






Compendium Commentary

The next frontier of healthcare-associated infection (HAI) surveillance metrics: Beyond device-associated infections

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Abstract

In recent years, it has become increasingly evident that surveillance metrics for invasive device-associated infections (ie, central-line-associated bloodstream infections, ventilator-associated pneumonias, and catheter-associated urinary tract infections) do not capture all harms; they capture only a subset of healthcare-associated infections (HAIs). Although prevention of device-associated infections remains critical, we need to address the full spectrum of potential harms from device use and non-device-associated infections. These include complications associated with additional devices, such as peripheral venous and arterial catheters, non-device-associated infections such as nonventilator hospital-acquired pneumonia, and noninfectious device complications such as trauma, thrombosis, and acute lung injury. As authors of the device-associated infection sections in the *SHEA/IDSA/APIC Compendium of Strategies to Prevent Healthcare-Associated Infections in Acute Care Hospitals*, we highlight catheter-associated urinary tract infection as an example of the strengths and limitations of the current emphasis on device-associated infection surveillance, suggest performance metrics that present a more comprehensive picture of patient harm, and provide a high-level overview of similar issues with other infection surveillance measures.

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Healthcare-associated infection (HAI) surveillance and reporting has traditionally focused on device-associated infections, such as central-line-associated bloodstream infection (CLABSI), ventilator-associated pneumonia (VAP), and catheter-associated urinary tract infection (CAUTI).^{1,2} Quality and safety advocates point out that the potential harms associated with invasive devices extend beyond infection alone, affecting quality of care and patient outcomes. For example, central lines are associated with thrombosis, occlusion, and venous scarring.^{3,4} Indwelling urinary catheters are associated with decreased mobility, increased risk of falls, and trauma to the genitourinary system.^{5–8} Endotracheal tubes and mechanical ventilation can be linked to volume and pressure-associated lung injury.⁹ Other devices such as peripheral venous and arterial catheters may cause infectious harm, but they have not been addressed in large surveillance programs to date. Furthermore, non-device-associated infections have garnered less attention than device-associated infections; however, recent surveys suggest that they account for similar or greater numbers of infections than device-associated infections. For example, two-thirds of hospital-acquired pneumonias occur in nonventilated patients, and more than half of healthcare-associated urinary tract infections (HAUTIs) occur in noncatheterized patients.^{10,11}

Current surveillance metrics overlook these additional sources of harms in hospitalized patients, so the national incidences of HAUTI, hospital-onset bacteremia (HOB), and nonventilator pneumonia (NV-HAP) are unknown.^{1,12,13} Additionally, our current surveillance methods for device-related infections involve manual chart review and complex definitions, which have led to significant workload and require infrastructure support. Furthermore, rates may be affected by common documentation errors.

In this commentary, we highlight CAUTI as an example of the strengths and limitations of the current emphasis on device-associated infection surveillance, describe emerging National Healthcare Safety Network (NHSN) metrics, and we recommend strategies to identify healthcare-associated patient harm to capture the array of preventable device-associated harms (in addition to device-associated infections) and non-device-associated HAIs as necessary precursors to developing comprehensive strategies to prevent, detect, and manage them.

The evolution of CAUTI metrics

Precisely defining a urinary tract infection (UTI), whether a CAUTI or nondevice UTI, is a significant challenge in evaluating CAUTI prevention efforts. The current NHSN CAUTI definition relies heavily on the presence of a positive urine culture and documented fever in a catheterized patient within the infection window,¹⁴ making the diagnosis of NHSN CAUTI event

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susceptible to the prevalence of fever and changes in testing practices over urinary catheter care and device stewardship.¹⁵ The standardized infection ratio (SIR), which calculates observed infections in relationship to predicted infections, is a metric widely used to compare a hospital's performance to a national benchmark based on a baseline period.^{5,16} Although valuable, the SIR does not adequately account for local factors such as reductions in low risk catheter use due to unit-specific interventions.^{16,17} For example, interventions that focus on reducing catheter use may decrease catheter days (the denominator) but leave behind catheterized patients with higher risk of CAUTI, thus resulting in a higher measured surveillance CAUTI rate. Furthermore, manual chart review and multidimensional definitions in surveillance methods introduce the risk of error and bias¹⁸ and shift the emphasis to reducing measured NHSN CAUTIs above reducing catheter harms experienced by patients.¹⁵ One proposal to improve patients' clinical outcomes is developing performance metrics to capture clinically significant harms (or the potential for harms) to provide actionable information for facilities.⁵ We describe 2 clinical vignettes to highlight noninfectious and infectious harms that are not captured by current CAUTI metrics.

