Since January 2020 Elsevier has created a COVID-19 resource centre with free information in English and Mandarin on the novel coronavirus COVID-19. The COVID-19 resource centre is hosted on Elsevier Connect, the company's public news and information website.

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Major article

Impact of COVID-19 pandemic on hospital onset bloodstream infections (HOBSI) at a large health system

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A B S T R A C T

Background: The COVID-19 pandemic has had a considerable impact leading to increases in health care-associated infections, particularly bloodstream infections (BSI).
Methods: We evaluated the impact of COVID-19 in 69 US hospitals on BSIs before and during the pandemic. Events associated with 5 pathogens (*Staphylococcus aureus*, *Escherichia coli*, *Klebsiella pneumoniae*, *Pseudomonas aeruginosa*, and *Candida sp.*) were stratified by community onset (CO) if ≤ 3 days from admission or hospital onset (HO) if > 3 days after admission. We compared pre-pandemic CO and HO rates with pandemic periods and the rates of BSI for those with and without COVID-19.
Results: COVID-19 patients were less likely to be admitted with COBSI compared to others (10.85 vs 22.35 per 10,000 patient days; $P < .0001$). There was a significant increase between pre-pandemic and pandemic HOBSI rates (2.78 vs 3.56 per 10,000 patient days; $P < .0001$). Also, COVID-19 infected patients were 3.5 times more likely to develop HOBSI compared to those without COVID-19 infection (9.64 vs 2.74 per 10,000 patient-days; $P < .0001$).
Conclusions: The COVID-19 pandemic period was associated with substantial increases in HOBSI and largely attributed to COVID-19 infected patients. Future research should evaluate whether such measures would be beneficial to incorporate in evaluating infection prevention trends.

The coronavirus disease 2019 (COVID-19) pandemic has brought unprecedented changes to the health care environment, having an impact on almost every component of delivering the care. The influx of COVID-19 infected patients forced hospitals to adjust workflows, address supplies, and manage patient and health care worker safety, in a busy and stressful environment. Furthermore, practices may have been altered to cope with a high-risk environment as well as product shortages. For example, vascular access care, generally standardized and evidence based, was vulnerable and became compromised for several reasons. Some early pandemic behaviors included placing intravenous pumps in the hallways, or extending the dwell time of the device, to reduce health care worker exposure risk. As the pandemic ensued, hospitals across the world started to note increases in hospital bloodstream infections.[1-5] We evaluated the impact of the pandemic on hospital onset bloodstream infections (HOBSI) in a multi-state health care system in the United States.

METHODS

Setting: Using one infection prevention surveillance system, we identified all positive blood cultures for 5 organisms commonly associated with health care infections[6-8] (*Staphylococcus aureus, Escherichia coli, Klebsiella pneumonia, Pseudomonas aeruginosa,* and Candida

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Table 1
Rates of community onset bloodstream infection (COBSI) Events and pathogens, pre-pandemic and during COVID-19 pandemic period

Community Onset (per 10,000 patient days)	Pre-Pandemic Period	Pandemic period	Pandemic Period Non COVID-19 Patients	Pandemic Period COVID-19 Patients	*P*-value (Pre-pandemic compared to all patients pandemic)	*P*-value (Pre-pandemic compared to pandemic Non COVID-19 patients)	*P*-value (Pandemic Non COVID-19 patients compared to COVID-19 patients)
COBSI Rate	21.12	20.98	22.35	10.85	0.68	0.0005	<0.0001
All organisms	(7,923/3,751,178)	(7,472/3,561,047)	(7,012/3,136,965)	(460/424,082)			
COBSI Rate	7.75	8.36	8.75	5.52	0.003	<0.0001	<0.0001
Staphylococcus aureus	(2,906/3,751,178)	(2,978/3,561,047)	(2,744/3,136,965)	(234/424,082)			
COBSI Rate	9.25	8.48	9.20	3.11	0.0005	0.85	<0.0001
Escherichia coli	(3,469/3,751,178)	(3,019/3,561,047)	(2,887/3,136,965)	(132/424,082)			
COBSI Rate	1.23	1.20	1.29	0.54	0.72	0.49	<0.0001
Pseudomonas aeruginosa	(463/3,751,178)	(429/3,561,047)	(406/3,136,965)	(23/424,082)			
COBSI Rate	0.64	0.64	0.66	0.50	0.99	0.74	0.21
Candida sp.	(240/3,751,178)	(228/3,561,047)	(207/3,136,965)	(21/424,082)			
COBSI Rate	2.40	2.30	2.45	1.18	0.34	0.71	<0.0001
Klebsiella pneumoniae	(902/3,751,178)	(818/3,561,047)	(768/3,136,965)	(50/424,082)			

