

Original Article

Pathogens causing central-line-associated bloodstream infections in acute-care hospitals—United States, 2011–2017

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Abstract

Objective: To describe pathogen distribution and rates for central-line-associated bloodstream infections (CLABSIs) from different acute-care locations during 2011–2017 to inform prevention efforts.

Methods: CLABSI data from the Centers for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN) were analyzed. Percentages and pooled mean incidence density rates were calculated for a variety of pathogens and stratified by acute-care location groups (adult intensive care units [ICUs], pediatric ICUs [PICUs], adult wards, pediatric wards, and oncology wards).

Results: From 2011 to 2017, 136,264 CLABSIs were reported to the NHSN by adult and pediatric acute-care locations; adult ICUs and wards reported the most CLABSIs: 59,461 (44%) and 40,763 (30%), respectively. In 2017, the most common pathogens were *Candida* spp/yeast in adult ICUs (27%) and Enterobacteriaceae in adult wards, pediatric wards, oncology wards, and PICUs (23%–31%). Most pathogen-specific CLABSI rates decreased over time, excepting *Candida* spp/yeast in adult ICUs and Enterobacteriaceae in oncology wards, which increased, and *Staphylococcus aureus* rates in pediatric locations, which did not change.

Conclusions: The pathogens associated with CLABSIs differ across acute-care location groups. Learning how pathogen-targeted prevention efforts could augment current prevention strategies, such as strategies aimed at preventing *Candida* spp/yeast and Enterobacteriaceae CLABSIs, might further reduce national rates.

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Central-line-associated bloodstream infections (CLABSIs) are a leading cause of healthcare-associated infections (HAIs).¹ They are associated with increased mortality, length of stay, and healthcare costs.^{2–6}

The Centers for Medicare and Medicaid Services (CMS) require some types of healthcare facilities to report HAIs, including CLABSIs, to the Center for Disease Control and Prevention (CDC) National Healthcare Safety Network (NHSN), the largest HAI surveillance system in the United States, which then reports to CMS on behalf of the healthcare facilities. These requirements have expanded over time. On January 1, 2011, CMS mandated CLABSI reporting as a condition of participation in the CMS Hospital Inpatient Quality Reporting Program in both adult intensive care units (ICUs) and pediatric ICUs (PICUs).⁷ On January 1, 2015, CMS mandated CLABSI reporting for all adult and pediatric medical, surgical, and combined medical-surgical wards.⁸

Adoption of evidence-based infection prevention measures and other best practices, often rolled into bundles, and summarized in guidelines^{9,10} have resulted in decreased CLABSI incidence rates at individual facilities.^{11–14} These decreases were reflected nationwide by a 50% decrease in CLABSIs from 2008 to 2014¹⁵ and a further 9% decrease from 2016 to 2017.¹⁶ However, ~24,000 CLABSIs were still reported by acute-care hospitals in 2017,¹⁶ showing that continued efforts to prevent CLABSIs are needed, including ensuring adherence to established prevention strategies as well as development of new interventions. Developing CLABSI prevention interventions targeting specific causative pathogens may be one such approach.

A better understanding of how CLABSI pathogen distribution has changed over time in different locations and the current predominant pathogens could inform prevention efforts. We analyzed nationwide CLABSI data from acute-care hospitals collected via the CDC NHSN to evaluate these questions.

Methods

CLABSI surveillance and reporting

Detailed descriptions of NHSN CLABSI surveillance methods are available.¹⁷ As currently defined, a bloodstream infection (BSI) is a

