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REVIEW ARTICLE

Prevention of Vascular Access Device-Associated Hospital Onset Bacteremia and Fungemia: A Review of Emerging Perspectives and Synthesis of Technical Aspects

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Significant events impacting healthcare over the last several years have been associated with escalating rates of healthcare-associated infections. This has resulted in increased efforts to reinstitute well-established and evidence-based infection prevention practices, particularly for central line associated bloodstream infections. However, implementation of prevention initiatives beyond central lines has not received the same level of acknowledgement and response as being

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a considerable risk to patients. This article, authored by infection prevention, infectious disease, and vascular access professionals, provides emerging perspectives and technical aspects associated with the complete lifecycle of a vascular access device. The intent is to provide insight and perspective into enhancing current IP practices in the acute care hospital setting. This will also help prepare hospitals for upcoming broader surveillance and intervention activities aimed at reducing Hospital Onset Bacteremia and Fungemia (HOB) associated with all types of vascular access devices.

Keywords: Bloodstream Infection, Hospital Onset Bacteremia, Vascular Access Device, Infection Prevention, Vascular Health and Preservation, Lifecycle

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BACKGROUND

Many critical issues challenge present-day infection prevention and control programs. [1] An event that is becoming of greater concern due to the widening impact on surveillance and prevention efforts is the occurrence of all-cause bloodstream infections (BSI). The requirement for hospitals to conduct surveillance and report central line-associated BSI (CLABSI) events provided the initial impetus for a twenty-year national movement to integrate evidence-based preventive bundle elements within hospital systems specifically addressing central venous access device (CVAD) insertion and maintenance practices. [2] These efforts contributed to an approximate 50% decrease in national CLABSI rates between 2008-2016. [3]

Although these accomplishments are to be commended, hospitals across the US in subsequent years encountered escalating CLABSI events, propagated by several significant events. National data compiled by the Centers for Disease Control and Prevention (CDC) indicates that hospitals witnessed a 48.4% rise in standardized infection ratio (SIR) CLABSI rates between 2019-Q3 and 2021-Q3 of the COVID-19 pandemic, thus negating the accomplishments gained during the previous years. [4] It is postulated that other factors contributed to increased infection risk, including alterations in insertion and maintenance practices, and reduced compliance rounds and use of checklists. [5,6] In addition, the recent Great Resignation of workers across the US included 100,000 registered nurses who left the workforce, [7,8] healthcare workers whose knowledge in applying proper IP methods during front-line practice is deemed invaluable in achieving successful outcomes. By 2027, projections are that 900,000 more nurses intend to leave the profession. [9]

Need for Expansion of BSI Surveillance and Prevention Initiatives

The need to re-establish CLABSI preventive measures is widely recognized, however, there is an ongoing discussion on the need for IP programs to expand surveillance beyond CLABSI and institute standardized interventions to prevent BSIs associated with *all* VADs. Determining infection risk associated with VADs first requires a method for accurately measuring the risk for individual types of VADs used in healthcare. Although data provides some insight into the nationwide prevalence of CLABSI events, the infection risk associated with non-central line VAD-associated BSIs is less well described, particularly in the US. Evidence in selected studies on infection risk with non-central line VADs indicates that such devices as arterial, hemodialysis, midline, and peripheral intravenous catheters (PIVCs), [1] are associated with substantial numbers of hospital-onset BSIs.

