Review of Strategies to Reduce Central Line-Associated Bloodstream Infection (CLABSI) and Catheter-Associated Urinary Tract Infection (CAUTI) in Adult ICUs

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Central line–associated bloodstream infection (CLABSI) and catheter-associated urinary tract infection (CAUTI) are costly and morbid. Despite evidence-based guidelines, Some intensive care units (ICUs) continue to have elevated infection rates. In October 2015, we performed a systematic search of the peer-reviewed literature within the PubMed and Cochrane databases for interventions to reduce CLABSI and/or CAUTI in adult ICUs and synthesized findings using a narrative review process.

The interventions were categorized using a conceptual model, with stages applicable to both CAUTI and CLABSI prevention: (stage 0) avoid catheter if possible, (stage 1) ensure aseptic placement, (stage 2) maintain awareness and proper care of catheters in place, and (stage 3) promptly remove unnecessary catheters. We also looked for effective components that the 5 most successful (by reduction in infection rates) studies of each infection shared. Interventions that addressed multiple stages within the conceptual model were common in these successful studies. Assuring compliance with infection prevention efforts via auditing and timely feedback were also common. Hospitalists with patient safety interests may find this review informative for formulating quality improvement interventions to reduce these infections. *Journal of Hospital Medicine* 2018;13:105-116. Published online first November 8, 2017. © 2018 Society of Hospital Medicine

Central line–associated bloodstream infection (CLABSI) and catheter-associated urinary tract infection (CAUTI) are morbid and expensive healthcare-associated infections (HAIs).[1-8] While these HAIs are prevalent in intensive care units (ICUs) and general wards, most of the research, prevention efforts, and financial penalties have been focused in the ICU.[9,10] For hospitalists, who are taking a larger role in caring for the critically ill,[11,12] it is optimal to understand best preventive practices.

There has been a national push to standardize procedures and products to prevent CLABSI and CAUTI.[2,13-16] CLABSI has transitioned from a common ICU complication to a "never event." Success has been reflected in the prevention of 25,000 CLABSIs over the last decade, translating to a 58% reduction in infections, with 6000 deaths prevented and $414 million saved.[2]

CLABSI prevention principles have been applied to CAUTI prevention (ie, aseptic insertion, maintenance care, prompting removal) but with slower adoption[17] and fewer dramatic CAUTI reductions,[18] due in part to weaker recognition[19] of CAUTI as a serious clinical event, despite its morbidity[20] and cost.[21]

Despite recent improvements in preventing HAIs, there is a marked variability in how hospitals perform in preventing these infections.[22] To inform infection prevention strategies for a large-scale implementation project funded by the Agency for Healthcare Research and Quality and focused on ICUs with persistently elevated CLABSI and/or CAUTI rates,[23] we performed a systematic search of interventions to prevent CLABSI and CAUTI in the ICU setting. This evidence was synthesized to help units select and prioritize interventions to prevent these HAIs.

METHODS

Literature Search Strategy

We performed a systematic search to identify CLABSI and CAUTI prevention studies and synthesized findings using a narrative review process. Using criteria developed and refined from seminal articles on the topic,[10,14,24-34] we searched the PubMed and Cochrane databases from their inception to October of 2015 using Medical Subject Headings (MeSHs) for "central venous catheters," "CLABSI," "central line associated bloodstream infection," "catheter related bloodstream

infection," "intravascular devices," "urinary catheterization," "urinary catheters," "urinary tract infections," "CAUTI," and "catheter associated urinary tract infections" and filtered for articles containing the MeSHs "intensive care unit" and "ICU." Supplemental Figure 1 details the search, yielding 102 studies for CLABSI and 28 studies for CAUTI, including 7 studies with CLABSI and CAUTI interventions.

Eligibility Criteria Review
Study Design
We included randomized and nonrandomized studies that implemented at least 1 intervention to prevent CLABSI or CAUTI in an adult ICU setting and reported the preintervention or control group data to compare with the postintervention data. We excluded general ward, outpatient/ambulatory, and neonatal/pediatric settings. Interventions to prevent CLABSI or CAUTI were included. We excluded interventions focused on diagnosis or treatment or those that lacked adequate description of the intervention for replication. Studies with interventions that are no longer standard of care in the United States (US) were excluded, as were studies not available in English.

Outcomes
### Primary Outcomes for Central Vascular Catheter Infection
- *CLABSI:* A lab-confirmed bloodstream infection in a patient who has had a central line for at least 48 hours on the date of the development of the bloodstream infection and without another known source of infection. We included studies that reported CLABSIs per 1000 central line days or those that provided data to permit calculation of this ratio. This measure is similar to current National Healthcare Safety Network (NHSN) surveillance definitions.[22]
- *Catheter-related bloodstream infection (CRBSI):* A lab-confirmed bloodstream infection attributed to an intravascular catheter by a quantitative culture of the catheter tip or by differences in growth between catheter and peripheral venipuncture blood culture specimens.[35] This microbiologic definition of a central line bloodstream infection was often used prior to NHSN reporting, with rates provided as the number of CRBSIs per 1000 central line days.

