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Short communication

Microbiology of catheter-associated bloodstream infection: differences according to catheter type

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ABSTRACT

Objectives: Catheter-associated bloodstream infections (CABSI) cause preventable morbidity. We compared the microbiological etiology of CABSI across different types of central and peripherally-inserted catheters.

Methods: We analyzed prospectively collected CABSI data in a 2100-bed hospital network in Switzerland between 2016 and 2022. We included: short-term non-tunneled central venous catheters (CVC); long-term catheters (tunneled, or peripherally-inserted central catheters); arterial catheters; dialysis catheters; and peripheral venous catheters (PVC). We used multivariable logistic regression models to describe the risk of *Staphylococcus aureus* and Gram-negative pathogens according to catheter type.

Results: Overall, 416 CABSI episodes were included, including 60 episodes of *S. aureus* and 92 episodes of Gram-negative CABSI. Microbiological profiles differed between catheter types. Together, PVC and dialysis catheters accounted for 43/60 (72%) of all *S. aureus* CABSI. After adjusting for age, sex, and hematology/oncology care, the odds of *S. aureus* were higher for hemodialysis catheters (odds ratio [OR] 17.3, 95% confidence interval [CI] 5.75-52.2, P <0.01) and PVC (OR 2.96, 95% CI 1.22-7.20, P = 0.02) compared to short-term non-tunneled CVC. Odds of Gram-negative organism as the cause of CABSI were higher in long-term catheters versus short-term non-tunneled CVC (OR 2.70, 95% CI 1.37-5.24).

Conclusions: CABSI in catheters other than short-term non-tunneled CVC is more commonly caused by virulent organisms including *S. aureus* and Gram-negative bacteria. Catheter type should be considered when selecting empirical antimicrobial therapies.

Introduction

Catheter-associated bloodstream infections (CABSI) cause substantial morbidity and mortality yet are largely preventable [1].

Routine surveillance by infection prevention and control (IPC) services is crucial to monitor and prevent CABSI. Existing surveillance systems focus on central line-associated BSI (CLABSI), primarily in patients with non-tunneled short-term central venous catheters (CVC) [2,3]. This is a consequence of landmark studies that demonstrated CLABSI to be preventable through best-practice IPC measures, in turn leading to mandatory CLABSI reporting in many jurisdictions [4–6]. In contrast, peripheral venous catheters (PVC) are often overlooked by routine surveillance [7]. Long-term catheters, such as peripherally-inserted central catheters (PICC) lines, and tunneled catheters such as Hickman-type or implantable ports, are also poorly captured [8].

Overall, this has resulted in a surveillance focus on short-term non-tunneled CVC at the expense of other catheter types [2,3]. However, CABSI associated with other catheter types represents an important clinical problem requiring further study. For example, PVCs are the most frequently used invasive devices in hospitalized patients [7] and collectively account for the vast majority of all catheters inserted in hospitals. Despite the lower relative risk of

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CABSI, the absolute burden of PVC-BSI is considerable and may be equal to that of CLABSI [3,7,9].

Understanding the microbiological etiology of CABSI is essential to guide empiric antibiotic therapy, assess the severity of infection, and attempt catheter salvage. Differences between catheter types may exist. A voluntary surveillance study of hospital-acquired bacteremia in the United Kingdom in 1997-2001 reported higher rates of *Staphylococcus aureus* in PVC than CVC, as did a single-center cohort study in Tokyo [10,11]. However, there is a lack of data describing CABSI microbiology across diverse catheter types.

We aimed to compare the microbiological etiology of CABSI in patients with different types of central and peripherally-inserted catheters.

Methods

Study design

We performed a cohort study of CABSI episodes across Geneva University Hospitals (HUG) from January 1, 2016, to December 31, 2022. HUG is a 2100-bed, 10-site, tertiary hospital network in Geneva, Switzerland. CABSI was prospectively investigated by infection prevention clinicians as previously described and data were analyzed retrospectively [12].

Inclusion criteria

All CABSI episodes during the study period were considered for inclusion. Exclusion criteria were: patient age <18 years; catheter type not documented; and multiple catheters of different types *in situ* at the time of BSI. In the case of repeat CABSI episodes with the same organism within 14 days, only the first episode was included. Arterial catheter-associated BSIs were excluded from multivariable analysis due to low numbers.

Outcomes and definitions

The primary outcome was CABSI, defined by the European Centre for Disease Control (ECDC) definitions (supplementary methods) [13].