Proposed federal regulations will have a pivotal effect on surveillance and reporting requirements. The Centers for Medicare and Medicaid Services (CMS) is considering revisions to the Hospital Inpatient Prospective Payment System (IPPS) aimed at expanding BSI surveillance in US hospitals under the Inpatient Quality Reporting (IQR) Program. [10] The Hospital-Onset Bacteremia and Fungemia (HOB) proposal would require hospitals to expand surveillance with the intent on broader reduction of BSIs regardless of causative organism or association with a medical device. [11] This measure is now endorsed by Battelle's Partnership for Quality Measurement (PQM). [12]

Instituting an HOB metric rather than focusing solely on a CLABSI outcome measure has been assessed in several published studies. Researchers have suggested that HOB is a more inclusive measure than CLABSI, [13,14] and has several other advantages: (1) non-CLABSI HOB events occur in substantially greater numbers than CLABSI events occurring in a 79% to 21% ratio, respectively, in an observational study of patients in 41 acute-care hospitals conducted over a four-year period; additional findings indicated that 68% of the non-CLABSI HOB events were not related to secondary culture sources such as urinary or respiratory sites, and therefore may have attribution to use of VADs; [15] (2) the benefits are achievable when evaluating all HO *Staphylococcus aureus* bacteremia rather than only HO-Methicillin Resistant *S. aureus* (MRSA) bacteremia; [16] (3) non-central line HOB events have poor clinical outcomes and are associated with a wide variety of risk factors; [17] and (4) HOB is perceived by hospital epidemiologists to nbe largely preventable and reflective of quality of care. [18]

Implementation of prevention initiatives beyond central lines has not received the same level of attention despite being acknowledged as a risk to patients. This article, authored by IP and vascular access specialists, aims to provide emerging perspectives in preparation for conducting broader surveillance, as well as identifying technical aspects, that together, extend hospital-based BSI prevention strategies in the care of all VADs.

Lifecycle of a Vascular Access Device

Understanding the lifecycle of a VAD helps in focusing discussion and organizes potential interventions into more refined targets. A conceptual model of a VAD lifecycle (Figure 1) considers the basic phases applicable to all VADs. In assessing the steps in the process, all inserters as well as those assigned to maintenance tasks associated with all types of VADs, need to recognize the proper actions necessary within the five-phases of the device "lifecycle", a process that should reflect real-world practice: (1) Assessment, (2) Pre-insertion, (3) Insertion, (4) Post-Insertion [Dressing and Care and Maintenance], and (5) Removal. While specific practices in each phase may differ among various types of VADs, the primary message is that each phase represents an opportunity for infection prevention.

Emerging perspectives in the mitigation of HOB BSI stress the necessity of ensuring for each patient the most appropriate device selection, optimal insertion technique, followed by standardization of post-insertion care. The concept of Vascular Health and Preservation (VHP), a vascular access framework, includes the primary goal to "...drive vascular access care, regardless of the point of entry into a healthcare facility, based on a system of evidence-based practices, standards, and guidelines by means of collaborative agreement by all disciplines and care providers." [19] VHP addresses all vascular access complications, including infectious outcomes. Thus, it makes sense to include this concept when structuring IP strategies for HOB BSI.

An example of the VHP framework application is outlined in Supplementary Table 1. This table describes each phase of the lifecycle and how it correlates to the VHP framework. The table uses CVAD insertion and care as the tenet that primarily emphasizes a standardized method for infection risk reduction. Supplementary Table 1 provides insight into key aspects that assist in optimizing practices in the lifecycle of VADs.

Guideline Recommendations on Technical Aspects of the VAD Lifecycle

Table 2: Synthesis of Selected Technical Aspects of Vascular Access Devices

Several organizations and societies with expertise in the prevention of catheter-associated BSI and associated complications [20,21,22] have published practical recommendations that have been widely reviewed by hospitals nationwide. Recommendations related to technical aspects contained in these guidelines have been synthesized into a format that sorts each by type of device and categorized by the individual phases of the lifecycle of VADs (Supplementary Table 2). The information in the table is not intended to replicate every recommendation but to state concisely key technical points from the expert organizations. Readers are urged to refer to the guidelines for greater detail.

Table 3: Summary of Vascular Access Recommendations

The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC) contains in-depth information related to VAD use, care, and maintenance. [23] In addition, the guide was developed according to specific patient populations, indication for insertion, and duration of use. Supplementary Table 3 summarizes appropriate and inappropriate vascular access applications.

