wanted to learn more about their role in stewardship, and identified venues to receive this education. Nurses with master's degrees were less likely to believe that nurses might play a role in ASPs, perhaps due to greater familiarity with the current state of ASP, and perhaps, therefore, they were less likely to think "outside the box" regarding a nursing role. Nonetheless, most nurses felt that they played a role in antimicrobial stewardship.

The strengths of this study include the large number of nursing respondents across different hospitals and patient care units. The study also has several limitations. The survey had a relatively low response rate, and because responses to the survey were voluntary, respondents may not be representative of all nurses at our hospital system. Similarly, responses obtained from nurses in our institution may not be generalizable among all nurses.

This study illustrates a need to educate nurses on general principles of antimicrobial stewardship, and our findings point to multiple areas for nursing-targeted interventions that merit additional research. Nurses could ensure or facilitate acquisition of proper allergy histories, blood culture techniques, prioritization of antimicrobial administration, and antimicrobial de-escalation. Given the number of bedside nurses in practice, such interventions have the potential to substantially lower inappropriate antimicrobial utilization.

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SUPPLEMENTARY MATERIAL

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To Be a CLABSI or Not to Be a CLABSI—That is the Question: The Epidemiology of BSI in a Large ECMO Population

Extracorporeal membrane oxygenation (ECMO) patients are at a higher risk of hospital-acquired infections (HAIs) than other critically ill patients.[1] Because nearly all patients on ECMO have ≥1 concurrent central venous catheters (CVCs), bloodstream infections (BSIs) in ECMO patients are often counted as central-line–associated bloodstream infections (CLABSIs) and thus contribute to penalties from the Centers for Medicare and Medicaid Services (CMS). We aimed to determine the incidence of BSI and CLABSI in ECMO patients at one of the largest ECMO centers in the United States.

We cross-referenced the ECMO patient registry and microbiology databases to identify patients who had positive blood cultures following ECMO cannulation at Duke University Hospital between January 1, 2014, and December 31, 2016. Duke University

TABLE 1. Descriptive Statistics of Study Population

Descriptive Statistic	Total, No. (%)[a]	CLABSI, No. (%)[a]	Secondary BSI, No. (%)[a]	Common Commensal, No. (%)[a]
No. of patients	24	11	5	8
Average patient age, y (SD)	48 (15)	52 (14)	38 (16)	49 (12)
Average patient BMI, kg/m^2 (SD)	30 (8)	29 (4)	28 (11)	33 (10)
ECMO duration prior to positive blood culture, d (range)	11 (2–39)	8 (2–39)	6 (3–16)	12 (6–19)
Pre-existing conditions				
Coronary artery disease or congestive heart failure	8 (33)	5 (45)	1 (20)	2 (25)
COPD, asthma, cystic fibrosis, or interstitial lung disease	10 (42)	5 (45)	2 (40)	3 (38)
Lung transplant	5 (21)	1 (10)	2 (40)	2 (25)
Heart transplant	2 (8)	2 (18)	0 (0)	0 (0)
Kidney transplant	1 (4)	1 (10)	0 (0)	0 (0)
Immunosuppressed	10 (42)	5 (45)	2 (40)	3 (38)
Diabetes mellitus	5 (21)	2 (18)	2 (40)	1 (13)
End-stage renal disease	0	0	0	0
Human immunodeficiency virus	1 (4)	1 (10)	0	0
Active cancer	1 (4)	0	1 (20)	0
Patients on total parenteral nutrition	0	0	0	0
Indication for ECMO				
Extracorporeal cardiopulmonary resuscitation	3 (13)	0	2 (40)	1 (13)
Acute respiratory failure	14 (58)	5 (45)	3 (60)	6 (74)
Cardiogenic shock	7 (29)	6 (55)	0	1 (13)
ECMO cannulation location				
Catheter lab	1 (4)	1 (10)	0	0
Intensive care unit	9 (41)	3 (27)	2 (40)	4 (50)
Operating room	7 (29)	2 (18)	2 (40)	3 (38)
Outside hospital	7 (29)	5 (45)	1 (20)	1 (13)
ECMO mode				
Venoarterial	7 (29)	4 (36)	1 (20)	2 (25)
Venovenous	14 (58)	5 (45)	3 (60)	6 (75)
Other[b]	3 (13)	2 (18)	1 (20)	0 (0)
Intensive care unit				
Cardiothoracic surgery	14 (58)	7 (64)	3 (60)	4 (50)
Medical	10 (42)	4 (36)	2 (40)	4 (50)
Patients on broad-spectrum antibiotics	22 (92)	10 (91)	5 (100)	7 (88)
Patients on antibiotics for another suspected infection	9 (41)	5 (45)	2 (40)	2 (25)
Patients on antibiotics for ECMO prophylaxis	11 (50)	5 (45)	2 (40)	4 (50)
Patients on antibiotics for transplant prophylaxis	2 (9)	0	1 (20)	1 (13)
Average length of stay, d (SD)	53 (56)	65 (71)	35 (29)	46 (36)
In-hospital mortality	16 (67)	8 (73)	4 (80)	4 (50)
Pathogens				
MRSA	2 (9)	0	2 (40)	0
MSSA	1 (4)	1 (10)	0	0
Coagulase-negative *Staphylococcus* spp	7 (29)	1 (10)	0 (0)	6 (75)
Enterococcus faecalis	1 (4)	1 (10)	0	0
Enterococcus faecium	1 (4)	1 (10)	0	0
Klebsiella pneumonia	3 (13)	3 (27)	0	0
Serratia marcescens	1 (4)	1 (10)	0	0
Enterobacter spp	1 (4)	0	1 (20)	0
Morganella morganii	1 (4)	0	1 (20)	0
Burkholderia spp	2 (9)	1 (10)	1 (20)	0
Achromobacter sp	1 (4)	1 (10)	0	0
Propionibacterium acnes	1 (4)	0	0	1 (13)
Micrococcus luteus	1 (4)	0	0	1 (13)
Anaerobic gram-positive cocci	1 (4)	1 (10)	0	0