Catheter type was classified as follows: short-term CVC (non-tunneled, e.g., jugular or subclavian CVC); long-term catheter (PICC or tunneled catheter such as Hickman or implantable port); arterial catheter (central or peripheral); dialysis catheter (short- or long-term); PVC.

Statistical analysis

Descriptive analysis was reported as *n* (%), mean (standard deviation [SD]), and median (interquartile range [IQR]). Group comparisons were made using Chi-square or Fisher's exact tests for equal proportion, and Kruskal-Wallis for continuous variables. We performed exploratory analyses using univariable and multivariable logistic regression models to describe the risk of *S. aureus* and Gram-negative pathogens according to catheter type, adjusting for age, sex, and care under a cancer service (hematology/oncology), with results expressed as odds ratios (ORs) and 95% confidence intervals (95% CIs). We conducted two sensitivity analyses: excluding patients admitted after the COVID-19 pandemic (2020-2022) and excluding patients admitted to an intensive care unit (ICU).

Results

We included 416 CABSI in 395 individual patients. Catheter types were short-term CVC (119/416, 29%); long-term catheters (128/416, 32% of which 24 PICC and 104 tunneled catheters); arterial catheters (10/416, 2%); PVC (133/416, 32%); and dialysis catheters (26/416, 6%, of which 14 short-term and 12 long-term dialysis catheters). CABSI was polymicrobial in 55 (13%) cases. Overall, 491 individual organisms were isolated. (Supplementary Figures 1 and 2.)

Patient characteristics are reported in Supplementary Table 1. Patients with PVC-CABSI were the oldest (median 68 years, IQR 59-77 years), and dialysis patients were the youngest (median 59 years, IQR 43-71 years).

Microbiological etiology

Marked differences in the microbiological etiology of CABSI between catheter types were observed (Figure 1). *S. aureus* was isolated in 60 CABSI (including in polymicrobial infections), most frequently in episodes associated with dialysis catheters and PVCs which together accounted for 43/60 (72%) of all *S. aureus* CABSI. The proportion of all CABSI isolating *S. aureus* was short-term CVC 9/119 (8%), long-term catheter 7/128 (5%), arterial catheters 1/10 (10%), PVC 27/133 (20%), and dialysis catheters 16/26 (62%).

Compared to short-term CVC, univariable odds of *S. aureus* as the causative pathogen in dialysis catheters were 19.56, (95% CI 6.90-55.4, P <0.01) and in PVC 3.11 (95% CI 1.40-6.93, P <0.01). After adjusting for age, sex, and hematology/oncology care, this remained significant (hemodialysis catheters OR 17.3, 95% CI 5.75-52.2, P <0.01; PVC OR 2.96, 95% CI 1.22-7.20, P = 0.02, Figure 2, Supplementary Table 2). Eleven (18%) of all *S. aureus* CABSI were caused by methicillin-resistant isolates (MRSA), with no significant difference between catheter types (P = 0.11, Supplementary Table 4).

Gram-negative organisms were isolated more frequently in CABSI associated with long-term catheters. The proportion of all CABSI isolating Gram-negative organisms (including in polymicrobial infections) was short-term CVC 15/119 (13%); long-term catheters 38/128 (30%); arterial catheters 4/10 (40%); PVC 29/133 (22%); dialysis catheters 6/26 (23%). Compared to short-term CVC, univariable odds of a Gram-negative pathogen in long-term catheters were 2.93 (95% CI 1.51-5.67, P <0.01). This remained significant after adjustment for age, sex, and hematology/oncology care (OR 2.70, 95% CI 1.37-5.24, Figure 2, Supplementary Table 2). Resistant Gram-negative organisms were uncommon (extended-spectrum beta-lactamase: n = 9, multidrug-resistant Pseudomonas aeruginosa n = 5, Supplementary Table 4).

Sensitivity analyses

The overall distribution of microorganisms remained similar before and after the COVID-19 pandemic. The distribution also remained similar after the exclusion of patients admitted to ICU (Supplementary Figures 3 and 4).

Discussion

We analyzed the microbiological etiology of 416 CABSI episodes and found substantial differences in causative pathogens between catheter types. Compared to short-term CVC, *S. aureus* was a more frequent cause of CABSI in PVC and dialysis catheters, which together accounted for over half of all *S. aureus* CABSI. Gram-negative CABSI were more commonly associated with long-term catheters, after controlling for confounders.