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positive blood culture growing a recognized pathogen (eg, *Staphylococcus aureus*) or at least 2 positive cultures (from separate blood draws collected on the same or consecutive days) growing a common commensal organism (eg, coagulase-negative staphylococci [CNS]) with at least 1 sign or symptom consistent with a BSI. Before 2013, 2 blood cultures drawn with no more than a single gap day between them could be used to classify a primary BSI associated with a common commensal organism. A primary BSI is a BSI event that is not secondary to infection at another body site. A CLABSI is a primary BSI occurring in a patient with a central venous catheter (CVC) in place on the day of or the day before the date of infection and the CVC has been in place >2 consecutive calendar days. In 2015, NHSN made changes to some HAI definitions including the urinary tract infection (UTI) and secondary BSI definitions that might impact the classification of BSIs as CLABSIs.¹⁸ These changes include excluding yeast, mold, dimorphic fungi and parasites as possible UTI pathogens, requiring a colony count of at least 100,000 CFU/mL for UTIs and utilizing a secondary BSI attribution period to determine the period during which a BSI can be considered secondary to another site.

For each CLABSI, facilities report the date of event and location to which the event is attributed. The definition of date of event has changed over time, primarily to quantify time frames during which all criteria must be met and reduce the opportunities to misclassify BSIs as secondary to another site of infection. Locations are classified according to the characteristics of patients present.¹⁹ Typically, 80% of the patients in a given location must match the typical patient population for it to be classified into a particular category. If not, then it is categorized as a more generalized location for a given acuity level. Up to 3 causative pathogens can be reported for each CLABSI.

Statistical analysis

We used data from CLABSIs that occurred from 2011 to 2017, were reported by acute-care locations, and met NHSN CLABSI surveillance definitions in place at the time of the date of event.

The NHSN acute-care locations were divided into 5 mutually exclusive patient care location groups: adult ICUs, PICUs, adult wards, pediatric wards, and oncology wards. Adult ICUs and PICUs included all critical care locations reporting to NHSN: medical, surgical, medical/surgical, and specialty ICUs, such as burn ICUs. Adult and pediatric wards included all wards reporting to NHSN (ie, medical, surgical, medical/surgical, and specialty wards such as neurology). Oncology wards included both pediatric and adult wards but not oncology ICUs. Critical access hospitals were included. We excluded data from locations that did not correspond to one of the aforementioned patient care location groups including neonatal intensive care units, step-down units, mixed acuity units, inpatient rehabilitation facilities, rehabilitation wards, specialty care areas, and long-term acute-care hospitals.

We divided pathogens into the following 6 categories based on prior literature showing they were a leading cause of CLABSIs or hypothesized modes of transmission: Enterobacteriaceae, gram-negative bacteria that originate primarily from environmental reservoirs (eg, *Pseudomonas aeruginosa* and *Serratia marcescens*), *Enterococcus* spp, *S. aureus*, CNS, and *Candida* spp/yeast. All pathogens that were not included in the prior 6 categories were grouped as “other” pathogens.

For CLABSIs with >1 pathogen, we counted each pathogen as a separate CLABSI event. For the pathogen categories, we calculated

the distribution by year in each acute-care location group and reported these as percentages. We calculated the annual pooled mean pathogen-specific CLABSI incidence density rate per 1,000 central-line days by acute-care location group. Annual pooled mean CLABSI rates were reported for descriptive and referential purposes. To examine temporal changes we used 3 different end-point comparisons, pathogen-specific CLABSI rates in 2011 and 2017 (beginning to end of time period), 2011 and 2014 (beginning of time period to NHSN 2015 definition changes), and 2015 and 2017 (time after NHSN 2015 definition change to the end of the study period). We calculated incidence rate ratios and 95% Wald confidence intervals (CIs). Statistical analyses were performed using SAS version 9.3 software (SAS Institute, Cary, NC).

To evaluate whether our findings could be explained, at least in part, by migration into or out of the surveillance network, a sensitivity analysis was conducted using data from continuous reporters, defined as units that participated in CLABSI surveillance for at least 1 month in each analysis year (2011–2017).

The CDC Ethical Review Board has previously determined that the reporting of HAI data to NHSN is surveillance and not research; therefore, it is not subject to institutional review board requirements. Our report was within the scope of routine surveillance activities and therefore was not subject to further institutional review.