Vignette 1

A 75 year-old-man with a history of hypertension was admitted to an acute-care hospital for worsening back pain. While undergoing additional work-up, his pain was managed with opioids. On day 3, he developed urinary retention, for which the clinician ordered the placement of an indwelling urinary catheter. Unfortunately, the patient's assigned nurse was not properly trained in catheter insertion—particularly for older men with higher risk for difficult urinary insertion due to benign prostatic hypertrophy—resulting in a traumatic hematuria and excessive discomfort for the patient. Due to absence of bacteriuria and fever, and no standard requirements or recommendations for documenting traumatic injuries from urinary catheter use, this adverse event was not included in the hospital's CAUTI count, was not flagged for inclusion in the hospital's quality review process (triggered by NHSN CAUTIs), and was not reported to the state health department or CMS.

Vignette 2

A 60 year old woman was admitted to an acute-care hospital from long-term care facility for management of a fall that caused to a hip fracture. An external urinary collection device was placed on admission due to immobility in the setting of acute fracture pain and chronic urinary incontinence, with the goal of preventing CAUTI by avoiding placement of an indwelling urinary catheter. On day 3 of the hospitalization, a urine culture was obtained for some discomfort with urination, interpreted by clinicians as dysuria (in the setting of an external urinary catheter whose placement and movement can irritate the female urethral meatus, particularly in postmenopausal women). A urine sample collected from the 3-day-old external catheter grew >100,000 colony-forming units per milliliter (CFU/mL) of *Escherichia coli*, for which she received 7 days of oral ciprofloxacin. The case did not meet the NHSN CAUTI definition due to absence of indwelling urinary catheter. This case was not reported, yet this was an instance of inappropriate urine testing. The patient had another likely and reversible cause of urethral meatus irritation than UTI, urine was collected from an external catheter that had been in place for days, from this postmenopausal older female patient with a high baseline

likelihood of asymptomatic bacteriuria. Ideally, this inappropriate antibiotic treatment—by initial antibiotic selection as well as starting an antibiotic in response to a positive urine culture collected by inappropriate method and indication—should have been flagged and reported for the purposes of quality improvement.

Proposal for metrics beyond CAUTI

Traditionally, CAUTI has been the focus of UTI prevention efforts by hospital infection prevention teams. However, if teams focus on the NHSN CAUTI metric alone, they may not be aware of the rates of inappropriate catheter use and care, urinalysis and urine-culture stewardship adherence, and urine-culture contamination rates. In this regard, we propose additional metrics so that facilities can better capture patient harms (Table 1).

Catheter utilization

Standardized utilization ratio (SUR) and device utilization ratio (DUR) are objective measures that capture overall catheter use and allow for some estimation of infectious and noninfectious harms. DUR is the ratio of catheter days to patient days for a specified period. SUR is the ratio of observed to predicted catheter days, is compared to a national benchmark, and is risk adjusted to allow comparisons across different populations and multiple hospitals.^{19–21}

Urine test utilization

Although efforts to identify symptomatic UTIs continue, a hospital's diagnostic performance can be evaluated by measuring urine-culture utilization rates (or urinalysis rates in outpatient settings), which can reflect urine test use in both catheterized and noncatheterized patients. Urine-culture utilization rates can be extracted from electronic medical records and can be risk adjusted, similar to blood-culture utilization rates.²² Furthermore, electronic identification of patients with hospital-onset bacteriuria (similar to hospital-onset bacteremia) is possible.