Patient decolonization

Colonization with healthcare-associated pathogens is associated with an increased risk of infection. Decolonization is an evidence-based intervention that can be used to prevent HAIs including BSIs. The goal of decolonization is to reduce or eliminate the bioburden on the patient, thereby reducing the risk of a subsequent infection. Since colonization can lead to infection, two overarching approaches to HAI prevention have emerged: (1) *vertical* approaches to reduce colonization or infection due to specific pathogens and (2) *horizontal* strategies to broadly reduce the burden of all pathogens.[24]

Vertical approaches are directed at a single pathogen and often utilize active surveillance testing. The classic example of vertical strategies are those directed at MRSA reductions. Horizontal decolonization approaches, conversely, can target all clinically meaningful healthcare-associated bacteria, including organisms commonly associated with BSI events such as *S. aureus*, enterococci, *Candida*, and Gram-negative bacteria. Chlorhexidine gluconate (CHG) skin decolonization of all high-risk patient populations is an example of a horizontal strategy. Since CHG has broad-spectrum activity, it has been shown to reduce infections due to BSI-associated pathogens.[25]

An updated guideline to prevent CLABSIs in acute-care hospitals considers bathing ICU patients more than 2 months of age with CHG an essential practice and is supported with a high level of evidence. [21] This recommendation is based on two major trials. One cluster-crossover study reported that daily 2% CHG cloth bathing in the ICU resulted in reduction of 28% in primary non-CLASBI events. [26] The second trial, called the REDUCE MRSA study, was a cluster randomized trial involving 74 adult ICUs. Universal decolonization (CHG plus intranasal mupirocin) was found to be associated with the greatest decrease in all-cause BSIs (44%; *P*, 0.001).[25] In a follow-up study, implementation of universal decolonization of ICU patients across a large health care system resulted in a decrease rate of CLABSIs by 23.5% (P=.001).[27] In a follow up to the REDUCE trial, the ABATE infection trial was designed to evaluate the role of CHG bathing among patients in non-ICU settings. In a post-hoc analysis, the investigators identified a high-risk sub-group of patients with medical devices including central lines and midlines which significantly decreased all-cause bacteremia by 32%.[28]

It should be noted that a multicentre cluster-randomized controlled trial examining the effect of daily bathing with CHG, octenidine, or soap and water demonstrated a lack of significant preventive effect on CLABSIs in ICUs. However, the trial was underpowered due to a CLABSI rate in the routine care group that was approximately 40% lower than initially assumed. [29]

In summary, these trails suggest that CHG bathing not only reduces the risk of CLABSIs but all-cause BSIs that include non-central line VADs.

Create/expand vascular access teams

Since 2002, the CDC has recommended specialized "IV teams" due to their "…unequivocal effectiveness in reducing the incidence of catheter-related infections and associated complications and costs".[20(CDC)] VA specialists (VAS) represent a diverse group of clinicians including medical providers, nurses, respiratory therapists, technicians, and others. A dedicated vascular access team (VAT) provides expert guidance in insertion, maintenance, and removal practices. [30] VATs demonstrate "…extensive knowledge in difficult blood draws, use of ultrasound guidance, dressing protocols, daily evaluation of catheter necessity, and removal of unnecessary catheters, as well as providing recommendations on alternative devices"[31,32] including validating indications for PIVCs, tunneled dialysis catheters, to fully implantable ports.[22] VATs also provide benefits to hospitals that may have healthcare workers with suboptimal insertion skills in PIVCs or midlines, phlebotomy and blood culture sampling. When bedside staff lack appropriate PIVC insertion skills, such workers often opt to unnecessarily order a catheter associated with greater infection risk, e.g., a PICC.[33] VAS assist with advanced education to other clinicians regarding best practice care for patients with complex vascular needs regarding selection, use of visualization technologies and dressing management.[34]