Primary Outcome for Urinary Catheter Infection
- *CAUTI:* Urinary tract infection occurring in patients during or after the recent use of an indwelling urinary catheter. We included studies that reported CAUTIs per 1000 urinary catheter days or those that provided data to permit calculation of this ratio (similar to the current NHSN surveillance definitions).[22] We excluded studies where CAUTI was defined as bacteriuria alone, without symptoms.

Secondary Outcomes
- *Central line utilization ratio:* The device utilization ratio (DUR) measure of central line use is calculated as central line days divided by patient days.
- *Urinary catheter utilization ratio:* The DUR measure of urinary catheter use is calculated as indwelling urinary catheter
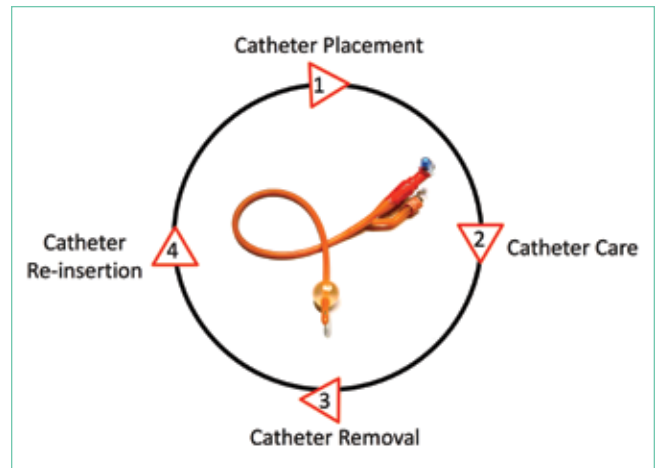
FIG 1. Life cycle of the urinary catheter.
From Meddings J, Saint S. Disrupting the life cycle of the urinary catheter. *Clin Infect Dis.* 2011;52(11):1291-1293, by permission of *Clinical Infectious Disease.*

days divided by patient days, as used in NHSN surveillance, excluding other catheter types.[22] We excluded other measures of urinary catheter use because of a large variation in definitions, which limits the ability to compare measures across studies.

Data Synthesis and Analysis
Information on the ICU and intervention type, intervention components, outcomes, and whether interventions were in use prior to the study was abstracted by CAUTI and CLABSI experts (JM and PKP) and confirmed by a second author.

We compared interventions found in the literature to components of the previously published urinary catheter "life cycle," a conceptual model used to organize and prioritize interventions for a reduction in CAUTI (Figure 1).[36] In this framework, there are 4 stages: (1) catheter placement, (2) catheter care, (3) catheter removal, and (4) catheter reinsertion. We sought to tailor the model for interventions in the ICU and for CLABSI prevention studies in addition to CAUTI prevention studies. In Table 1, we also provided the recommendation level for each intervention type provided in the CLABSI and CAUTI prevention guidelines from the Centers for Disease Control and Prevention Healthcare Infection Control Practices Advisory Committee, as close as was feasible, as the guidelines describe general strategies, not specific interventions.[13,37]

RESULTS
Conceptual Model for Disrupting the Life Cycle of a Catheter
Our data analysis demonstrated that components of the urinary catheter life cycle (Figure 1) were useful and could be applied to vascular catheters, but changes were needed to make the model more valuable to hospitalists implementing CLABSI and CAUTI prevention interventions. We found that the previously named stage 1 (catheter placement) is better described in 2 stages: stage 0, avoid catheter if possible, and stage 1, ensure aseptic placement. Additionally, we tailored the model

to include actionable language, describing ways to disrupt the life cycle. Finally, we added a component to represent interventions to improve implementation and sustainability, such as auditing compliance and timely feedback to clinicians. Thus, we introduce a new conceptual model, "Disrupting the Life Cycle of a Catheter" (Figure 2)—including stages appropriate for targeting both CAUTI and CLABSI prevention: (stage 0) avoid catheter if possible (ie, prevent catheter "life cycle" from beginning), (stage 1) ensure aseptic placement, (stage 2) optimize catheter maintenance care, and (stage 3) promptly remove unnecessary catheters—as well as apply interventions to improve implementation and sustainability. We used this modified conceptual model to synthesize the CLABSI and CAUTI prevention interventions found in the systematic search.