Urine-culture contamination

Urine-culture contamination is usually reflected by the rate of mixed flora in urine cultures, the incidence of which is increasing in inpatient and outpatient settings (>40%).²³ Contaminated or mixed-flora (usually defined as ≥ 3 species in a urine culture) urine-culture rates often reflect specimen collection, transport, and storage practices. They can pose a diagnostic challenge to clinicians due to false-positive or false-negative test results. Measuring urine-culture contamination is important for the same reasons as measuring blood-culture contamination: to improve collection, transport, and diagnostic accuracy and to reduce overuse of additional tests and antibiotics.^{24,25}

Composite measure of catheter harm

Catheter harm encompasses both infectious complications (eg, catheter-associated bacteriuria, infection) and noninfectious catheter-related complications (eg, urethral injury, pain, falls, catheter obstruction, deep vein thrombosis).²⁶ Future research is needed to develop and validate a composite measure for catheter harm that reflects a comprehensive picture of catheter care and urine testing while allowing for electronic capture of data elements (Fig. 1).²⁷

Table 1. Characteristics of Proposed Future Performance Metrics Related to CAUTI

Proposed Measure	Captures Catheter Use	Captures Infectious Harm ^a	Captures Noncatheterized Patients	Captures Noninfectious Harm ^b	Captures Patients without Urinary Catheters	Electronically Captured	Can Be Adapted to an Outpatient Measure
Catheter utilization (SUR/DUR)	Yes	Possibly	NA	Possibly	No	Yes	Yes
Urine culture or urinalysis utilization rates	No	Yes	Yes	No	Yes	Yes	Yes
Urine culture contamination (mixed flora) rates	No	Yes	Yes	No	Yes	Yes	Yes
Composite catheter harm score	Yes	Yes	NA	Yes	No	Possibly	Possibly

Note. CAUTI, catheter-associated urinary tract infections; SUR, standardized utilization ratio; DUR, device utilization ratio. Color scheme: white: no; solid grey: yes; light grey: possibly.
^aTrue infection, antibiotic use.
^bFalls, deep vein thrombosis, insertion trauma.

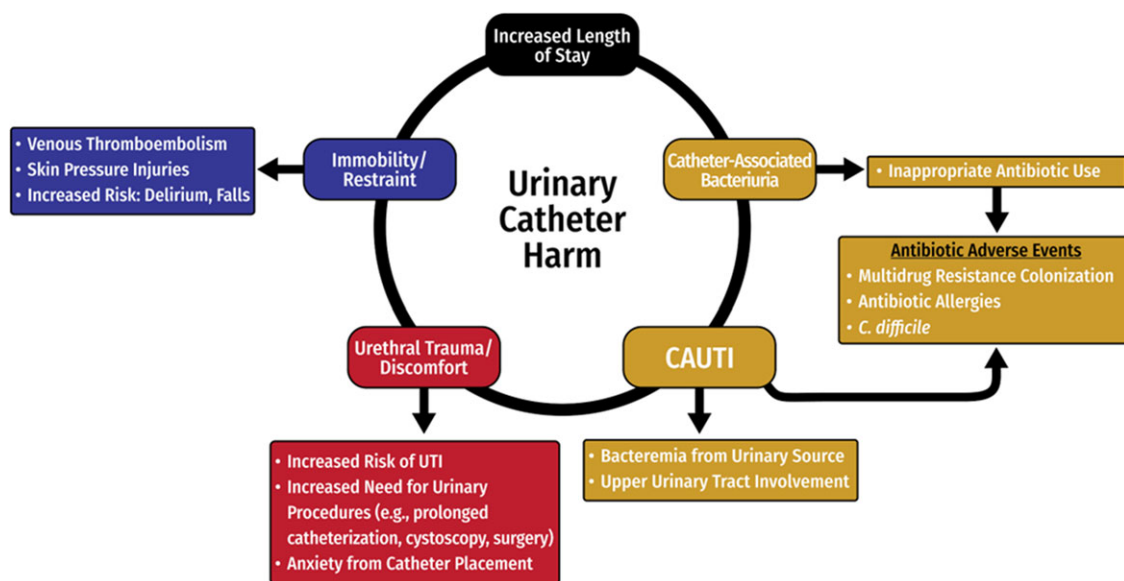


Figure 1. Full spectrum of catheter harm.

Parallels with pneumonia, ventilator harm, vascular device-associated infections and harms, and hospital-acquired sepsis

As with CAUTI, there are similar concerns with underdetection of device-associated harms, non-device-associated infections (of the respective organ system), inappropriate diagnostic testing, and overuse of antibiotics for colonization rather than infection with many of the other HAIs that hospitals are currently required to report to NHSN. A number of emerging surveillance metrics and reporting initiatives being stewarded by NHSN are starting to address these concerns.

