dedicated to this role leads not only to greater placement skills and reduced insertion complications, but also to reduced rates of institutional CLABSI.[25,33,38,111] The use of dedicated and trained staff ensures predictable adherence to evidence-based practices such as hand hygiene and maximal sterile barriers. The advent of nursing-led PICC teams represents an important transformation in the placement of CVCs in both critically ill and hospitalized patients. Preliminary studies suggest that these teams are associated with high rates of insertion success and low rates of mechanical complications in a variety of patient settings.[118-120] However, no data comparing the risk of CLABSI in patients who undergo PICC placement by nursing PICC teams compared with other providers (such as hospitalists or radiologists) are currently available. The HICPAC guidelines recommend the use of trained personnel to insert CVCs (Category IA).[20]

How Has CLABSI Prevention Been Implemented?

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With the realization that CLABSI can be curtailed by the use of evidence-based practices, CLABSI prevention has increasingly become an attainable goal for hospitals, health care systems, and payors. The Michigan Keystone ICU study underscored how both technical (e.g., asepsis during insertion, standardized surveillance), and adaptive (e.g., buy-in from leadership, a culture of safety) components were needed to successfully implement a CLABSI prevention initiative.[121] The identification of these two distinct, yet complementary, realms highlights how engagement and

education of staff, consistent execution of the bundle, and rigorous evaluation of process—critical activities embodied within the CLABSI bundle—are fundamental components of CLABSI reduction.[122] To ensure validity outside of Michigan, this model was replicated and tested in Rhode Island and in the Adventist multistate health care system, where declines in CLABSI at participating sites were also observed.[122,123]

Fueled by these successes, the U.S. Department of Health and Human Services prioritized CLABSI reduction by designating it as Tier I of a comprehensive national healthcare-associated infection prevention program. Ambitiously, the program aimed to reduce the incidence of CLABSI by 50 percent in ICUs and specific patient populations over a period of 5 years, primarily by encouraging the use of insertion bundles. A 2011 interim analysis found that providers are on track with meeting this target, although continued opportunities remain for patients in non-ICU settings and those receiving hemodialysis.[124] In similar fashion, the Agency for Healthcare Research and Quality (AHRQ) funded and launched an implementation program called "On the CUSP: Stop BSI." This national venture includes Federal agencies (e.g., CDC), State organizations, and various professional societies, and aims to reduce the mean CLABSI rate to less than 1 per 1,000 catheter days in each of the 50 United States.

What Have We Learned About CLABSI Prevention?

Go to:

A decade's worth of quality improvement, clinical research and policy change has led to greater understanding of a number of pivotal aspects of prevention and control of CLABSI. These important lessons and ongoing challenges are summarized below.

Importance of Organizational Context

CLABSI reduction efforts using bundles have been successful at some sites, but not at others. This variable success has led to a renewed appreciation of organizational complexities (e.g., local culture, clinical care team engagement) that influence the implementation of evidence-based practices in health care settings. In a study that sought to answer why certain hospitals were more likely to succeed in CLABSI reduction efforts than others, Krein and colleagues found that themes involving structure and hierarchy within hospitals, politics and relationships between key stakeholders, a missing sense of mission and value, and lack of commitment and passion explained why some hospitals were not as successful at implementing CLABSI reduction practices as others. The authors suggest that the use of externally-facilitated initiatives (e.g., infection prevention measures, technology-based solutions or a quality collaborative), may provide the motivation, and sometimes resources, needed for implementation needed to implement CLABSI prevention measures and overcome these major obstacles.[125] In another article studying the influence of context on outcomes, Dixon-Woods and colleagues examined the Michigan Keystone ICU-initiative to develop an ex-post theory of why this quality improvement program was so successful.[126] These investigators posited that a number of components ensured the success of the program: (a) recruitment of a large number of ICUs that created pressure for others to join (e.g., isomorphic pressure), (b) the use of scheduled teleconferences and meetings that created a sense of a densely networked community, (c) reframing of CLABSI as a social problem (e.g., one that involved human action and behavior, not a technical fix), which convinced stakeholders that they should organize to solve this issue, (d) influencing hospital culture through checklists and integration of nursing and management, and (e), robust measurement of outcomes as a means to enforce practice.

Similar themes emerged from a multi-ICU study involving the Department of Veterans Affairs (VA) health care system, one of the largest integrated health care systems in the world. Render and colleagues studied the effects of a centralized inpatient evaluation center that supported not only bundle implementation, but also provided support by recruiting leadership, and providing feedback, learning tools, and mentoring at VA ICUs. Although the bundle was implemented in all ICUs, the investigators found marked declines in CLABSI specifically at sites where the additional support tools were well received. In contrast, sites that struggled with CLABSI reduction lacked a functional improvement team, forcing functions, or real-time feedback systems, underscoring the importance of these factors in CLABSI reduction.[127]

In a national study of 1,212 health care professionals from 33 different hospitals, Flanagan and colleagues conducted an open-ended survey and also found that poor adherence to guidelines, lack of culture change, no impetus to change, insufficient resources, and issues related to education were

perceived barriers to achieving success in CLABSI improvement programs.[128] In the context of the work by Krein, Dixon-Woods, and others, these findings highlight the importance of understanding, appreciating, and addressing contextual factors in the quest to control CLABSI throughout the world.