Central Vascular Catheter Interventional Study Results
Characteristics of Included Central Vascular Catheter Infection Studies
Of the 102 central vascular catheter (CVC) studies that met the inclusion criteria (reporting outcomes for 105 intervention cohorts), 59 studies[10,14,16,24-27,38-89] reporting outcomes for 61 intervention cohorts were performed in the US. Study designs included 14 randomized controlled trials (RCTs)[48,64,68,74,79,90-98] and 88 before–after studies (Appendix Table 1). [10,14,16,24-27,33,38-47,49-63,69-73,75-78,80-89,99-131] Many RCTs evaluated antimicrobial products (CVCs, hubs, bathing) as interventions,[48,68,74,90-95,97,98] but a few RCTs studied interventions[64,79,93] impacting catheter care or use (Appendix Table 1). Fifty-one studies took place in tertiary care hospitals and 55 in academic hospitals. Thirty-one studies were multicenter; the largest included 792 hospitals and 1071 ICUs.[24] ICU bed size ranged from 5 to 59.

Central Vascular Catheter Study Outcomes
Sixty-three studies reported CLABSI outcomes, and 39 reported CRBSI outcomes (Table 2). Many studies had preintervention or control rates above the 2013 NHSN 75th percentiles,[22] which varied by ICU type. Preintervention or control infection rates per 1000 catheter days varied widely (means: CLABSI 7.5, CRBSI 6.3); US studies reported ranges of 1.1 to 12.1 CLABSI and 1.2 to 11.0 CRBSI per 1000 catheter days; non-US studies reported ranges of 1.4 to 45.9 CLABSI and 1.6 to 22.7 CRBSI per 1000 catheter days. Postintervention rates varied widely, with overall means of 2.8 CLABSI and 2.5 CRBSI per 1000 catheter days, including US study ranges of 0 to 8.9 CLABSI and 0 to 5.4 CRBSI, and non-US study ranges of 0 to 17.1 CLABSI and 0 to 15.9 CRBSI.

Overall (Table 2), 99 of the 105 intervention cohorts described in the 102 studies reported either a reduced CLABSI or a reduced CRBSI outcome, including all ICU types. Of the 63 CLABSI studies, 60 reported lower postintervention CLABSI rates, with a mean reduction of 62.6%, though only 36 demonstrated statistical significance. Of the 39 studies that reported CRBSI outcomes, 37 reported lower postintervention CRBSI rates, with a mean reduction of 66%, of which 23 were statistically significant.

Central line DURs were reported in only 5 studies; 3 reported decreased postintervention DURs (2 with statistical significance), with a mean 11.7% reduction (Table 2).

Central Vascular Catheter Interventions
CVC study interventions are summarized in Table 1, categorized by catheter life cycle component (Figure 2). Thirty-two included studies used a single intervention to prevent CVC infection. Interventions to avoid placement when possible were infrequent. Insertion-stage interventions were common and included avoiding the femoral site during placement, ensuring maximal sterile barriers, and chlorhexidine skin preparation. Standardizing basic products for central line insertion was often done by providing ICUs with a CLABSI insertion kit or stocked cart. In some studies, this was implemented prior to the intervention, and in others, the kit or cart itself was the intervention. Maintenance-stage interventions included scrubbing the hub prior to use, replacing wet or soiled dressings, accessing the catheter with sterile devices, and performing aseptic dressing changes. A recent systematic review and meta-analysis of CVC infection prevention studies indicated that implementing care bundles and/or checklists appears to yield stronger risk reductions than interventions without these components.[132] The most common catheter removal interventions were daily audits of line removal and CLABSI rounds focused on ongoing catheter necessity.

Common implementation and sustainability interventions included outcome surveillance, such as feedback on CLABSI, and socio-adaptive interventions to prompt improvements in patient safety culture. Process and outcome surveillance as interventions were implemented in about one-quarter of the studies reviewed (AppendixTable 1).

CAUTI Interventional Study Results
Characteristics of Included CAUTI Studies
Of the 28 CAUTI studies that met the inclusion criteria (reporting outcomes for 30 intervention cohorts), 14 studies (reporting outcomes for 16 intervention cohorts) were performed in the US.[28,34,53,66,68,133-141] Study designs included 2 RCTs (focused on urinary catheter avoidance or removal[142] and chlorhexidine bathing[68]) and 26 nonrandomized, before–after studies[28,30,33,34,53,66,109,114-116,133-141,143-149] (Appendix Table 1). The number of hospitals per study varied from 1 to 53, with the majority being single-hospital interventions.