Patient-based COVID-19 prevalence available for 63 hospitals.

sp.) in 69 hospitals of a single health system over two periods: 14-month pre-COVID-19 (January 1, 2019 to February 28, 2020), and during a 14 month COVID-19 pandemic period (March 1, 2020 to April 30, 2021). Events associated with the 5 organisms were classified as community and hospital onset. Community-onset BSI (COBSI) was defined for patients with BSI the first 3 days of admission. Each HOBSI event was classified based on a modified National Health Care Surveillance Network (NHSN) definition of lab-ID event, and identified >3 days after admission, if the patient had no prior event in the previous 14 days.[9] We evaluated the overall COBSI and HOBSI rates per 10,000 patient-days (based on patient length of stay) pre-pandemic and during the pandemic period (stratified out further by COVID-19 infected vs. others), as well as the contributing pathogen. We also evaluated the relative proportions of COBSI versus HOBSI during the entire time period. Patients with COVID-19 infection were identified by a confirmed SARS-CoV-2 positive result by polymerase chain reaction testing, or a COVID-19 encounter diagnosis of International Classification of Diseases 10 code U07.1.

Data analysis: Descriptive analyses of the pre-pandemic and pandemic periods for BSI for the 5 organisms combined and at the individual level were done. COBSI and HOBSI were also evaluated between COVID-19 infected and non-COVID-19 infected patients during the pandemic. The analyses were further stratified by percent of COVID-19 admissions. Overall COVID-19 prevalence was calculated during the pandemic period. Final data were de-identified and evaluated as aggregates. The study underwent Institutional Review Board evaluation and was deemed to be exempt from further review.

RESULTS

There were 1,417,036 admissions over the 28 months of the study in 69 hospitals (≤ 100 beds: 28; 101-300 beds: 20; >300 beds: 21), 703,556 admissions were during the pre-pandemic time frame, and 713,480 were during the pandemic period. COVID-19 infected patients represented 7.49% (n = 53,470) of admissions during the pandemic period. During the 28 months study period, there were a total of 15,395 COBSI and 2,308 HOBSI infections within the five organisms evaluated. Of the 15,395 COBSI events, 9.4% (1,447) were in ≤ 100 bed grouping, 33.2% (5,111) were in 101 to 300 bed grouping and 57.4% (8,837) were in the > 300 bed grouping. Of the 2,308 HOBSI events, 1.6% (37) were in ≤ 100 bed grouping, 25.0% (577) were in 101 to 300 bed grouping and 73.4% (1,694) were in the > 300 bed grouping. The mean length of stay for non-COVID-19 infected patients was similar pre-pandemic (4.65 days) and during pandemic (4.68 days) periods, and higher for those COVID-19 infected (7.54 days; $P < .0001$). Patients who developed HOBSI had much longer length of stay (pre-pandemic: 29.55 days; pandemic non-COVID-19: 26.44 days; pandemic COVID-19: 24.65 days; *P* value < .0001).

Community onset bloodstream infection (COBSI)

The rate of COBSI for all organisms combined did not significantly change during the pre-pandemic and pandemic periods (21.12 vs 20.98 per 10,000 patient days; $P = .68$) (Table 1). When evaluating