Establishment of dedicated teams whose responsibilities include assistance during insertion procedures, ensuring adherence to a checklist, and conducting rounds that include assessment of dressings, has been correlated with an overall 47% reduction in insertion related CLABSI.[35] Higher compliance levels with prevention interventions in hospitals with a designated VAT has been noted when compared with hospitals that have no designated teams.[36]

Although there have been no randomized controlled trials (RCT) that support or refute the use of VAT,[37] expert organizations advocate the use of specialized teams in the prevention of VAD-associated complications and infection events.[20,21,22] Preliminary research on professional perspectives on VAT benefits, organization, challenges, and opportunities on a global scale has concluded a unanimous endorsement of the value of VAT while outlining strategies for overcoming barriers to successful implementation.[38] The expansion of surveillance and prevention initiatives to include all VADs will require a corresponding extension of standardized and consistent quality practices for both insertion and maintenance phases that should integrate collaboration with VATs.

Use and Disinfection of Ultrasound Transducers

As challenges with difficult access patients increase, use of visualization technologies is necessary to gain successful VAD access. Use of ultrasound guidance is advocated by the CDC [39] and INS,[22] and is considered an essential practice during a wide-range of VAD insertion procedures.[21] A wider use of ultrasound transducers (UT) for PIVC placement has been observed

due to difficult placement issues such as in patients with obesity, intravenous drug abuse, and hypovolemia.[40] Multiple reports, including those associated with national outbreaks, have indicted occurrences of bacteremia due to events such as those involving ultrasound guided procedures when the needle punctures through contaminated gel. [41,42]

With the use of UTs to enhance visualization now widely adopted throughout healthcare settings, and with the understanding there exists risk of infection associated with improper cleaning and disinfection practices, it is important to clarify current recommendations in safe processing. The American Institute of Ultrasound in Medicine (AIUM) guideline addressing the processing of UTs recommends the disinfection process to be undertaken based on the type of examination performed: percutaneous versus endocavitary.[43] The AIUM states "preparation of *external* transducers between patients requires a low level disinfection (LLD) process", while "preparation of *internal* transducers between patients requires routine mandatory high level disinfection (HLD) and the use of a high-quality single-use transducer cover during each examination". A joint position statement issued by various scientific organizations, including the Association of Professionals in Infection Control and Epidemiology (APIC), Association for Vascular Access (AVA), and Society for Healthcare Epidemiology of America (SHEA), support recommendations that UTs, when used on intact skin and in conjunction with a transducer cover can be safely processed using LLD. [44] The AIUM recommended methodology for disinfection of ultrasound transducers is supported by a randomized control trial in which UTs are processed by LLD or HLD processes. [45]

In addition, the joint statement states "...if contamination of covered transcutaneous transducers with blood or other body fluids occurs...can be eliminated with low-level disinfectants that are effective against mycobacteria and bloodborne pathogens...".[44.] In circumstances where a needle punctures through gel, it is recommended that sterile gel be used.

It is strongly suggested that healthcare personnel involved in VAD insertion procedures in which ultrasound transducers are used review published guidelines and studies to determine best practices within their organizations. A manufacturer has developed a useful toolkit that aids healthcare providers in the assessment process by providing information on facility location of ultrasound machines, procedure identification, processing recommendations based on disinfection classifications, risk assessment, recommendations for gel usage, and policy development frameworks.[46]

Peripheral intravenous catheters

While there has been an intensive focus on infections and complications from CVADs for more than five decades, there has been a growing awareness that PIVCs can also cause significant morbidity and mortality. Several studies in the US have focused on *S. aureus* as a particular pathogen of concern associated with VAD usage.[47,48,49] In two of these reviews,[48,49] researchers identified that more than a third of the hospital onset *S. aureus* BSIs were associated with PIVCs

rather than central lines. In addition, increased BSI rates associated with PIVCs have been observed during the COVID-19 pandemic period. [50] The change to a clinical indication methodology rather than a time-based process for site selection,[22] provides impetus for enhancing optimal efforts to ensure appropriate care is given to insertion, care and maintenance of these devices. Without such efforts, patients can be left at considerable risk of both infectious and non-infectious complications.