CAUTI Study Outcomes
All 28 studies reported CAUTIs per 1000 catheter days for both intervention and comparison groups (Table 2). Preintervention or control CAUTI rates varied widely, with an overall mean of 12.5 CAUTIs per 1000 catheter days; US studies reported a range from 1.4 to 15.8 CAUTIs per 1000 catheter days; non-US studies reported a range from 0.8 to 90.1 CAUTIs per 1000 catheter days. Many studies had preintervention or control rates above the 2013 NHSN 75th percentiles.[22] Postintervention CAUTI rates varied widely, with an overall mean of 7.0 CAUTIs per 1000 catheter days, including a US study range

TABLE 1. Intervention Characteristics of Included Studies (With HICPAC Recommendation Category[a])

A. Central Line-Associated Bloodstream Infection (CLABSI) Prevention Studies

Stage of Life Cycle[b] Intervention Characteristic	N (%) of Included Studies Employing each Intervention Characteristic (n = 102)
Stage 0 Avoid[b]	
Insertion Appropriateness (1A)	3 (2.9)
Stage 1 Insertion[b]	
Provide a Checklist (1B)	25 (24.5)
Avoid Femoral Site (1A)	31 (30.4)
Provide Insertion Kit/Cart (Not Graded)	24 (23.5)
Improve Hand Hygiene (1B)	31 (30.4)
Ensure Maximum Sterile Barriers (1B)	36 (35.3)
Chlorhexidine Skin Preparation (1A)	30 (29.4)
Cover Site with Sterile Dressing (1A)	6 (5.9)
Education on Insertion/Aseptic Technique (1A)	55 (53.9)
Empower Staff to Stop Procedure (Not Graded)	10 (9.8)
Process Surveillance (Not Graded)	15 (14.7)
Dedicated Staff for Catheter Insertion (1A)	2 (2.0)
Stage 2 Maintenance[b]	
Scrub the Hub Prior to Use (1A)	7 (6.9)
Access Catheter with Sterile Device (1A)	4 (3.9)
Ensure Best Dressing Change Practices (1B)	17 (16.7)
Maintenance Checklist or Kit (1B)	5 (4.9)
Antimicrobial Hubs/Chlorhexidine Impregnated (1B)	5 (4.9)
Chlorhexidine Bathing (II)	12 (11.8)
Stage 3 Removal[b]	
CLABSI Rounds or Daily Audit for Line Removal (1A)	30 (29.4)
Replacement of Emergent Lines (1B)	4 (3.9)
Multiple Stages[b]	
Antimicrobial CVC (1A) (Stages 2 & 3)	19 (18.6)
Electronic Checklist for Documentation (Not Graded) (Stages 1-3)	5 (4.9)
Interventions to Improve Implementation & Sustainability	
Outcomes Surveillance: Feedback on CLABSI (Not Graded)	27 (26.5)
Promote Culture of Quality and Safety (Not Graded)	17 (16.7)
CUSP Implementation (1B)	13 (12.7)

B. Catheter-Associated Urinary Tract Infection (CAUTI) Prevention Studies

Stage of Life Cycle[b] Intervention Characteristic	N (%) of Included Studies Employing each Intervention Characteristic (n = 28)
Stage 0 Avoid[b]	
UC Placement Restrictions (1B)	12 (42.9)
Promoting UC Alternatives (II)	11 (39.3)
Require UC Order by Physicians (1B)	2 (7.1)
Stage 1 Insertion[b]	
Standardized UC Kit (1B)	3 (10.7)
Commercial Securement Device (1B)	2 (7.1)
UC Insertion Cart (1B)	1 (3.6)
UC Aseptic Insertion Training (1B)	12 (42.9)
Stage 2 Maintenance[b]	
UC Maintenance Care Training (1B)	15 (53.6)
UTI Bundle Checklist in Rounds (1B)	3 (10.7)
Bowel Management Program (Not Graded)	2 (7.1)
Stage 3 Removal[b]	
Foley Catheter Rounds (1B)	5 (17.9)
UC Removal Reminder (1B)	12 (42.9)
UC Removal Stop Order (1B)	4 (14.3)
Multiple Stages[b]	
Antimicrobial UCs (1B) (Stages 1 & 2)	2 (7.1)
Interventions also in ED or OR (Not Graded) (Stages 0 & 3)	2 (7.1)
Chlorhexidine Intervention (No Recommendations) (Stages 1 & 2)	5 (17.9)
Healthcare Worker Hand Hygiene (1B) (Stages 1-3)	13 (46.4)
Interventions to Improve Implementation & Sustainability	
Multidisciplinary Prep Meeting (Not Graded)	7 (25)
Data Feedback to ICUs (II)	12 (42.9)
CAUTI Root Cause Analysis (Not Graded)	1 (3.6)
Measure Intervention Compliance (II)	10 (35.7)
Patient Education about UCs (Not Graded)	3 (10.7)
Adaptable Interventions, Reboot (Not Graded)	7 (25)