Results

Participating facilities and locations

In 2011, 3,624 facilities participated in NHSN CLABSI surveillance for at least 1 month during the year, increasing to 4,502 in 2017 (Table 1). Adult ICUs and wards have the highest number of reporting locations with 3,313 and 4,325, respectively, in 2017. Between 2014 and 2015, the number of adult, and pediatric, wards increased corresponding to new reporting mandates. Central-line days reported from these locations increased correspondingly. From 2011 to 2017, 136,264 CLABSIs were reported to the NHSN; adult ICUs and wards reported the most CLABSIs: 59,461 (44%) and 40,763 (30%), respectively.

ICU location groups

Adult ICUs. The percentage of CLABSIs for which each of the pathogen groups was reported is shown in Figure 1. In 2017, *Candida* spp/yeast made up the largest proportion, followed by *Enterococcus* spp and then Enterobacteriaceae. *Candida* spp/yeast and CNS accounted for a larger proportion of CLABSIs in adult ICUs than any other location group.

Among unadjusted pathogen-specific CLABSI rates, *Candida* spp/yeast was the only pathogen group to increase from 2011 to 2017 (rate ratio [RR], 1.30; 95% confidence interval [CI], 1.22–1.38) (Table 2). Rates for the other pathogen groups decreased, and the greatest reductions were identified for *S. aureus*, CNS, and environmental gram-negative bacteria.

PICUs. Enterobacteriaceae were reported from the largest proportion of CLABSIs, ~25% in 2017 (Fig. 1), followed by *Enterococcus* spp, environmental gram-negative bacteria, and *S. aureus*. *Enterococcus* spp and environmental gram-negative bacteria each made up a larger proportion of CLABSIs in the PICU than in any other location group.

Unadjusted rates of CNS and *Candida* spp/yeast fell from 2011 to 2017 (Table 3). The greatest reductions were identified for CNS.

Table 1. Acute-Care Facilities and Locations Participating in National Healthcare Safety Network (NHSN) Central-Line–Associated Bloodstream (CLABSI) Surveillance, 2011–2017

Facility or Location	2011	2012	2013	2014	2015	2016	2017
Acute-care facilities and locations participating in CLABSI surveillance^a							
Facilities	3,624	3,711	3,767	3,909	4,284	4,367	4,502
Adult ICUs	3302	3338	3313	3313	3308	3300	3313
PICUs	335	349	349	353	361	365	364
Adult wards	1,486	1,730	1,847	2,494	4,082	4,179	4,325
Pediatric wards	388	425	469	554	998	1,020	1,030
Oncology wards	186	201	244	302	416	435	457
No. of CLABSIs reported by acute-care location groups							
Adult ICUs	9,200	9,136	8,472	7,672	9,028	8,348	7,605
PICUs	963	805	705	686	964	1,030	958
Adult wards	3,503	3,670	3,879	4,547	9,632	8,250	7,282
Pediatric wards	296	293	283	336	632	628	636
Oncology wards	1,741	1,975	2,904	3,239	5,302	5,673	5,991
Central-line days reported by acute-care location groups							
Adult ICUs	8,718,286	8,679,798	8,686,661	8,692,550	8,712,871	8,571,214	8,268,079
PICUs	549,999	567,349	567,597	588,267	633,933	646,380	658,787
Adult wards	3,980,972	4,416,976	5,068,452	6,392,043	11,453,537	11,213,816	10,802,442
Pediatric wards	245,435	282,790	306,864	357,313	550,154	563,194	557,613
Oncology wards	949,746	1,069,993	1,473,960	1,734,171	2,343,183	2,462,183	2,501,467

Note. CLABSI, central-line–associated bloodstream infection; ICU, intensive care unit; PICU, pediatric intensive care unit; NHSN, National Healthcare Safety Network. ^aReported at least 1 month of central-line days during given year.