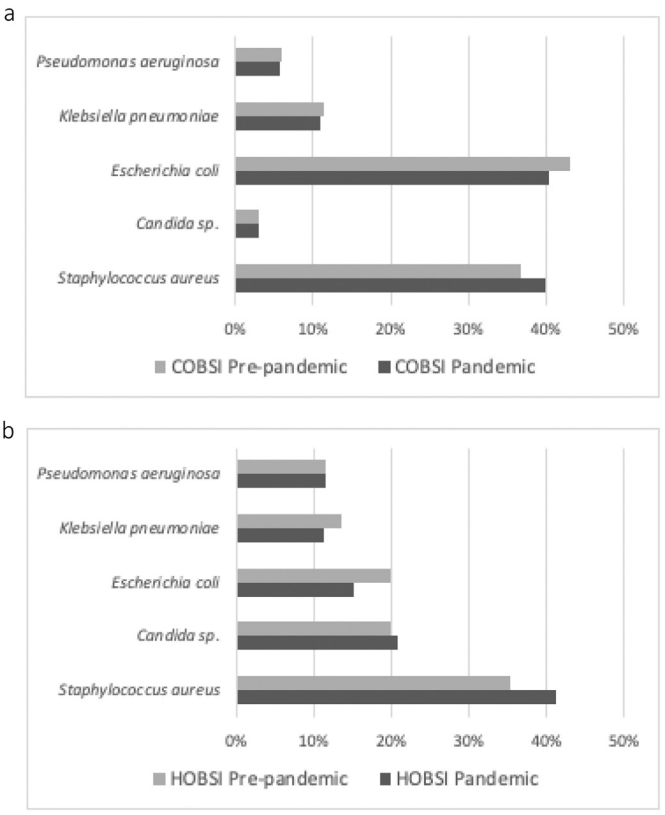

Fig 1. The proportion of each organism within bloodstream infections (BSI) comparing (A) pre-pandemic to pandemic community-onset (COBSI), and (B) pre-pandemic and pandemic hospital-onset (HOBSI).

Table 2
Rates of hospital onset bloodstream infection (HOBSI) events and pathogens, pre-pandemic and during COVID-19 pandemic period

Hospital Onset (per 10,000 patient days)	Pre-Pandemic Period	Pandemic period	Pandemic Period Non COVID-19 Patients	Pandemic Period COVID-19 Patients	*P*-value (Pre-pandemic compared to all patients pandemic)	*P*-value (Pre-pandemic compared to pandemic Non COVID-19 patients)	*P*-value (Pandemic Non COVID-19 patients compared to COVID-19 patients)
HOBSI Rate	2.78	3.56	2.74	9.64	<0.0001	0.75	<0.0001
All organisms	(1,041/3,751,178)	(1,267/3,561,047)	(858/3,136,965)	(409/424,082)			
HOBSI Rate	0.98	1.47	1.04	4.60	<0.0001	0.40	<0.0001
Staphylococcus aureus	(367/3,751,178)	(522/3,561,047)	(327/3,136,965)	(195/424,082)			
HOBSI Rate	0.55	0.54	0.48	0.99	0.85	0.20	<0.0001
Escherichia coli	(206/3,751,178)	(192/3,561,047)	(150/3,136,965)	(42/424,082)			
HOBSI Rate	0.32	0.41	0.28	1.39	0.04	0.35	<0.0001
Pseudomonas aeruginosa	(120/3,751,178)	(147/3,561,047)	(88/3,136,965)	(59/424,082)			
HOBSI Rate	0.55	0.74	0.57	1.96	0.002	0.74	<0.0001
Candida sp.	(208/3,751,178)	(263/3,561,047)	(180/3,136,965)	(83/424,082)			
HOBSI Rate	0.37	0.40	0.36	0.71	0.54	0.78	0.0008
Klebsiella pneumoniae	(140/3,751,178)	(143/3,561,047)	(113/3,136,965)	(30/424,082)			

Patient-based COVID-19 prevalence available for 63 hospitals.

specific pathogens, COBSI rates also remained stable between the 2 time periods for *P. aeruginosa, Candida sp.* and *K. pneumoniae*. However, COBSI rate was significantly higher for *S. aureus* during the pandemic period compared to the pre-pandemic period (8.36 vs 7.75; $P = .003$). Further analysis revealed that this increase was only noted in non-COVID-19 patients compared to COVID-19 patients during the pandemic period (8.75 vs 5.52; $P \leq .0001$). Similar findings were noted for *E. coli*, which was significantly higher for the non-COVID-19 patients during the pandemic versus the COVID-19 patients (9.20 vs 3.11; $P \leq .0001$) as well as *K. pneumoniae* (2.45 vs 1.18; $P \leq .0001$). Patients without COVID-19 infection were twice as likely to be admitted with a COBSI event compared to those with COVID-19 during the pandemic period (22.35 vs 10.85; $P < .0001$). There were significant changes in the proportion of *S. aureus* (increase, $P = .003$) and *E. coli* (decrease, $P = .0002$) contributing to pre-pandemic and pandemic COBSI events (Fig 1).