[a]Healthcare Infection Control Practices Advisory Committee (HICPAC) Recommendation Category from the Guidelines for Prevention of Intravascular Catheter-Related Infections, 2011, and Guideline for Prevention of Catheter-Associated Urinary Tract Infections, 2009: Category 1A = strong recommendation supported by high to moderate quality evidence; Category 1B = strong recommendation supported by low quality evidence; Category 1C = required by state or federal regulations; Category II = weak recommendation; No recommendation = unresolved issue; Not graded = not addressed in guidelines.
[b]Stages as defined in Figure 2 "Disrupting the Life Cycle of a Catheter."
NOTE: Abbreviations: CUSP, Comprehensive Unit-Based Safety Program; CVC, central vascular catheter; ED, emergency department; HICPAC, Healthcare Infection Control Practices Advisory Committee; ICU, intensive care unit; Int., intervention; OR, operating room; UC, urinary catheter, indwelling; UTI, urinary tract infection.

TABLE 2. **Study Outcomes, As Reported in Included ICU Intervention Studies**

A. Central Line-Associated Bloodstream Infection (CLABSI) and Catheter-Related Bloodstream Infection (CRBSI)

Study	CLABSIs per 1000 Catheter Days		CRBSIs per 1000 Catheter Days		Central Line Utilization Rates	
	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate
Allen 2014[38]	2.72 (M) 1.09 (S)	0.4 (M)* 1.14 (S)	--	--	--	--
Arora 2014[39]	--	--	3.5	1.6	--	--
Barsuk 2009[41]	3.2	0.5*	--	--	--	--
Barsuk 2014[41]	3.82	1.29*	--	--	--	--
Berenholtz 2014[42]	1.96	1.15*	--	--	--	--
Berenholtz 2004[24]	11.3	0	--	--	--	--
Bion 2013[99]	3.7	1.48*	--	--	--	--
Bonne 2015[43]	2.7	1.4*	--	--	--	--
Borschel 2006[44]	--	--	8.2	5.4*	--	--
Brun-Buisson 2004[90]	--	--	5.2	2	--	--
Burden 2012[45]	--	--	6.47	2.44*	--	--
Carrasco 2004[91]	--	--	3.24	2.6	--	--
Cherifi 2013[100]	--	--	4	1.81*	--	--
Cherry 2011[46]	--	--	3.53	2.26*	--	--
Chua 2010[47]	--	--	4.08	0*	--	--
Collin 1999[48]	--	--	3.95	1.14	--	--
Coopersmith 2002[49]	--	--	10.8	3.7*	--	--
Coopersmith 2004[50]	--	--	3.4	2.8	--	--
Corral 2003[92]	--	--	2.8	0.8*	--	--
Depalo 2010[27]	3.73	0.97*	--	--	--	--
Dixon 2010[51]	12.07	3.17*	--	--	--	--
Entesari-Tatafi 2015[101]	2.2	0.5*	--	--	1.22	1.37+
Exline 2013[52]	2.65	0.53*	--	--	--	--
Fox 2015[53]	1.1	0.5	--	--	--	--
Frankel 2005[54]	--	--	11	1.7*	--	--
Galpern 2008[55]	--	--	5	0.9*	--	--
Gozu 2011[56]	6	0.8*	--	--	--	
Hagau 2009[93]	--	--	6.9	3.1	--	--
Hakko 2015[102]	12.5	0	--	--	--	
Hanna 2003[57]	--	--	1.4	0.46*	--	--
Hansen 2014[103]	1.4	0.46*	--	--	--	--
Hatler 2006[58]	--	--	12.8	2.88	--	--
Hermon 2015[104]	15.6	0.4	--	--		
Hong 2013[14]	1.8	1.1	--	--	--	--
Jaggi 2013[105]	6.44	3.5	--	--	--	--
Jeong 2013[107]	4.7	1.8	--	--	--	--
Kalfon 2007[94]	--	--	1.9	2.1	--	--
Kamboj 2015[59]	4.93	4.47	--	--	--	--
Khalid 2013[106]	6.9	1.06*	--	--	0.65	0.51+
Khouli 2011[60]	--	--	3.5 (M) 3.6 (S)	1* (M) 3.4* (S)	--	--
Klintworth 2014[108]	2.3	0.9*	--	--	--	--
Koll 2008[61]	4.85	2.21*	--	--	--	--
Kurtz 2008[95]	--	--	11.4	4.8	--	--

TABLE 2. Study Outcomes, As Reported in Included ICU Intervention Studies (continued)