NOTE. CLABSI, central-line–associated bloodstream infection; BSI, bloodstream infection; BMI, body mass index; ECMO, extracorporeal membrane oxygenation; SD, standard deviation; COPD, chronic obstructive pulmonary disease; MRSA, methicillin-resistant *Staphylococcus aureus*; MSSA, methicillin-susceptible *Staphylococcus aureus*.

[a]Unless otherwise specified.

[b]Other ECMO modes included venoarterial/venovenous to right ventricular assist device (RVAD) to oxygenator or venoarterial to left ventricular assist device (LVAD) to oxygenator.

Hospital is a 957-bed tertiary-care hospital and, by volume, has been among the 5 best ECMO programs in the country since 2014. The ECMO exposure period was defined as 2 days after cannulation through 1 day after decannulation to mirror the National Healthcare Safety Network's (NHSN) CLABSI definition. Infection preventionists adjudicated whether BSIs were primary CLABSI, secondary to another infection site, or neither (eg, single positive culture for common commensal organism), using NHSN criteria. An infectious diseases physician also reviewed each chart and abstracted clinical data using a standardized template. The Duke University Institutional Review Board approved this study.

During the study period, 426 patients received 3,534 days of ECMO; 24 patients (5.6%) had a documented BSI during the ECMO exposure period (incidence rate [IR], 6.8 per 1,000 ECMO days). Overall, 11 BSIs met the criteria for CLABSI (IR, 3.1 per 1,000 ECMO days). In addition, 5 patients had BSIs secondary to pneumonia and 8 patients had single cultures positive for common commensal organisms (Table 1).

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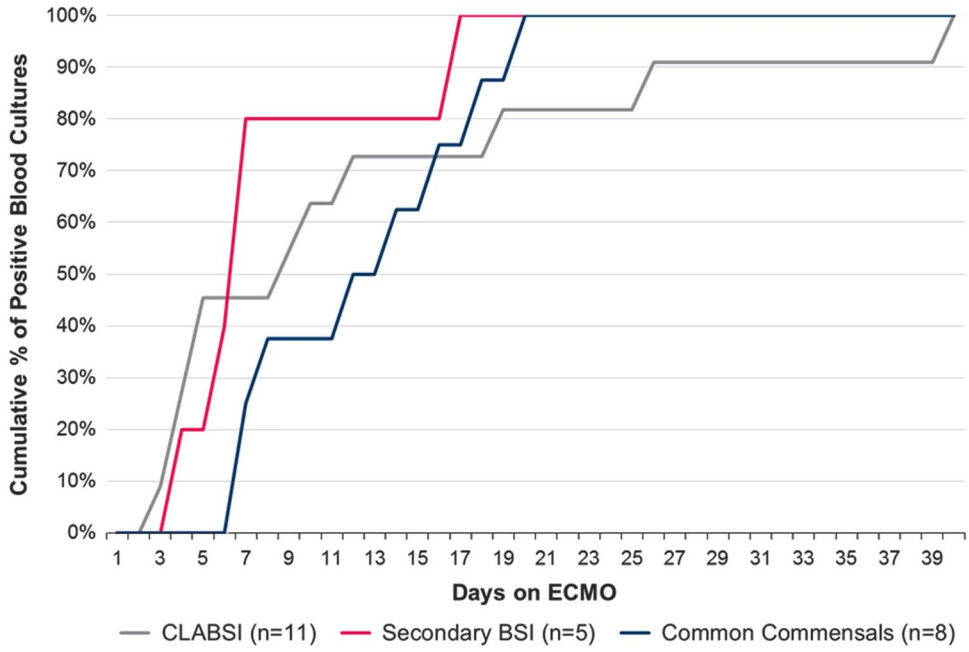