Hospital onset bloodstream infection (HOBSI)

The HOBSI rate for all patients in the pre-pandemic period was 2.78 compared to 3.56 per 10,000 patient days ($P \leq .0001$) during the pandemic period (Table 2). There were significant increases in HOBSI rates associated with *S. aureus* (+50%), *Candida sp.* (+35%), and *P. aeruginosa* (+28%). Furthermore, significant increases were witnessed in the proportion of *S. aureus* associated with HOBSI during the pandemic compared to pre-pandemic ($P = .005$), whereas the proportion of *E. coli* decreased ($P = .003$) (Fig 1). HOBSI rates per 10,000 patient-days in COVID-19 infected patients were higher in hospitals >300 beds (11.34; $P = .0001$) and 101-300 beds (7.11; $P = .008$) compared to hospitals ≤ 100 beds (2.25; reference). No significant differences were found between patients with HOBSI pre-pandemic when compared to patients not infected with COVID-19 during the pandemic period (2.78 vs 2.74 per 10,000 patient days; $P = .75$).

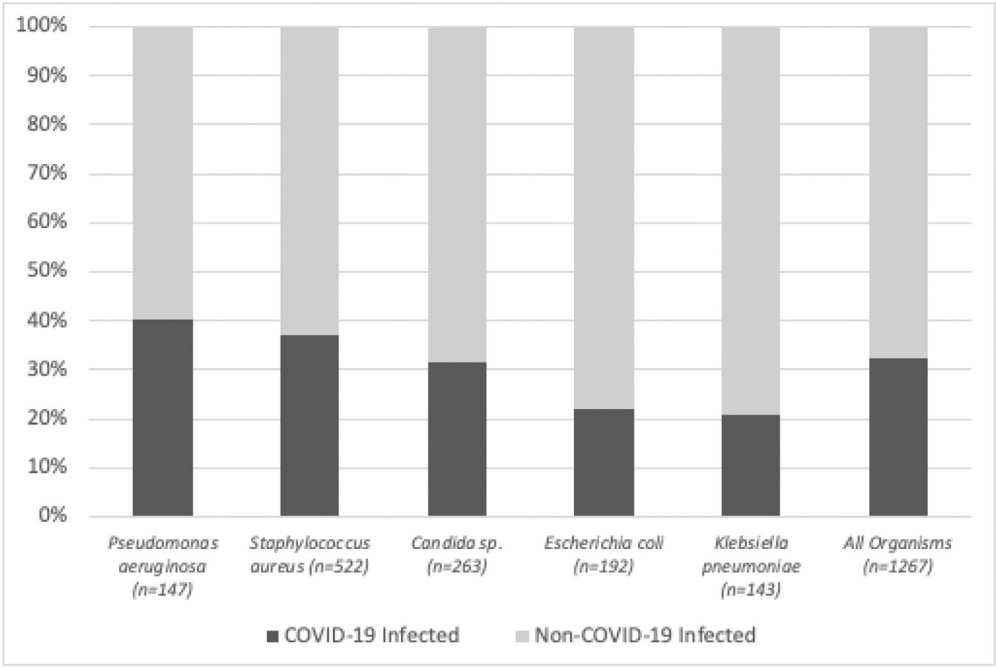

Fig 2. Proportion of patients as a percentage of hospital onset bloodstream infections (HOBSI) during the pandemic period based on organism by COVID-19 status.

Table 3
Ratios of community and hospital onset bloodstream infections (COBSI:HOBSI) pre-pandemic and during COVID-19 pandemic periods