A. Central Line-Associated Bloodstream Infection (CLABSI) and Catheter-Related Bloodstream Infection (CRBSI)

Study	CLABSIs per 1000 Catheter Days		CRBSIs per 1000 Catheter Days		Central Line Utilization Rates	
	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate
Latif 2015[110]	3.02	0.74	--	--	--	--
Leblebicioglu 2013[109]	22.7	15.85*	--	--	--	--
Leon 2003[97]	--	--	10.2	4.8	--	--
Leon 2004[98]	--	--	22.7	15.85*	--	--
Lin 2012[25]	1.5	0.6	--	--	--	--
Lin 2013[16]	1.49	0.25	--	--	--	--
Lobo 2010[112]	--	--	12 (M[1]) 16.2 (M[2])	0 (M[1]*) 13.7 (M[2])	--	--
Longmate 2011[111]	--	--	3.4	0	--	--
Lopez 2011[62]	5.7	0.2*	--	--	--	--
Lorente 2014[113]	--	--	5.04	0*	--	--
Maki 1997[63]	--	--	7.6	1.6*	--	--
Marra 2010[114]	6.4	3.2*	--	--	--	--
Marsteller 2012[64]	2.56	0	--	--	--	--
Martinez-Resendez 2014[115]	14.37	15.23	--	--	--	--
Mathur 2015[116]	27.6	7.2	--	--	--	--
Mazi 2014[117]	3.87	1.5*	--	--	--	--
McMullan 2013[65]	6.37	0.76	--	--	--	--
Menegueti 2015[118]	--	--	9.3	5.1*	--	--
Miller 2010[66]	8.53	2.23*	--	--	--	--
Montecalvo 2012[67]	6.4	2.9*	--	--	--	--
Mueller 2014[87]	1.16	0.8*	--	--	--	--
Muto 2005[10]	--	--	4.31	1.36*	--	--
Noto 2015[68]	5.45	5	--	--	--	--
Osma 2006[96]	--	--	1.6	5.3	--	--
Palomar 2013[121]	--	--	3.07	1.12*	--	--
Paula 2012[119]	15.85	3.91	--	--	--	--
Peredo 2010[122]	--	--	6.7	2.4*	--	--
Perez Parra 2010[123]	4.22	2.94	--	--	--	--
Popovich 2009[69]	--	--	5.31	0.69	--	--
Popovich 2010[70]	3.81	4.6	--	--	--	--
Pronovost 2006[26]	7.7	1.4*	--	--	--	--
Pronovost 2016[71]	2.5	0.76	--	--	--	--
Rangachari 2015[72]	--	--	2.63	0.49	--	--
Reddy 2014[120]	2.99	1.47*	--	--	--	--
Render 2011[73]	3.85	1.8*	--	--	0.32	0.39
Rosenthal 2003[124]	45.94	17.06*	--	--	--	--
Rosenthal 2010[125]	16	7.4*	--	--	--	--
Rupp 2005[74]	--	--	1.24	0.42	--	--
Sacks 2014[75]	5.02	1.6*	--	--	--	--
Salama 2016[126]	14.9	11.08	--	--	--	--
Salemi 2002[76]	3.2	1.4	--	--	--	--
Santana 2008[127]	9.5	5.4*	--	--	--	--
Scheithauer 2014[128]	5.87	1.51*	--	--	--	--
Seguin 2010[33]	--	--	2.8	0.7	--	--
Shannon 2006[77]	--	--	10.6	0.39*	--	--

TABLE 2. **Study Outcomes, As Reported in Included ICU Intervention Studies (continued)**

A. Central Line-Associated Bloodstream Infection (CLABSI) and Catheter-Related Bloodstream Infection (CRBSI)

Study	CLABSIs per 1000 Catheter Days		CRBSIs per 1000 Catheter Days		Central Line Utilization Rates	
	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate
Singh 2012[129]	44	3.1*	--	--	--	--
Sopirala 2013[78]	3.35	0.28*	--	--	--	--
Speroff 2011[79]	2.42	2.73	--	--	--	--
Thom 2014[80]	5	1.5*	--	--	--	--
Venkatram 2010[81]	--	--	10.77	1.67*	0.44	0.4
Vigorito 2011[88]	1.85	1.66	--	--	--	--
Wall 2005[82]	7	3.8	--	--	--	--
Walz 2015[83]	5.86	0.33*	--	--	--	--
Warren 2004[85]	9.4	5.5*	--	--	--	--
Warren 2006[84]	11.2	8.9*	--	--	0.68	0.65+
Watson 2009[86]	2.7	0	--	--	--	--
Zack 2008[89]	10.8	3.7	--	--	--	--
Zingg 2009[131]	--	--	3.9	1*	--	--
Zingg 2014[130]	--	--	1.7	0.4*	--	--