Healthcare systems are encouraged to develop bundled approaches to PIVC insertion and care based on local factors combined with the learnings from CLABSI prevention to minimize the risk to patients.[51,52] However, additional research is needed to identify an optimal bundle, a process that requires consistent approaches such as the role of site selection, appropriate skin antisepsis prior to access, maximizing first stick success through the use of competent staff and visualization technology when indicated, maintaining clean, dry and intact dressings and ensuring device patency.

Similar considerations for prevention strategies for long PIVCs and midline catheters are indicated as well. Device design and insertion techniques vary considerably and often influence policy decisions regarding bundle elements such as maximum barrier precautions and dressing type used after VAD insertion. Individual organizations have approached prevention through different strategies with varying results.[53,54] Understanding the performance of specific device outcomes and ensuring their appropriate use can help avoid unnecessary patient infection risk.

Regarding PIVC dwell time, historically, there have been two approaches: the first based on a scheduled removal, with the second leaving a catheter until a complication occurs, also known as clinically indicated removal. Multiple randomized studies have supported peripheral catheter removal based on clinical indication. In these studies, and subsequent studies factors minimizing patient risk of infection have included education, monitoring, and close assessment. [22] Guideline recommendations addressing PIVC replacement in included in Supplemental Table 2.

Antimicrobial intravenous dressings

Despite the application of a skin antiseptic prior to catheter insertion, skin is not sterile. Bacteria may continue to survive in folds and among other skin appendages, with continued microbial growth being affected by such factors as body temperature and sweating. Development of dressings with antimicrobial components were developed with an aim at suppressing the occurrence of microbial growth in the days after initial catheter insertion. Studies examining the effect of Intravenous site dressings in the form of a circular patch or an impregnated dressing, both containing CHG, were reported by researchers conducting a comprehensive meta-analysis to have reduced CRBSI rates by 33%. [55] These studies, however, were limited to use of CVADs. Data that supports the use of antimicrobial dressings in other VADs, such as PIVCs, is limited. [56]

The CDC's 2017 update to the 2011 *Guideline for the Prevention of Intravascular Catheter-Related Infections* states that "…for patients aged 18 years and older chlorhexidine-impregnated

dressings with an FDA-cleared label that specifies a clinical indication for reducing catheter-related bloodstream infection (CRBSI) or catheter-associated bloodstream infection (CABSI) are recommended to protect the insertion site of short-term, non-tunneled central venous catheters".[57] This CDC recommendation is highest graded as a Category IA, strongly supported by well-designed experimental, clinical, or epidemiologic studies. In addition, the use of CHG impregnated dressings is also considered an "essential practice" in the compendium *Strategies to Prevent Central Line-associated Bloodstream Infections in Acute-Care Hospitals: 2022 Update*.[20] No recommendation is made for non-central line VADs.

Advancements in enhancing chlorhexidine formulations may in the future contribute to prevention of HOB BSI in a wider VA application. A majority of currently available antimicrobial dressings are based on a chlorhexidine salt formulation such as chlorhexidine diacetate (CHA). Dressings based on these formulations encounter reduced chemical availability for reaction due to ionic binding and steric restriction of the chlorhexidine molecules themselves. New research suggests that advanced chlorhexidine formulations provide more effective antimicrobial action. A well-designed in vitro study examining the effects of chlorhexidine (CHA) and silver salt-based antimicrobial dressing versus a novel free base chlorhexidine (CHX) dressing,[58] used inoculated samples of both dressing types with microorganisms that are most often implicated as causative pathogens in CRBSI events, namely *Candida* species, *Enterococcus* species, Enterobacteriaceae, and *Staphylococcus epidermidis*, as well as sensitive and resistant strains of *S. aureus.* The researchers assessed the $\log_{10}$ reduction of the pathogens at days 1, 3 and 7. A benchmark of 4.0 $\log_{10}$ reduction was used to define substantial antimicrobial dressing efficacy.