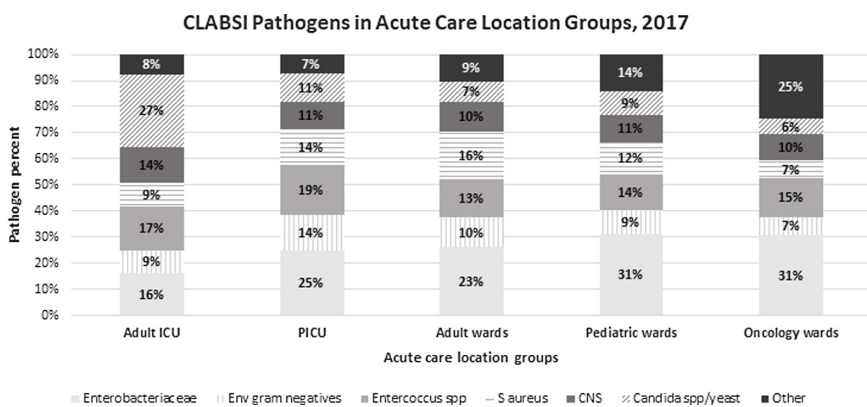


Fig. 1. Central-line–associated bloodstream infection (CLABSI) pathogen categories by acute-care location groups, 2017. Note. CNS, coagulase-negative staphylococci; Env, environmental; ICU, intensive care unit; PICU, pediatric intensive care unit.

Ward location groups

Adult wards. In 2017, Enterobacteriaceae made up the largest proportion of CLABSIs (23%) (Fig. 1). The pathogen group with the second-highest proportion was *S. aureus* (16%). From 2011 to 2017, unadjusted CLABSI rates decreased for all pathogen groups and CNS had the largest decrease (Table 4).

Pediatric wards. In 2017, Enterobacteriaceae were reported from a larger percentage of CLABSIs than any other pathogen group (31%) (Fig. 1). No other pathogen group accounted for >14% of CLABSIs. Enterobacteriaceae also made up a larger

proportion of CLABSIs from pediatric wards than from any other location (except oncology wards where the proportion remained the same). Unadjusted pathogen-specific rates were all unchanged (Table 5).

Oncology wards. In 2017, Enterobacteriaceae accounted for the largest proportion of CLABSIs (31%) (Fig. 1). “Other” pathogens were the second-highest group at 25%. Among the “other” pathogens, 42% were viridans group streptococci (VGS). From 2011 to 2017, Enterobacteriaceae rates increased (RR, 1.55; 95% CI, 1.40–1.71) (Table 6). Rates of other pathogen groups remained unchanged except VGS, which also increased (RR, 2.33; 95% CI, 1.91–2.84).

Table 2. Yearly Pathogen-Specific Central-Line–Associated Bloodstream Infection (CLABSI) Incidence Density Rates per 1,000 Central-Line Days (2011–2017) and Incidence Rate Ratios in Adult Intensive Care Units

Pathogen	CLABSI Incidence Density Rates per 1,000 Central-Line Days							Rate Ratio (95% CI)		
	2011	2012	2013	2014	2015	2016	2017	2011–2014	2015–2017	2011–2017
CLABSI	1.055	1.053	0.975	0.883	1.036	0.974	0.920	...	...	...
Enterobacteriaceae	0.185	0.197	0.174	0.166	0.195	0.170	0.165	0.90 (0.84–0.97)	0.85 (0.79–0.91)	0.90 (0.83–0.96)
Environmental gram-negative bacteria	0.127	0.129	0.117	0.102	0.106	0.095	0.089	0.80 (0.73–0.88)	0.84 (0.76–0.93)	0.7 (0.64–0.77)
<i>Enterococcus</i> spp	0.224	0.213	0.205	0.171	0.196	0.187	0.174	0.76 (0.71–0.82)	0.89 (0.83–0.95)	0.78 (0.73–0.83)
<i>Staphylococcus aureus</i>	0.130	0.126	0.118	0.101	0.106	0.097	0.090	0.78 (0.71–0.85)	0.85 (0.77–0.94)	0.69 (0.63–0.76)
Coagulase-negative staphylococci	0.212	0.206	0.177	0.170	0.154	0.149	0.144	0.80 (0.75–0.86)	0.93 (0.86–1.01)	0.68 (0.63–0.73)
<i>Candida</i> spp/yeast	0.216	0.219	0.219	0.210	0.285	0.290	0.281	0.97 (0.91–1.04)	0.99 (0.93–1.04)	1.30 (1.22–1.38)