Ventilator-associated harm

In the realm of ventilator-associated harm, the Centers for Disease Control and Prevention (CDC) developed the ventilator-associated event (VAEs) metric. The VAE metric was specifically designed to broaden the scope of surveillance to include noninfectious harms in addition to pneumonia.⁹ Indeed, pneumonia only accounts for ~33% of VAEs. The rest are mostly

attributable to volume overload, acute respiratory distress syndrome (ARDS), and atelectasis. Comprehensive programs to prevent VAEs consequently include measures designed to avoid noninfectious harm from ventilators such as avoiding mechanical ventilation when possible, minimizing sedation, facilitating early extubation, maintaining euolemia, and using low-tidal-volume ventilation, in addition to pneumonia prevention measures such as elevating the head of the bed, providing comprehensive oral care including toothbrushing, and maintaining ventilator circuits.^{28,29}

Nonventilator pneumonia

The CDC is currently exploring novel metrics to capture nonventilator hospital-acquired pneumonia (NV-HAP). NV-HAP accounts for ~65% of all hospital-acquired pneumonia. It is associated with morbidity and mortality rates similar to VAP, yet hospital surveillance programs and prevention guidelines traditionally have not addressed NV-HAP. The CDC has sponsored the ongoing development of a potentially automatable surveillance definition for NV-HAP to facilitate widespread, objective, and efficient surveillance.^{30,31} The latest version of the *Compendium*:

2022 Updates on prevention of hospital-acquired pneumonia now includes a section on preventing NV-HAP, highlighting the importance of rigorous oral care, mobilizing patients, and identifying patients with dysphagia so that additional measures to prevent aspiration can be implemented.²⁹

Vascular device-associated infections and harms

The NHSN has a forthcoming metric on hospital-onset bacteremia that will broaden bloodstream infection surveillance to include all hospital-onset bacteremia and fungemia cases, not just those associated with central lines. This metric considers additional indwelling vascular devices that may serve as foci for bacteremia besides central lines, including arterial catheters, midline catheters, and peripheral intravenous catheters.³² More broadly, some HAIs may lead to secondary bacteremia independent of an intravascular catheter, and they are also important sources of morbidity and mortality that merit attention and prevention. As with CAUTI, contamination of culture is a risk with the potential for triggering unnecessary and harmful treatments.³³ Noninfectious risks, such as catheter thrombosis, may lead to obstruction and malpositioning that can result in vascular injuries. These noninfectious risks are more appreciated with vascular catheters than with urinary catheters and also can increase the risk for infection.³ Lastly, although only 1 urinary catheter or 1 endotracheal tube is usually in place, many patients may have 1 or more concurrent lines for vascular access.³ This can further increase the risk of harms to patients from vascular catheters.

Hospital-acquired sepsis

Similar considerations described below have informed the NHSN's surveillance definition for adult sepsis events.³⁴ Sepsis is present at some time during hospitalization in 35%–50% of hospital deaths and costs Medicare alone >\$22 billion per year.³⁵ Notwithstanding its outsized impact on patient outcomes and costs, there is currently no systematic reporting of sepsis overall or hospital-acquired sepsis in particular to public health authorities. An advantage of surveillance for hospital-acquired sepsis in particular is 2-fold: (1) by definition, it focuses surveillance on a subset of patients with severe HAIs and (2) it captures many serious infections that are currently not-reportable including non-device-associated UTIs that lead to secondary sepsis, NV-HAP, surgical-site infections (both those that are currently reportable to CMS and those that are not), and hospital-onset bacteremia cases. The scope of hospital-acquired sepsis surveillance is broader than hospital-onset bacteremia insofar as only 15%–20% of patients with sepsis or septic shock are bacteremic.³⁵

The CDC adult sepsis event definition is designed to enable automated surveillance using electronic health record (EHR) data alone. It defines a sepsis event as the combination of suspected infection (as suggested by a blood culture draw, initiation of antibiotics, and continuation of antibiotics for at least 4 days) and concurrent organ dysfunction (initiation of vasopressors or mechanical ventilation, rise in creatinine or bilirubin, or drop in platelets). A side-by-side comparison of hospital-onset adult sepsis event surveillance with traditionally reportable HAIs in 3 hospitals revealed that hospital-onset adult sepsis events detected twice as many infections compared to currently reportable HAIs and identified more serious events than currently reportable HAIs insofar as reflected by higher mortality rates.²

Conclusion

In conclusion, we propose the continued development and validation of performance metrics to capture a comprehensive picture of infectious and noninfectious patient harms associated with devices and to broaden surveillance to include non-device-associated serious infections.^{29,36} Future research in surveillance metrics should focus on efficient and accurate means of identifying HAIs in all populations, evaluating the utility of biomarkers as infection flags, methodologies to differentiate between colonization versus active infection, and strategies to automate surveillance using EHR data. Surveillance data should be actionable to make improvements that avert patient harm. Accordingly, the device utilization ratio may represent a more useful tool than just the HAI rate. Addressing inappropriate practice patterns and leveraging the laboratory's role in improving testing can help reduce unnecessary testing and unnecessary treatment.