The study demonstrated two significant findings. First, the CHX dressing demonstrated a superior *in vitro* antimicrobial effect at 67% of the experimental time points than the CHA dressing, with at least equivalent efficacy at all other testing time points, including a >5.0 $\log_{10}$ reduction at the 7-day period against eleven of the twelve test organisms. Second, although the CHA dressing has a 36% greater chlorhexidine mole content than the CHX dressing, the CHX dressing achieved a more effective microorganism kill in vitro. A reduced total chlorhexidine content may be of benefit when considering the existence of patient events involving skin sensitivity or rare allergic reactions when exposed to chlorhexidine formulations. *In vivo* research is needed to determine the effectiveness of advanced antimicrobial dressings on BSI rates among diverse patient populations and settings and when used with distinct types of VADs.

Limitations

The perspectives outlined apply to adult patients in acute care settings and are not necessarily relevant to long–term care, home care, pediatrics, or neonatal populations.

CONCLUSION

The emerging perspectives presented in this article outline IP and VA topics supported by recent research relevant to the prevention of BSIs in a surveillance setting that includes expanding efforts to all VADs. The key evidence-based interventions include appropriate selection of VADs, proper insertion of a VAD which will permit optimal care and maintenance, compliance with elements in a prevention bundle to include proper skin antisepsis and maximal barrier precautions, appropriate maintenance of catheters to include scrubbing the hub, adherence to dressing protocols, CHG bathing for high-risk patients, removal of catheters when indicated, and use of VATs to oversee and assist in the care of all VADs. These areas of focus addressing technical aspects, highlight avenues of intervention that when integrated into quality improvement initiatives should prove to be beneficial in mitigating VAD HOB events which are associated with serious, and often life-threatening, complications.

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References

1. Garcia R, Barnes S, Boukidjian R, Goss LK, Spencer M, Septimus E, et al. Recommendations for change in infection prevention programs and practice. Am J Infect Control, 2022;50:1281-1295.
2. Institute for Healthcare Improvement. How-to Guide: Prevent Central Line-Associated Bloodstream Infection. Available at: https://www.ihi.org/resources/white-papers/using-care-bundles-improve-health-care-quality. Accessed 14 April 2024.
3. Centers for Disease Control and Prevention. Data Summary of HAIs in the US: Assessing Progress 2006-2016. Available at: https://www.cdc.gov/hai/data/archive/data-summary-assessing-progress.html. Accessed 14 April 2024.
4. Weiner LM, Alvarez CR, Kofman A, Konner RY, Kuhar DT, Nkwata A, et al. Continued increases in the incidence of healthcare-associated (HAI) during the second year of the coronavirus disease 2019 (COVID-19) pandemic. Infect Control Hosp Epidemiol, 2022;44:997-1001.
5. Sturm LK, Saake K, Roberts PB, Masoudi FA, Fakih M. Impact of COVID-19 pandemic on hospital onset bloodstream infections (HOBSI) at a large health system. Am J Infect Control, 2022;50:245-249.
6. Baker MA, Sands KE, Huang SS, Kleinman K, Septimus EJ, Varma N, et al. The impact of coronavirus disease 2019 (COVID-19) on healthcare-associated infections. Clin Infect Dis, 2022;74:1748-1754.
7. ECRI. Top 10 Patient Safety Concerns 2022. Available at: ECRI-Top-10-Patient-Safety-Concerns-2022-Special-Report.pdf. Accessed 14 April 2024.