Table 3. Yearly Pathogen-Specific Central-Line–Associated Bloodstream Infection (CLABSI) Incidence Density Rates per 1,000 Central-Line Days (2011–2017) and Incidence Rate Ratios in Pediatric Intensive Care Units

Pathogen	CLABSI Incidence Density Rates per 1,000 Central-Line Days							Rate Ratio (95% CI)		
	2011	2012	2013	2014	2015	2016	2017	2011–2014	2015–2017	2011–2017
CLABSI	1.751	1.419	1.242	1.521	1.593	1.454	1.191	...	...	...
Enterobacteriaceae	0.475	0.349	0.337	0.320	0.420	0.473	0.411	0.67 (0.56–0.81)	0.98 (0.83–1.16)	0.87 (0.73–1.03)
Environmental gram-negative bacteria	0.196	0.196	0.183	0.168	0.241	0.277	0.231	0.86 (0.65–1.13)	0.96 (0.76–1.20)	1.17 (0.92–1.50)
<i>Enterococcus</i> spp	0.364	0.296	0.248	0.231	0.304	0.350	0.316	0.64 (0.51–0.79)	1.04 (0.85–1.26)	0.87 (0.72–1.05)
<i>Staphylococcus aureus</i>	0.242	0.204	0.194	0.182	0.218	0.207	0.226	0.75 (0.58–0.97)	1.04 (0.82–1.31)	0.94 (0.74–1.18)
Coagulase-negative staphylococci	0.364	0.275	0.176	0.165	0.189	0.172	0.176	0.45 (0.36–0.58)	0.93 (0.72–1.20)	0.48 (0.39–0.61)
<i>Candida</i> spp/yeast	0.244	0.182	0.173	0.124	0.196	0.224	0.181	0.51 (0.38–0.68)	0.92 (0.72–1.19)	0.74 (0.58–0.95)

Table 4. Yearly Pathogen-Specific Central-Line–Associated Bloodstream Infection (CLABSI) Incidence Density Rates per 1,000 Central-Line Days (2011–2017) and Incidence Rate Ratios in Adult Wards

Pathogen	CLABSI Incidence Density Rates per 1,000 Central-Line Days							Rate Ratio (95% CI)		
	2011	2012	2013	2014	2015	2016	2017	2011–2014	2015–2017	2011–2017
CLABSI	0.879	0.831	0.765	0.711	0.840	0.735	0.674	...	...	...
Enterobacteriaceae	0.195	0.202	0.190	0.179	0.216	0.198	0.174	0.92 (0.84–1.01)	0.81 (0.76–0.86)	0.89 (0.82–0.97)
Environmental gram-negative bacteria	0.092	0.096	0.097	0.087	0.099	0.076	0.077	0.94 (0.82–1.07)	0.78 (0.71–0.85)	0.83 (0.74–0.94)
<i>Enterococcus</i> spp	0.147	0.142	0.127	0.115	0.131	0.110	0.100	0.78 (0.70–0.87)	0.76 (0.70–0.82)	0.68 (0.61–0.75)
<i>Staphylococcus aureus</i>	0.171	0.157	0.147	0.131	0.146	0.128	0.120	0.76 (0.69–0.84)	0.82 (0.77–0.89)	0.70 (0.64–0.77)
Coagulase-negative staphylococci	0.151	0.120	0.114	0.113	0.111	0.090	0.075	0.75 (0.67–0.83)	0.68 (0.62–0.74)	0.50 (0.45–0.55)
<i>Candida</i> spp/yeast	0.157	0.154	0.139	0.134	0.166	0.144	0.131	0.86 (0.77–0.95)	0.79 (0.74–0.85)	0.83 (0.76–0.92)

Continuous reporters

Our sensitivity analyses limited to continuous reporters were consistent with the findings reported above, including pathogen percentage and pathogen-specific CLABSI rates in adult and pediatric location groups.