Need for Accurate and Reliable Reporting

AHRQ has emphasized the reduction of CVC-associated BSI by designating it as Patient Safety Indicator (PSI)-7 on nationally reported scorecards. Although a technical brief outlining specifications of measurement for this PSI is publicly available,[18] variations in measurement of this indicator have led to consternation in the literature. In a criterion validity study, Zrelak and colleagues conducted a retrospective cross-sectional study of 23 U.S. hospitals using trained abstractors and found that among 191 cases that met PSI-7 criteria, only 104 (positive predictive value [PPV] 54%; 95% CI, 40% to 69%) represented true CLABSI.[129] In another study examining the validity of PSI-7, Cevasco and colleagues used similar methodology and found that only 42 of 112 reviewed cases represented true CLABSI events (PPV 38%; 95% CI, 29% to 47%).[130] In both studies, coding-related issues and present-on-admission diagnoses explained a large fraction of incorrect reporting. Inaccurate measurement is further compounded by continued variation in public reporting of PSI-7. In a study of 14 states with mandatory CLABSI monitoring laws, Aswani and colleagues found numerous disparities in how participating sites selected the time span of their data collection, variably presented their infection rates, used inconsistent methods of risk adjustment, chose which locations and care settings to report, and demonstrated significant time lag to reporting.[131] Using a standard definition of CLABSI to retrospectively study institutional variation in reporting bloodstream infections, Lin and colleagues found marked variability among 20 ICUs when comparing infection preventionists-reported CLABSI rates to those from a computer-generated algorithm.[132] In a provocative study, Niedner and colleagues showed that more-aggressive surveillance using stricter definitions and written policies was associated with higher CLABSI reporting rates in 16 pediatric ICUs.[133] This variability in reporting has profound implications in pay-for-performance and benchmarking applications that use this measure, as those most likely to accurately report CLABSI stand to be the most penalized. This dilemma underscores the need to standardize, audit, and constantly evaluate this system of quality measurement.

Importance of Continued Performance Improvement Efforts

Despite major strides involving knowledge generation and dissemination over the past decade, important gaps remain in the practice of CLABSI prevention. In a cross-sectional survey of 1,000 randomly selected physician-members of the American College of Physicians-American Society of Internal Medicine, the reported use of maximal sterile barriers and chlorhexidine gluconate at the time of CVC insertion remained low among internists who identified themselves as having recently inserted a CVC.[134] Similarly, around 15 percent of U.S. hospitals report routinely changing CVCs at predetermined time intervals despite abundant evidence that this practice should be discontinued.[43,135] In an audit of staff practice and awareness of post-insertion catheter care, Shapey and colleagues found multiple breaches involving knowledge about dressing and catheter hub decontamination.[136] Are these behaviors and practices remediable? In a 36-month followup study of the Keystone Project, zero incidents of CLABSI were found in participating sites, despite completion of the original study. The durability of this effect suggests that not only can behaviors be changed, but engagement, education, monitoring, and feedback can sustain these behaviors beyond the intervention stage.[113] Ongoing performance measurement and process improvement must thus come to represent a fundamental facet of national and local efforts directed towards CLABSI prevention.

Identification of New Challenges

Most BSIs related to CVCs occur not in those with long-term CVCs, but in patients with short-term CVCs.[137] A major shift in the landscape of short-term CVCs, the remarkable growth of PICC use in hospitalized and critically ill patients, may therefore bring new challenges to CLABSI prevention.[12,76,120] Despite the rapid growth in the use of PICCs, little is known about the indications, prevalence, and patterns of use of this device. Consequently, little is known regarding the adherence to or appropriateness of CLABSI prevention techniques when inserting and maintaining PICC lines. As PICCs are frequently placed in vulnerable populations such as children and those with cancer[138] and are associated with important complications, further study of this technology and its association with CLABSI is needed.[139,140] In addition, considerably less

attention has been devoted to the study and testing of best practices in maintaining long-term CVCs, such as PICCs. As the risk of CLABSI is greatly influenced by the manner in which a CVC is handled and treated following insertion, this knowledge gap represents an important area for future study.

Conclusions and Comment

Go to:

The intervening decade between the original "Making Health Care Safer" report[18,21,22] and this update has borne witness to a number of practices, approaches, and technologies that have controlled and eliminated CLABSI in specific settings. Despite this progress, a number of important policy, knowledge, and implementation gaps remain. While a CLABSI bundle that incorporates five practices that have reasonable evidence underlying their use appears to be successful in reducing CLABSI within ICUs, the extent to which this bundle is effective at preventing and reducing CLABSI outside of the ICU is unknown. As the majority of CVCs are now found in non-ICU settings, a research agenda that targets this population is necessary. Understanding how best to assess and address the complexities of culture and behavior are critical in this context, as these factors are likely to vary to a greater extent than ICU settings. A summary table is located in Table 2, Chapter 10.

Table 2, Chapter 10

Summary table.

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