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References

1. Hospital-Acquired Condition Reduction Program (HACRP). Centers for Medicare and Medicaid Services (CMS) website. <https://www.cms.gov/Medicare/Medicare-Fee-for-Service-Payment/AcuteInpatientPPS/HAC-Reduction-Program.html>. Published July 30, 2018. Accessed December 15, 2023.
2. Page B, Klompas M, Chan C, *et al*. Surveillance for healthcare-associated infections: hospital-onset adult sepsis events versus current reportable conditions. *Clin Infect Dis* 2021;73:1013–1019.
3. Jumani K, Advani S, Reich NG, Gosey L, Milstone AM. Risk factors for peripherally inserted central venous catheter complications in children. *JAMA Pediatr* 2013;167:429–35.
4. Kovacich A, Tamma PD, Advani S, *et al*. Peripherally inserted central venous catheter complications in children receiving outpatient parenteral antibiotic therapy (OPAT). *Infect Control Hosp Epidemiol* 2016;37:420–424.
5. Advani SD, Fakhri MG. The evolution of catheter-associated urinary tract infection (CAUTI): is it time for more inclusive metrics? *Infect Control Hosp Epidemiol* 2019;40:681–685.
6. Fakhri MG, Gould CV, Trautner BW, *et al*. Beyond infection: device utilization ratio as a performance measure for urinary catheter harm. *Infect Control Hosp Epidemiol* 2016;37:327–333.
7. Saint S, Trautner BW, Fowler KE, *et al*. A multicenter study of patient-reported infectious and noninfectious complications associated with indwelling urethral catheters. *JAMA Intern Med* 2018;178:1078–1085.