	Pre-Pandemic Period	Pandemic period	Pandemic Period Non COVID-19 Patients	Pandemic Period COVID-19 Patients	*P*-value (Pre-pandemic compared to all Patients pandemic)	*P*-value (Pre-pandemic compared to pandemic Non COVID-19 patients)	*P*-value (Pandemic Non COVID-19 patients compared to COVID-19 patients)
COBSI:HOBSI Ratio	7.61 (7,923/1,041)	5.90 (7,472/1,267)	8.17 (7,012/858)	1.12 (460/409)	<0.0001	0.15	<0.0001
All organisms							
COBSI:HOBSI Ratio	7.92 (2,906/367)	5.71 (2,978/522)	8.39 (2,744/327)	1.20 (234/195)	<0.0001	0.49	<0.0001
Staphylococcus aureus							
COBSI:HOBSI Ratio	16.84 (3,469/206)	15.72 (3,019/192)	19.25 (2,887/150)	3.14 (132/42)	0.53	0.23	<0.0001
Escherichia coli							
COBSI:HOBSI Ratio	3.86 (463/120)	2.92 (429/147)	4.61 (406/88)	0.40 (23/59)	0.051	0.28	<0.0001
Pseudomonas aeruginosa							
COBSI:HOBSI Ratio	1.15 (240/208)	0.87 (228/263)	1.15 (207/180)	0.25 (21/83)	0.03	0.99	<0.0001
Candida sp.							
COBSI:HOBSI Ratio	6.44 (902/140)	5.72 (818/143)	6.80 (768/113)	1.67 (50/30)	0.37	0.74	<0.0001
Klebsiella pneumoniae							

The differences in HOBSI rates during the pandemic were more striking when we evaluated those with COVID-19 infection compared to those without. The rate of HOBSI in COVID-19 infected patients was 3.5 times higher than those non-infected with COVID-19 (9.64 vs 2.74 per 10,000 patient days; $P \leq .0001$). Organism specific analysis showed significantly higher rates for each of the five organisms per 10,000 patient-days when comparing COVID-19 infected versus non-infected during the pandemic; *S. aureus* (4.60 vs 1.04; $P < .0001$), *P. aeruginosa* (1.39 vs 0.28; $P < .0001$), *Candida sp.* (1.96 vs 0.57; $P < .0001$), *E. coli* (0.99 vs 0.48; $P < .0001$) and *K. pneumoniae* (0.71 vs 0.36; $P = .0008$). Although COVID-19 patients represented less than 12% of total patient days during the pandemic, they accounted for more than 30% of HOBSI events during the same period (Fig 2).

Difference between COBSI and HOBSI based on periods and COVID-19 infection

We evaluated changes in COBSI to HOBSI event ratios pre-pandemic and pandemic periods. For all organisms combined, COBSI events were almost 8 times higher than HOBSI (7.61) in the pre-pandemic period but dropped down to approximately 6 times higher (5.9) during the pandemic period ($P < .0001$; Table 3). The ratio of COBSI:HOBSI for COVID-19 infected patients during the pandemic period was 1.12, compared to 8.17 for pandemic non-COVID-19 infected patients ($P \leq .0001$). These differences were significant for each organism under evaluation. On the other hand, there were no significant differences in COBSI:HOBSI ratios for non-COVID-19 infected patients for pre-pandemic and pandemic periods.

DISCUSSION

We report the impact of the COVID-19 pandemic on community onset and hospital onset BSI, in COVID-19 infected patients and non-infected patients, in 69 hospitals of a single multistate health system. We found that the pandemic was not associated with significant changes in COBSI prevalence, but a large increase in HOBSI rates of the five organisms surveilled. Although the overall COBSI rates did not significantly change during the two study periods, non-COVID-19 infected patients were twice more likely to present with COBSI compared to COVID-19 infected patients during the pandemic. Our findings indicate that patients with acute COVID-19 infection are less likely to present with invasive bacterial infections when admitted compared to other patients. On the other hand, the increase in HOBSI was almost all attributed to the COVID-19 infected patient population, underscoring the vulnerability of this population to health care associated invasive infections.