8. American Hospital Association. AHA letter: Challenges facing America's healthcare workforce as the US workforce enters third year of the COVID-19 pandemic. Available at: https://www.aha.org/lettercomment/2022-03-01-aha-provides-information-congress-re-challenges-facing-americas-health. Accessed 14 April 2024.
9. National Council of State Boards of Nursing. NCSBN Research Projects Significant Nursing Workforce Shortages and Crisis. Available at: https:// www.ncsbn.org/news/ncsbn-research-projects-significant-nursing-workforce-shortages-and-crisis. Accessed 14 April 2024.
10. Centers for Medicare and Medicaid Services. FY 2023 Hospital Inpatient Prospective Payment System (IPPS) and Long Term Care Hospitals (LTCH PPS) Proposed Rule - CMS-1771-P. Available at: https:// www.cms.gov/newsroom/fact-sheets/fy-2023-hospital-inpatient-prospective-payment-system-ipps-and-long-term-care-hospitals-ltch-pps. Accessed 14 April 2024.
11. Centers for Disease Control and Prevention. Spring 2023 Vendor Meeting. Available at: https:// www.cdc.gov/nhsn/pdfs/April-2023-Vendor-Webinar_Finalv2.pdf. Accessed 31 March 2024.
12. Battelle's Partnership for Quality Measurement. Available at: https://p4qm.org/. Accessed 14 April 2024.
13. Sturm L, Bufalino A, Huang R-H. Is hospital-onset bloodstream infection (HOBSI) a useful measure to evaluate infection prevention progress? Infect Control Hosp Epidemiol, 2020;41;S307-S308.
14. Page B, Klompas M, Chan C, Filbin MR, Dutta S, McAvoy DS, et al. Surveillance for healthcare-associated infections: hospital-onset adult sepsis events versus current reportable conditions. Clin Infect Dis, 2021;73:1013-1019.
15. Yu KC, Jung M, Ai C. Characteristics, costs, and outcomes associated with central-line-associated bloodstream infection and hospital-onset bacteremia and fungemia in US hospitals. Infect Control Hosp Epidemiol, 2023;44:1920-1926.
16. Fakih M, Battjes R, Sturm L, Jones L, Groves C, Bufalino A, et al. Hospital-onset *Staphylococcus aureus* bacteremia is a better measure than MRSA bacteremia for assessing infection prevention: evaluation of 50 US hospitals. Infect Control Hosp Epidemiol, 2018;39:476-478.
17. Zhu S, Kang Y, Cai L, Sun X, Zong Z. The clinical impacts and risk factors for non-central line-associated bloodstream infection in 5406 intensive care unit patients: an observational study based on electronic medical records. Crit Care, 2019; 23(1):52. doi: 10.1186/s13054-019-2353-5.
18. Dantes RB, Abbo LM, Anderson D, Hall L, Milstone AM, Morgan DJ, et al. Hospital epidemiologists' opinions regarding hospital-onset bacteremia and fungemia as a potential healthcare-associated infection metric. Infect Control Hosp Epidemiol, 2019;40:536-540.
19. Moureau N, Trick N, Nifing T, Perry C, Kelly C, Carrico R, et al. Vessel health and preservation (Part 1): A new evidence-based approach to vascular access selection and management. J Vasc Access 2012;13:351-356.
20. Centers for Disease Control and Prevention. Guidelines for the Prevention of Intravascular Catheter-Related Infections. MMWR Recommendations and Reports. August 9, 2002. Vol. 51. No. RR-10.
21. Buetti N, Marschall J, Dress M, Fakih M, Hadaway L, Maragakis LL, et al. Strategies to prevent central line-associated bloodstream infections in acute-care hospitals. Infect Control Hosp Epidemiol, 2022;43:553-569.