B. Catheter-Associated Urinary Tract Infection (CAUTI) Outcomes

Study	CAUTIs per 1000 Catheter Days		Urinary Catheter Utilization Rates	
	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate
Alexaitis 2014[133]	3.85	3.06	0.74	0.76
Amine 2014[143]	90.12	65.69	0.66	0.71
Apisarnthanarak 2007[149]	23.4	3.5*	--	--
Chen 2013[142]	17.2	10.3	0.88	0.68+
Dumigan 1998[28]	10.3 (M) 15.8 (S) 15.1 (C)	8.6 (M) 11.2 (S) 8.3* (C)	--	--
Elpern 2009[134]	4.7	0*	--	--
Fox 2015[53]	9.1	5.6	--	--
Fuchs 2011[135]	2.88	1.46	--	--
Huang 2004[30]	11.5	8.3*	--	--
Jain 2006[136]	3.8	2.4	--	--
Kanj 2013[144]	13.07	2.21*	0.96	0.96
Leblebicioglu 2013[109]	10.63	5.65*	0.9	0.84+
Marra, 2011[150]	7.6	5*	0.62	0.53
Martinez-Resendez 2014[115]	16.68	12.62*	--	--
Mathur 2015[116]	37.13	15.5	--	--
Miller 2010[66]	7.48	1.74*	--	--
Navoa-Ng 2013[145]	11	2.66*	0.67	0.6+
Noto 2015[68]	1.54	1.09	--	--
Popp, 2014[137]	2.7	0	--	--
Reilly 2006[138]	--	"33% Reduction"	0.96	0.86
Rosenthal 2012[146]	7.86	4.95	0.72	0.7
Saint, 2015[139]	1.4	2.1	--	--
Salama 2013[147]	5.5	5.9	--	--
Schelling 2015[140]	8.18	0.93	--	--
Seguin 2010[33]	5.0	4.9	--	--
Seyman 2014[148]	0.87	1.88	--	--

TABLE 2. Study Outcomes, As Reported in Included ICU Intervention Studies (continued)

B. Catheter-Associated Urinary Tract Infection (CAUTI) Outcomes

Study	CAUTIs per 1000 Catheter Days		Urinary Catheter Utilization Rates	
	Pre-Int./Control Rate	Post-Int. Rate	Pre-Int./Control Rate	Post-Int. Rate
Sutherland 2015[141]	5.4	2.2	.47	.76
Titsworth 2012[34]	13.3	4*	1	0.73+

Superscript numbers denote multiple ICUs of the same type included in one study.

Statistically significant outcomes (when p<0.05 or confidence interval did not contain a null hypothesis value) are noted with * for CLABSIs, CRBSIs, and CAUTIs and + for Central Line Device and Urinary Catheter Utilization Rates.

NOTE: Abbreviations: CLABSI,Central Line-Associated Bloodstream Infection; CRBSI,Catheter-Related Bloodstream Infection; CAUTI,Catheter-Associated Urinary Tract Infection; Int.,Intervention; -- , not reported in study; ICU Types: M,Medical ICU, S,Surgical ICU, C,Cardiac ICU.

from 0 to 11.2 and a non-US study range from 1.9 to 65.7.

Overall (Table 2), 27 of the 30 intervention cohorts described in the 28 studies reported fewer CAUTIs, including all ICU types. Lower postintervention CAUTI rates were reported in 25 studies, with a mean 49.4% reduction, including 11 statistically significant reductions; many studies did not report the level of statistical significance or described inadequate power to detect a significant change (Table 2).

Urinary catheter utilization rates were reported for 11 studies (Table 2). A decreased urinary catheter utilization rate was reported in 7 studies (4 with statistically signficiant reductions), with a mean 16% reduction (Table 2). Other outcomes included cost savings, the potential for unintended negative outcomes, and clinician compliance with intervention components. Positive cost savings were reported in 5 studies.[30,34,133,141,149]

CAUTI Interventions

Of the 28 included CAUTI prevention studies, only 5 studied single interventions. Interventions were categorized in Table 1 by "life cycle" stages or as interventions to improve implementation and sustainability (Figure 2). Interventions to restrict indwelling urinary catheter use were common, including creating lists of approved indications selected by unit or hospital policy and requiring catheter orders with approved indications. Eight studies published approved indication lists.[28,34,133-135,138,142,146] Although several studies describe the encouragement and use of bladder scanners and urinary catheter alternatives, none described purchasing these catheter alternatives.

Interventions to avoid indwelling urinary catheters included education about external catheters,[28,34,109,133,140,144-146] urinary retention protocols,[34,144,135,141] and bladder scanner simulation training.[133] Interventions to improve aseptic insertion[28,34,66,109,116,139-141,143-146,150] and maintenance care[28,34,66,109,116,133,135,136,139-141,143-146,150] of urinary catheters were common. Four studies used a standardized urinary catheter kit or cart,[28,34,139,142] and 2 studies used a commercial urinary catheter securement device.[34,140] A CAUTI bundle checklist in daily patient care rounds was tested in 3 studies (Table 1).[66,136,150] Reminder and stop order strategies, with the potential to reduce CAUTI rates by >50%,[151] were included in 15 studies, with inteventions such as nurse-empowered stop orders. Several implementation and sustainability interventions were described, including socio-adaptive strategies such as holding multidisciplinary meetings

to obtain unit or clinician feedback to inform design and improve buy-in and providing frequent feedback to ICU clinicians, including audits of catheter use appropriateness and catheter-associated infections.