Discussion

This report describes CLABSI pathogen distribution in 2017 and rates in acute-care location groups from 2011 to 2017. Overall, the pathogen distribution varied by location group;

Enterobacteriaceae was the most commonly reported pathogen group in all locations except adult ICUs, for which the most commonly reported pathogen group was *Candida* spp/yeast. Incidence density rates also varied over the study period. Most pathogens in adult locations decreased; exceptions include *Candida* spp/yeast in adult ICUs and Enterobacteriaceae in oncology wards, which both increased. In PICUs, only CNS and *Candida* spp/yeast decreased, and in other pediatric locations, pathogen groups did not change.

This evaluation yielded several notable findings. First, this analysis reinforces the important role that Enterobacteriaceae have as a cause of BSIs. Enterobacteriaceae made up the largest pathogen

Table 5. Yearly Pathogen-Specific Central-Line-Associated Bloodstream Infection (CLABSI) Incidence Density Rates per 1,000 Central-Line Days (2011–2017) and Incidence Rate Ratios in Pediatric Wards

Pathogen	CLABSI Incidence Density Rates per 1,000 Central-Line Days							Rate Ratio (95% CI)		
	2011	2012	2013	2014	2015	2016	2017	2011–2014	2015–2017	2011–2017
CLABSI	1.206	1.036	0.922	0.940	1.149	1.115	1.141	...	...	...
Enterobacteriaceae	0.444	0.339	0.303	0.311	0.442	0.430	0.396	0.70 (0.54–0.91)	0.90 (0.75–1.08)	0.89 (0.71–1.12)
Environmental gram-negative bacteria	0.090	0.099	0.091	0.084	0.113	0.089	0.111	0.94 (0.54–1.62)	0.99 (0.69–1.4)	1.24 (0.76–2.02)
<i>Enterococcus</i> spp	0.175	0.152	0.163	0.137	0.151	0.204	0.179	0.78 (0.52–1.18)	1.19 (0.89–1.59)	1.02 (0.72–1.46)
<i>Staphylococcus aureus</i>	0.130	0.166	0.134	0.137	0.169	0.139	0.156	1.05 (0.67–1.64)	0.92 (0.69–1.24)	1.20 (0.80–1.79)
Coagulase-negative staphylococci	0.204	0.124	0.121	0.165	0.171	0.140	0.147	0.81 (0.56–1.18)	0.86 (0.64–1.16)	0.72 (0.51–1.03)
<i>Candida</i> spp/yeast	0.134	0.159	0.114	0.123	0.124	0.133	0.118	0.92 (0.58–1.44)	0.96 (0.68–1.34)	0.88 (0.58–1.34)

Table 6. Yearly Pathogen-Specific Central-Line-Associated Bloodstream Infection (CLABSI) Incidence Density Rates per 1,000 Central Line-Days (2011–2017) and Incidence Rate Ratios in Oncology Wards