Our measure of HOBSI includes five organisms common to be pathogenic, and accounts for a significant proportion of nosocomial BSIs, and are associated with considerable morbidities and mortality.[7,8,10,11] We have witnessed an increase of HOBSI rates for all organisms combined and each individual one. Of note is that *S. aureus* represented 41% of HOBSI events in all patients, and 48% of HOBSI events for COVID-19 infection during the pandemic period. Reports of increases in secondary infections with *S. aureus* have been reported in COVID-19 infected patients.[1,12] Another interesting finding was the large increase in candidemia in the patients with COVID-19, which was >3 times more than other patients, and an increase in *P. aeruginosa* with ~5 times more in COVID-19 patients compared to others. Similar reports[4] recently support our findings, and may be reflective of a higher severity of illness of the COVID-19 infected patients, in addition to other factors that increase their risk for invasive infections. For example, steroids[13] are used in the majority of patients with COVID-19, in addition to other immunomodulators, and broad spectrum antimicrobials. Furthermore, patients with COVID-19 tend to have a longer length of stay with a high proportion of them requiring intensive care and invasive devices. We have also recently reported higher mortality for COVID-19 infected patients when admitted to facilities with high corresponding COVID-19 prevalence.[14] During pandemic surges, many of the processes and practices that mitigate infection risk were adversely affected. Particularly, routine central line associated bloodstream infections (CLABSI) prevention practices were altered, with less use of the insertion checklist, universal decolonization (eg, routine mupirocin, chlorhexidine bathing), alterations in line care, line and dressing integrity gaps (potentially due to proning), and reduced scrub-the-hub compliance.[15] In addition, infection prevention practices may have been affected with staffing changes, and increased patient load and complexity.

Prior to the COVID-19 pandemic, key infection prevention interventions focused on reducing the risk of publicly reported CLABSI, catheter-associated urinary tract infections (CAUTI), surgical site infections, and lab ID hospital onset MRSA bacteremia and

Clostridioides difficile infection. These measures, also linked to the Hospital Acquired Conditions program,[16] had a variable performance during the pandemic.[5] For example, both CLABSI and HO lab ID MRSA bacteremia exhibited significant increases, while *C. difficile*, surgical site infections, and CAUTI did not have similar changes.[5,15] The standardized infection ratio (SIR) has been the gold standard to risk adjust the population and evaluate its infectious outcomes. However, with the drastic change in patient population admitted to US hospitals since 2020 influenced by the pandemic, the SIR (with a baseline to 2015 data) has had significant limitations evaluating infection prevention performance.[17] In addition, with the Centers for Medicare & Medicaid Services allowing hospitals the option not to report health care associated infections in 2020,[18] the Centers for Disease Control & Prevention witnessed a drop in submission by 12% and 32% depending on the type of infection.[5]

Our HOBSI measure trends over time all-cause hospital onset bloodstream infections, comprised of 5 key organisms associated with either common or severe invasive infections, may better reflect the impact of COVID-19 pandemic on infections in acute care, compared to lab ID MRSA bacteremia or active surveillance-based central line associate bloodstream infections. Furthermore, the five organisms we selected may be associated with different infections from vascular access associated, to skin and/or soft tissue and surgical, to respiratory source, and abdominal or urinary focus. It is noteworthy that our metric includes both methicillin susceptible and resistant *S. aureus* HOBSI.[19] With the increased responsibilities of the infection preventionist and continued changes in patient population cared for in US hospitals, electronically captured measures may provide valuable information of infection prevention performance over time. Electronically captured measures reflecting hospital onset invasive infections, particularly bloodstream infections, may provide very valuable and actionable information real-time to address abrupt changes in infections for US hospitals. Trending such measures will be independent of shortages in infection preventionists or their increased workload. The electronically captured outcomes for infection prevention will be less susceptible to attrition in reporting and will provide a better picture of the national performance. The pandemic has resulted in significant changes in patient care practices and has had a considerable impact on outcomes. Our proposed metric may allow for more rapid identification of changes in outcomes with minimal surveillance workload on the infection prevention professional.

Our study has some limitations. We present the changes in events for five pathogens commonly associated with HOBSIs. It is not inclusive of all organisms that have been reported to increase during the pandemic.[2,15] However, our measure avoids including organisms considered commensals (eg, coagulase negative staphylococci) and others that may be associated with contamination from skin flora (eg, streptococci, enterococcus species). Furthermore, the HOBSI measure is not risk-adjusted to the patient's severity of illness and comorbidities. Finally, we address the experience of one health system with a history of focus on reducing health care associated infections. Notwithstanding these limitations, our study represents a large evaluation of HOBSI during COVID-19 pandemic in the US, from a large number of hospitals of diverse geographic locations, making our findings generalizable.

In conclusion, the COVID-19 pandemic period was associated with substantial increases in HOBSI and largely attributed to COVID-19 infected patients. The HOBSI measure provides support to the evaluation of infection prevention performance over time and helps identify significant changes in hospital onset invasive disease associated with COVID-19 pandemic. Future research should evaluate whether such measures would be beneficial to incorporate in evaluating infection prevention trends.

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