We observed high proportions of virulent organisms in non-CVC CABSI episodes which may not be captured in current surveillance systems; previous calls have been made to extend surveillance to all catheter types [14]. In clinical practice, CABSI occurring in these line types may require aggressive management and a high index of suspicion for virulent organisms.

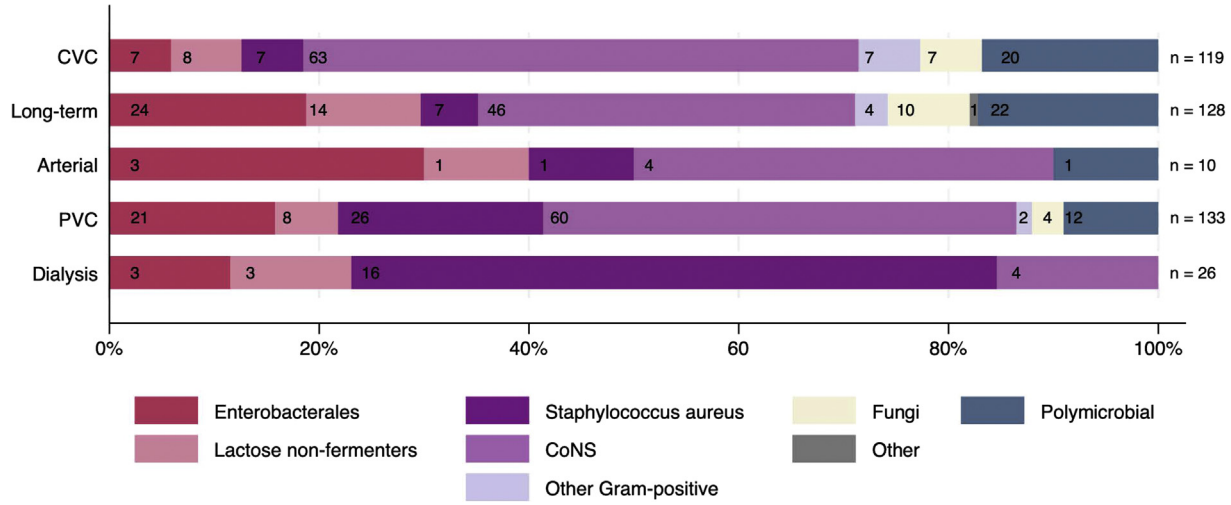

Figure 1. Microbiological etiology of catheter-associated bloodstream infections according to different catheter types.
CVC, central venous catheter; PVC, peripheral venous catheter; CoNS, coagulase-negative staphylococci.