DISCUSSION

This extensive literature review yielded a large body of literature demonstrating success in preventing CLABSI and CAUTI in all types of adult ICUs, including in general medical and surgical ICUs and in specialized units with historically higher rates, such as trauma, burn, and neurosurgical. Reported reductions in catheter infections were impressive (>65% for CLABSI or CRBSI and nearly 50% for CAUTI), though several studies had limited power to detect statistical significance. DURs were reported more rarely (particularly for vascular catheters) and often without power to detect statistical significance. Nevertheless, 7 studies reported reduced urinary catheter use (16% mean reduction), which would be anticipated to be clinically significant.

The conceptual model introduced for "Disrupting the Life Cycle of a Catheter" (Figure 2) can be a helpful tool for hospitalists and intensivists to assess and prioritize potential strategies for reducing catheter-associated infections. This study's results in-
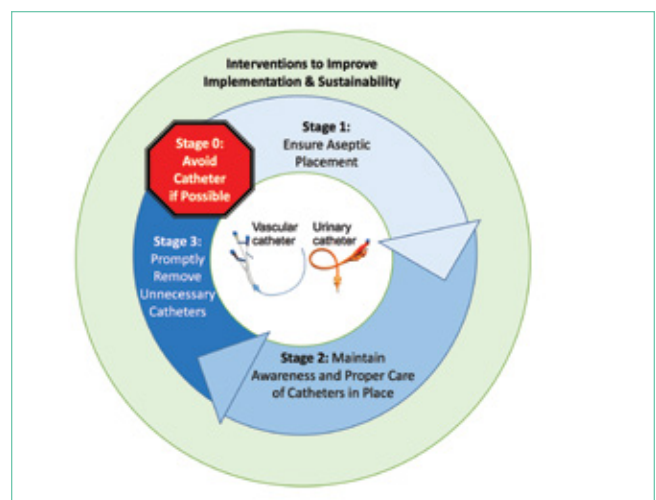

FIG 2. Disrupting the life cycle of a catheter.

Adapted from Meddings J, Saint S. Disrupting the life cycle of the urinary catheter. *Clin Infect Dis.* 2011;52(11):1291-129.

dicate that CLABSI prevention studies often used interventions that optimize best practices during aseptic insertion and maintenance, but few studies emphasized reducing inappropriate central line use. Conversely, CAUTI prevention often targeted avoiding placement and prompting the removal of urinary catheters, with fewer studies evaluating innovative products or technical skill advancement for aseptic insertion or maintenance, though educational interventions to standardize aseptic catheter use were common. Recently, recommendations for reducing the inappropriate use of urinary catheters and intravenous catheters, including scenarios common in ICUs, were developed by using the rigorous RAND/UCLA Appropriateness Method[152,153]; these resources may be helpful to hospitalists designing and implementing interventions to reduce catheter use.

In reviewing the US studies of 5 units demonstrating the greatest success in preventing CLABSI[56,62,65,78,83] and CAUTI,[28,34,66,134] several shared features emerged. Interventions that addressed multiple steps within the life cycle of a catheter (avoidance, insertion, maintenance, and removal) were common. Previous work has shown that assuring compliance in infection prevention efforts is a key to success,[154] and in both CLABSI and CAUTI studies, auditing was included in these successful interventions. Specifically for CLABSI, the checklist, a central quality improvement tool, was frequently associated with success. Unique to CAUTI, engaging a multidisciplinary team including nurse leadership seemed critical to optimize implementation and sustainability efforts. In addition, a focus on stage 3 (removal), including protocols to remove by default, was associated with success in CAUTI studies.

Our review was limited by a frequent lack of reporting of statistical significance or by inadequate power to detect a significant change and great variety. The ability to compare the impact of specific interventions is limited because studies varied greatly with respect to the type of intervention, duration of data collection, and outcomes assessed. We also anticipate that successful interventions are more likely to be published than are trials without success. Strengths include the use of a rigorous search process and the inclusion and review of several types of interventions implemented in ICUs.

In conclusion, despite high catheter use in ICUs, the literature includes many successful interventions for the prevention of vascular and urinary catheter infections in multiple ICU types. This review indicates that targeting multiple steps within the life cycle of a catheter, particularly when combined with interventions to optimize implementation and sustainability, can improve success in reducing CLABSI and CAUTI in the ICU.

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