Pathogen	CLABSI Incidence Density Rates per 1,000 Central-Line Days							Rate Ratio (95% CI)		
	2011	2012	2013	2014	2015	2016	2017	2011–2014	2015–2017	2011–2017
CLABSI	1.833	1.845	1.970	1.868	2.263	2.304	2.395	...	...	...
Enterobacteriaceae	0.601	0.519	0.536	0.623	0.761	0.773	0.802	1.20 (1.08–1.33)	1.05 (0.99–1.12)	1.55 (1.40–1.71)
Environmental gram-negative bacteria	0.210	0.174	0.174	0.172	0.188	0.179	0.187	0.82 (0.69–0.98)	1.00 (0.88–1.14)	0.89 (0.76–1.06)
<i>Enterococcus</i> spp	0.355	0.337	0.341	0.325	0.382	0.371	0.389	0.92 (0.80–1.05)	1.02 (0.93–1.12)	1.10 (0.97–1.24)
<i>Staphylococcus aureus</i>	0.191	0.188	0.181	0.171	0.196	0.184	0.179	0.90 (0.74–1.08)	0.91 (0.80–1.04)	0.94 (0.79–1.12)
Coagulase-negative staphylococci	0.313	0.303	0.277	0.250	0.252	0.255	0.260	0.80 (0.69–0.93)	1.03 (0.92–1.15)	0.83 (0.73–0.95)
<i>Candida</i> spp/yeast	0.138	0.098	0.116	0.116	0.160	0.163	0.148	0.84 (0.67–1.05)	0.92 (0.80–1.07)	1.07 (0.88–1.31)

group in all location groups except adult ICUs. In addition, only 1 of 2 pathogen group and location combinations increased between 2011 and 2017; the rate ratio for Enterobacteriaceae CLABSIs from oncology wards increased 50% during that time. This finding is particularly concerning in light of the emergence and spread of highly resistant Enterobacteriaceae, including extended-spectrum β -lactamases (ESBL)-producing and carbapenemase-producing strains.

Novel interventions targeting resistant gram-negative bacteria are being evaluated including selective decontamination of the digestive tract (SDD); however, recent data have suggested that this method might be less effective than originally thought.²⁰ Other interventions designed to reduce the carriage of gram-negative bacteria in the gastrointestinal tract, including manipulation of the patient's microbiome, may have potential for reducing Enterobacterial infections. Colonization with these organisms has been shown to increase the risk of subsequent HAIs including gram-negative bacteremias.²¹ Although some studies have shown chlorhexidine gluconate (CHG) bathing to be effective in reducing gram-negative HAIs,²² if done poorly, this intervention might have less effect on gram-negative bacteria due to suboptimal levels of CHG on the skin as well as the potential for reduced susceptibility of some of these bacteria to this antiseptic.²³ A recent meta-analysis concluded CHG bathing had no effect on gram-negative infections.²⁴ More information is needed to better define why some patients are at risk and to develop prevention strategies targeted at Enterobacteriaceae.

A second notable finding is the substantial contribution of *Candida* spp/yeast to CLABSIs, particularly in adult ICUs. The rate of *Candida* spp/yeast CLABSIs in adult ICUs has increased since 2011, and this increase is, at least in part, related to the 2015 NHSN urinary tract infection definition changes. BSIs that were previously classified as secondary to another source (ie, the urinary tract) became reclassified as primary BSIs and potentially CLABSIs because yeast are no longer considered eligible organisms for UTIs. However, other evaluations have identified *Candida* spp as an important cause of BSIs, including a CDC-led 2015 point prevalence survey of acute-care locations that found *Candida* spp to be the second most common cause of primary BSIs.¹ In our analysis, *Candida* spp/yeast were reported from >25% of CLABSIs in the ICU but smaller proportions of CLABSIs from the other locations (6%–11%). Rates fell in adult wards and PICUs and were unchanged in oncology and pediatric wards.

Historically, *Candida* BSIs have often been thought to be related to translocation from a gastrointestinal source²⁵ in which case interventions aimed at CVC insertion and maintenance practices might be expected to have less of an effect. Notably, the emergence of *Candida auris*, which has been shown to persist in the healthcare environment, has raised the possibility that the environment might play a role in spread and subsequent HAIs for other non-albicans *Candida* spp.²⁶ The CDC has recognized improved environmental cleaning in healthcare as a critical area for addressing HAIs and spread of resistant organisms and has instituted several important initiatives designed to improve these processes.²⁷

Prior reports showed a decrease in *S. aureus* CLABSI rates in the early 2000s, primarily in adult ICUs,^{28–30} largely due to the widespread uptake of evidence-based central-line care bundles that focus mainly on insertion practices. However, PICUs did not see the same improvement.²⁸ Rates continued to decline from 2011 to 2017 in adult locations, but rates in pediatric and oncology locations did not change. Reasons for this are unclear and might be related to limited infection prevention and control practices evidence-base in the pediatric population^{31–34} and differential uptake of practices such as CHG bathing across different patient groups and in different locations (eg, wards vs ICUs).