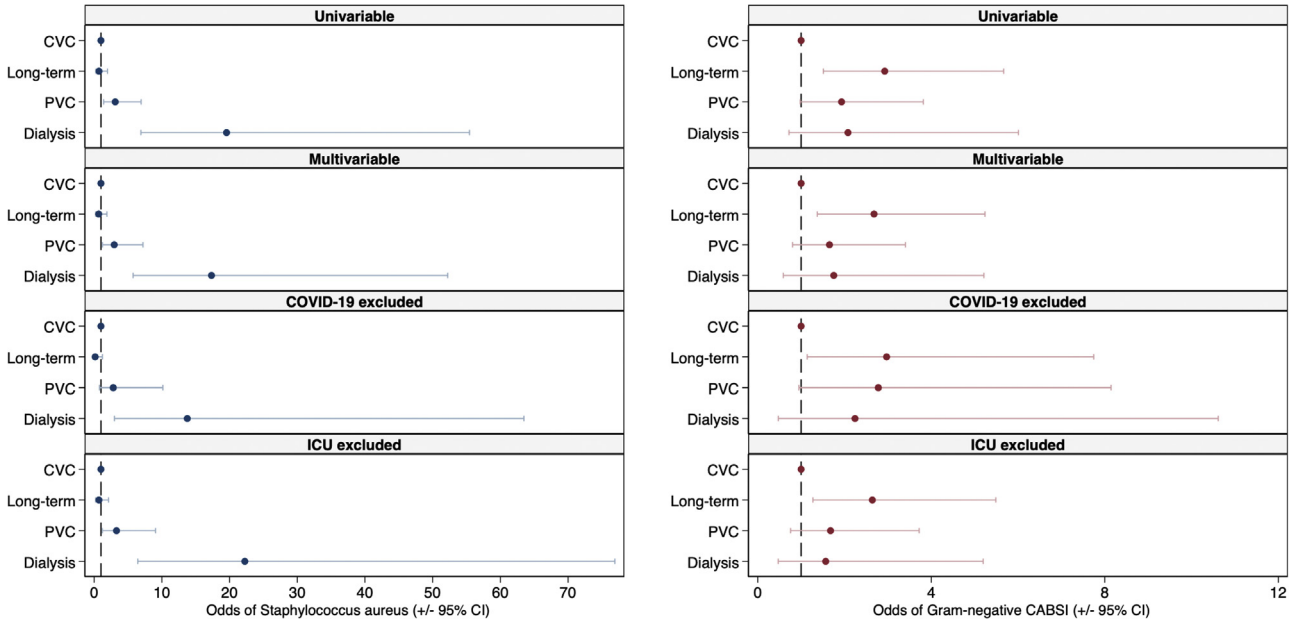

Figure 2. Odds of causative pathogens for CABSI by catheter type. (a) Odds of *Staphylococcus aureus*. (b) Odds of Gram-negative organism.
CABSI, catheter-associated bloodstream infection; CI, confidence interval; CVC, central venous catheter; ICU, Intensive care unit; PVC, peripheral venous catheter.
Long-term line = tunneled catheter or peripherally inserted central catheter.

Previous single-center studies have reported high rates of *S. aureus* in PVC-associated BSI [10,15] but lack a comparison with other catheter types. In patients with end-stage kidney disease (including those without hemodialysis catheters), high rates of *S. aureus* bacteremia have been previously reported [16], possibly relating to impaired specific adaptive immunity [17], and high rates of intermittent colonization [18]. In our institution, screening and decolonization of *S. aureus* is performed every 2 months in hemodialysis patients, and overall bacteremia rates have substantially reduced since this practice began in 2001 [19]. However, in the present analysis, the proportion of CABSI in patients with hemodialysis catheters remained high. There are several possible explanations for this. Patients with dialysis catheters represent only a small subset of all dialysis patients, and over half of the dialysis catheters associated with CABSI in this study were short-term catheters. Therefore, proportionally high rates of *S. aureus* infection in this group might occur in patients undergoing early or urgent in-hospital dialysis, not subject to the institutional *S. aureus* BSI prevention program. Additionally, patients receiving dialysis in external centers who receive treatment for CABSI in our institution do not receive *S. aureus* screening and decolonization.

Relatively high rates of Gram-negative CABSI in tunneled catheters were also reported in the PROBAC study, an observational cohort study of BSI in Spain, however a formal comparison of catheter types was not performed [20]. Importantly, Gram-negative hospital-acquired infections were associated with severe infections and high rates of septic shock in the same study [20].

Differences in microbiology of CABSI across catheter types may result from differences in physical catheter properties, insertion technique, catheter site, dwell time, antibiotic exposure, or catheter use as well as uncaptured patient characteristics. A lack of detailed patient-level and catheter-level data is a limitation of this analysis. Also, our study period overlaps with a local intervention, where a policy of clinically indicated PVC replacement was trialed for 18

months and was associated with a transient rise in S. aureus PVC-BSI [12]. This may be a source of bias, and further investigations including multicenter data are needed.

In conclusion, we identified differences in the microbiology of CABSI across catheter types. CABSI associated with PVC, dialysis catheters, and long-term catheters are more commonly caused by virulent organisms including *S. aureus* and Gram-negative bacteria, and increased surveillance efforts are warranted to better target prevention and treatment.

Declarations of competing interest

The authors have no competing interests to declare

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Ethical approval

Analysis was performed on anonymized non-genetic surveillance data. Ethical consent was not required according to the Swiss law for human research (Article 33, Paragraph 2, Human Research Act).

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Authors contributions

Concept and design: Niccolò Buetti, Aleece MacPhail; Data collection: Marie-Noëlle Chraïti, Gaud Catho; Data and statistical analysis: Niccolò Buetti, Aleece MacPhail; Data interpretation: Niccolò Buetti, Aleece MacPhail, Stephan Harbarth, Nasreen Hassoun-Kheir; Drafting of the manuscript: Aleece MacPhail, Niccolò Buetti; Revision of the manuscript: Niccolò Buetti, Maire-Céline Zanella, Aleece MacPhail, Stephan Harbarth, Aude Nguyen, Marie-Noëlle Chraïti, Nasreen Hassoun-Kheir, Gaud Catho.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to patient confidentiality. Data may be made available on reasonable request, and these can be addressed to the corresponding author.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijid.2024.107247.

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