FIGURE 1. Number of positive blood cultures versus days on extracorporeal membrane oxygenation (ECMO), stratified by type of bloodstream infection.

Clinical features of patients with BSI are shown in Table 1. Importantly, 8 patients (33%) were solid-organ transplant recipients, and 2 patients were immunosuppressed following receipt of chemotherapy and a tumor necrosis factor (TNF)-α inhibitor, respectively. The median numbers of days on ECMO prior to a positive blood culture were 8 days (range, 2–39 days) for CLABSI, 6 days (range, 3–16 days) for secondary BSI, and 12 days (range, 6–19 days) for common commensal organisms (Figure 1). Of 11 total CLABSIs, 5 (45%) occurred between days 2 and 5 of ECMO exposure, which suggests the possible introduction of bacteria with ECMO cannulae insertion.

Most identified pathogens causing CLABSI and secondary BSI were gram-negative organisms (Table 1). Furthermore, 2 (92%) patients were receiving broad-spectrum antibiotics at the time of positive blood culture, either as prophylaxis or as treatment of another infection,. Of the 11 identified CLABSI pathogens, 8 were resistant to broad-spectrum antibiotics, 2 were sensitive to concurrent antibiotics, and 1 occurred in a patient not receiving antimicrobials. Of the 11 CLABSI patients, 6 had femoral ECMO cannulae and 4 had a femoral CVC insertion site.

Although the rate of total BSI among ECMO patients in our cohort was comparable to those of other published reports,[1] the incidence rate of CLABSI among ECMO patients was 3 times higher than nationally reported rates for medical and cardiothoracic ICUs at academic teaching hospitals.[2] Furthermore, ECMO patients accounted for 18% of CLABSIs occurring in our cardiothoracic and medical intensive care units (ICUs), despite representing only 8% of CVC days in these ICUs. While the risk of infection in ECMO patients has been well described,[1] our study is among the few publications to specifically report on the impact of ECMO utilization and CLABSIs. We were not able to determine the definitive BSI source from chart review, but we suspect that at least a portion of "CLABSIs" were not associated with CVCs and may have originated from the ECMO cannulae insertion sites. Moreover, ECMO cannulae are often inserted at femoral sites, and maintenance of sterile dressings is challenging due to the large caliber of the cannulae and high incidence of bleeding at the insertion site.

We believe that many of the CLABSIs identified in our study were not preventable with existing CVC bundles. Additional research is needed to better understand how to prevent BSI in this high-risk patient population. The Extracorporeal Life Support Organization (ELSO) specifies that cannulation be performed with full sterile preparation but does not comment on cannula maintenance practices. Additionally, the role of prophylactic antibiotics for patients on ECMO is unclear. At our institution, all patients in the cardiothoracic ICU are placed on vancomycin, cefuroxime, and fluconazole unless they have other indications for antibiotics. In the medical ICU, ECMO patients are only placed on antibiotics if this approach is indicated based on suspicion or diagnosis of an infection or if prophylaxis is required for another indication such as following organ transplant. Of all patients in our study, 92% were on broad-spectrum antibiotics, either for prophylaxis or for treatment of another infection, when they developed a BSI. Additional studies are needed to determine whether prophylactic antibiotics provide benefit or harm.

This study has limitations inherent in a single-center, retrospective study. Our findings may not be applicable to other centers with different patient populations. Data were obtained by

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retrospective chart review, and it is possible that we misidentified BSI events as CLABSI that were secondary to another site of infection. Also, we could not reliably determine whether blood cultures were drawn from an indwelling line, which may have increased the risk of blood culture contamination.

In conclusion, we support the 2018 proposed NHSN CLABSI definition change that excludes BSI occurring in patients on ECMO.[3] This recommendation will improve the reliability of interhospital comparisons and reduce potential CMS penalties for centers with ECMO populations.

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