8. Schweiger A, Kuster SP, Maag J, *et al.* Impact of an evidence-based intervention on urinary catheter utilization, associated process indicators, and infectious and noninfectious outcomes. *J Hosp Infect* 2020;106:364–371.
9. Klompas M. Complications of mechanical ventilation—the CDC’s new surveillance paradigm. *N Engl J Med* 2013;368:1472–1475.
10. Magill SS, O’Leary E, Janelle SJ, *et al.* Changes in prevalence of healthcare-associated infections in US hospitals. *N Engl J Med* 2018;379:1732–1744.
11. Strassle PD, Sickbert-Bennett EE, Klompas M, *et al.* Incidence and risk factors of non-device-associated urinary tract infections in an acute-care hospital. *Infect Control Hosp Epidemiol* 2019;40:1242–1247.
12. Calderon LE, Kavanagh KT, Rice MK. Questionable validity of the catheter-associated urinary tract infection metric used for value-based purchasing. *Am J Infect Control* 2015;43:1050–1052.
13. Waters TM, Daniels MJ, Bazzoli GJ, *et al.* Effect of Medicare’s nonpayment for hospital-acquired conditions: lessons for future policy. *JAMA Intern Med* 2015;175:347–354.
14. Advani SD, Gao CA, Datta R, *et al.* Knowledge and practices of physicians and nurses related to urine cultures in catheterized patients: an assessment of adherence to IDSA guidelines. *Open Forum Infect Dis* 2019;6:ofz305.
15. Bardossy AC, Williams T, Jones K, *et al.* Culturing practices and the care of the urinary catheter in reducing NHSN-defined catheter-associated urinary tract infections: the tale of two teaching hospitals. *Infect Control Hosp Epidemiol* 2018;39:1494–1496.
16. Pepe DE, Maloney M, Leung V, *et al.* An evaluation of metrics for assessing catheter-associated urinary tract infections (CAUTIs): a statewide comparison. *Infect Control Hosp Epidemiol* 2020;41:481–483.
17. Fakh MG, Huang RH, Bufalino A, *et al.* The case for a population standardized infection ratio (SIR): a metric that marries the device SIR to the standardized utilization ratio (SUR). *Infect Control Hosp Epidemiol* 2019;40:979–982.
18. Fakh MG, Greene MT, Kennedy EH, *et al.* Introducing a population-based outcome measure to evaluate the effect of interventions to reduce catheter-associated urinary tract infection. *Am J Infect Control* 2012;40:359–364.
19. The NHSN standardized utilization ratio (SUR): a guide to the SUR. Centers for Disease Control and Prevention (CDC) website. <https://www.cdc.gov/nhsn/pdfs/ps-analysis-resources/nhsn-sur-guide-508.pdf>. Accessed December 15, 2023.
20. Saint S, Greene MT, Krein SL, *et al.* A program to prevent catheter-associated urinary tract infection in acute care. *N Engl J Med* 2016;374:2111–2119.
21. Abrantes-Figueiredo JI, Ross JW, Banach DB. Device utilization ratios in infection prevention: process or outcome measure? *Curr Infect Dis Rep* 2018;20:8.
22. Bates DW, Goldman L, Lee TH. Contaminant blood cultures and resource utilization. The true consequences of false-positive results. *JAMA* 1991;265:365–369.
23. Whelan P, Nelson A, Kim CJ, *et al.* Investigating risk factors for urine culture contamination in outpatient clinics: a new avenue for diagnostic stewardship. *Antimicrob Steward Healthc Epidemiol* 2022;2:e29.
24. Alahmadi YM, Aldeyab MA, McElnay JC, *et al.* Clinical and economic impact of contaminated blood cultures within the hospital setting. *J Hosp Infect* 2011;77:233–236.
25. Garcia RA, Spitzer ED, Beaudry J, *et al.* Multidisciplinary team review of best practices for collection and handling of blood cultures to determine effective interventions for increasing the yield of true-positive bacteremias, reducing contamination, and eliminating false-positive central-line-associated bloodstream infections. *Am J Infect Control* 2015;43:1222–1237.
26. Patel PK, Advani SD, Kofman AD, *et al.* Strategies to prevent catheter-associated urinary tract infections in acute-care hospitals: 2022 update. *Infect Control Hosp Epidemiol* 2023;44:1209–1231.
27. Fakh MG, Advani SD. Striving to reach the optimal measure for catheter-associated urinary tract infection (CAUTI): moving to catheter harm. *Clin Infect Dis* 2021;72:e424.
28. Klompas M. Potential strategies to prevent ventilator-associated events. *Am J Respir Crit Care Med* 2015;192:1420–1430.
29. Klompas M, Branson R, Cawcutt K, *et al.* Strategies to prevent ventilator-associated pneumonia, ventilator-associated events, and nonventilator hospital-acquired pneumonia in acute-care hospitals: 2022 update. *Infect Control Hosp Epidemiol* 2022;43:687–713.
30. Ji W, McKenna C, Ochoa A, *et al.* Development and assessment of objective surveillance definitions for nonventilator hospital-acquired pneumonia. *JAMA Netw Open* 2019;2:e1913674.
31. Jones BE, Sarvet AL, Ying J, *et al.* Incidence and outcomes of non-ventilator-associated hospital-acquired pneumonia in 284 US hospitals using electronic surveillance criteria. *JAMA Netw Open* 2023;6:e2314185.
32. Buetti N, Marschall J, Drees M, *et al.* Strategies to prevent central-line-associated bloodstream infections in acute-care hospitals: 2022 update. *Infect Control Hosp Epidemiol* 2022;43:553–569.
33. Doern GV, Carroll KC, Diekema DJ, *et al.* Practical guidance for clinical microbiology laboratories: a comprehensive update on the problem of blood culture contamination and a discussion of methods for addressing the problem. *Clin Microbiol Rev* 2019;33.
34. Rhee C, Dantes RB, Epstein L, Klompas M. Using objective clinical data to track progress on preventing and treating sepsis: CDC’s new ‘adult sepsis event’ surveillance strategy. *BMJ Qual Saf* 2019;28:305–309.
35. Rhee C, Dantes R, Epstein L, *et al.* Incidence and trends of sepsis in US hospitals using clinical vs claims data, 2009–2014. *JAMA* 2017;318:1241–1249.
36. Magill SS, Klompas M, Balk R, *et al.* Developing a new national approach to surveillance for ventilator-associated events: executive summary. *Am J Infect Control* 2013;41:1096–1099.