Rates of CLABSIs due to CNS decreased in all locations except for pediatric wards, and the decreases over the entire period were larger for CNS than any other pathogen in 3 of the 4 locations where rates decreased. This might be, at least in part, due to increased attention to CVC insertion and maintenance practices. In addition, increased use of CHG bathing could also have contributed to declines in CLABSIs due to skin commensals like CNS; however, reductions occurred even outside of adult ICUs, the setting where CHG bathing has been most widely recommended. In the REDUCE MRSA trial, the reductions in BSIs in the group undergoing universal decolonization were, in large part, due to reductions in gram-positive skin commensals.³⁵ In a subanalysis of that project, the largest reduction in blood culture contamination rates was seen in the CHG bathing group.³⁶ Notably, CLABSIs due to *S. aureus* did not decrease in the same locations; other interventions may have played a larger role in the reduction in CNS CLABSIs in some locations. For example, a renewed focus on blood culture collection practices might have played a role in this result. Implementing practices like phlebotomy teams with specialized training for blood culture collection has resulted in reductions in contamination from skin commensals like CNS.^{37,38}

Finally, environmental gram-negative bacteria were associated with a sizable proportion of CLABSIs. The proportion in most locations was similar to that seen with *S. aureus*, which is a more commonly recognized cause of CLABSI. These organisms can often be associated with exposure to water.³⁹ Interventions aimed at improving water quality in healthcare settings through the development and implementation of water management programs have the potential to impact this proportion of CLABSIs.⁴⁰ In addition, decreasing environmental contamination through improved cleaning and disinfection of surfaces around sinks and sink bowls and by keeping supplies outside of the sink splash zone are important ways to minimize exposure to these pathogens.

This analysis was subject to several important limitations. Small numbers of facilities reported CLABSIs in some acute-care location groups, particularly earlier in the surveillance period. We cannot exclude that migration into or out of the surveillance system impacted our findings. However, our sensitivity analysis of continuous reporters revealed the same predominant pathogens and rates over time as the primary analysis. We did group pathogens and locations, which may have obscured or amplified some pathogen rankings. We reported raw frequencies, distributions, and rates; we did not control for some factors that might influence particular pathogens, such as hospital type, bed size, and teaching status. We were unable to describe adherence to evidence-based CVC insertion and maintenance practices or to analyze the impact of particular practices such as blood culture collection site selection or water management programs on CLABSI reduction. We did not make statistical comparisons of pathogen differences between locations. Only the absolute differences in pathogen percentages were reported, so this report does not provide definitive conclusions

regarding pathogen differences between locations. Finally, changes in surveillance definitions and reporting mandates over time may have affected the number of CLABSIs and types of pathogens ultimately classified as CLABSIs.

Great strides have been made in reducing CLABSIs over the last decade, but further reductions in these serious infections are needed including work to ensure implementation of proven interventions around CVC insertion and maintenance. In locations that are adhering routinely to these interventions but are still having higher than expected CLABSIs, additional novel solutions for CLABSI prevention may be needed. Better understanding the pathogen distribution can help identify emerging trends and issues that might inform more targeted pathogen-specific prevention strategies leading to further reductions in these highly morbid infections. Prevention strategies for some pathogen groups are not currently well defined. For some pathogen groups, such as Enterobacteriaceae and *Candida* spp/yeast, we need to better understand why patients are at risk for CLABSIs from these pathogens and work toward more targeted prevention strategies that could augment current prevention efforts.

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