22. Infusion Nurses Society. Infusion Therapy Standards of Practice 2024. 9th Edition. Available at: https://www.ins1.org/publications/infusion-therapy-standards-of-practice/. Accessed 14 April 2024.
23. Chopra V, Flanders SA, Saint S, Woller SC, O'Grady NP, Safdar N, et al. The Michigan Appropriateness Guide for Intravenous Catheters (MAGIC): Results from a multidisciplinary panel using the RAND/UCLA appropriateness method. Ann Inten Med, 2015;163:S1-S40.
24. Wenzel RP, Edmond MB. Infection control: the case for horizontal rather than vertical interventional programs. Int J Infect Dis, 2019;14(Suppl 4):S3-S5.
25. Huang SS, Septimus E, Platt R. Targeted decolonization to prevent ICU infections. N Engl J Med, 2013;369:1470-1471.
26. Climo MW, Yokoe DS, Warren DK, Perl TM, Bolon M, Herwaldt LA, et al. Effect of daily chlorhexidine bathing on hospital-acquired infection. N Engl J Med, 2013;368:533-542.
27. Septimus E, Hickok J, Moody J, Kleinman K, Avery TR, Huang SS, et al. Closing the translation gap: toolkit-based implementation of universal decolonization in adult intensive care units reduces central line-associated bloodstream infections in 95 community hospitals. Clin Infect Dis, 2016;63:172-177.
28. Huang SS, Septimus E, Kleinman K, Moody J, Hickok J, Heim L, et al. Chlorhexidine versus routine bathing to prevent multidrug-resistant organisms and all-cause bloodstream infections in general medical and surgical units (ABATE Infection trial): a cluster-randomized trial. Lancet, 2019;393:1205-1215.
29. Denkel LA, Schwab F, Clausmeyer J, Behnke M, Golembus J, Wolke S, et al. Effect of antiseptic bathing with chlorhexidine or octenidine on central line-associated bloodstream infections in intensive care patients: a cluster-randomized controlled trial. Clin Micro Infect, 2022;28:825-831.
30. Moureau N. Establishing vascular access teams for patient safety. Infection Control Today. 2020. Available at: https:// www.infectioncontroltoday.com/view/establishing-vascular-access-teams-patient-safety. Accessed 14 April 2024.
31. Garcia R. Moving beyond central line-associated bloodstream infections: enhancement of the prevention process. J Infusion Nur, 2023;46:217-222.
32. Quinn M, Horowitz JK, Krein SL, Gaston A, Ullman A, Chopra V. The role of hospital-based vascular access teams and implications for patient safety: A multi-methods study. J Hosp Med, 2023;19:13-23.
33. Fakih M, Sturm F. Paving the PICC journey: building structures, process, and engagement to improve outcomes. BMJ, 2021;30:618-621.
34. Harpel J. Best practices for vascular resource teams. J Inf Nur, 2013;36:46-50.
35. Summerlin-Long S, DiBlase LM, Padgett M, Mack J, Clark C, Teal L, et al. A helping hand: the impact of a central line insertion support team. Am J Infect Control, 2023;51:1438-1440.
36. Krein SL, Kuhn L, Ratz D, Chopra V. Use of designated nurse PICC teams and CLABSI prevention practices among U.S. hospitals: A survey-based study. J Patient Safety, 2019;15:293-295.
37. Carr PJ, Niggins NS, Cooke ML, Mihala G, Rickard CM. Vascular access specialist teams for device insertion and prevention of failure. Cochrane Reviews. 2018; Issue 3. Available at: https://www.cochranelibrary.com/cdsr/doi/10.1002/14651858.CD011429.pub2/epdf/full. Accessed 14 April 2024.

38. Morrow S, DeBoer E, Potte C, Gala S, Alsbrooks K. Vascular access teams: a global outlook on challenges, benefits, opportunities, and future perspectives. Br Med J, 2022;31:S26-S35.
39. Centers for Disease Control and Prevention. A Rational Approach to Disinfection and Sterilization. Available at: https://www.cdc.gov/infectioncontrol/guidelines/disinfection/rational-approach.html. Accessed 14 April 2024.
40. Presley B, Isenberg JD. Ultrasound Guided Intravenous Access. StatPearls. July 25, 2023. https://www.ncbi.nlm.nih.gov/books/NBK525988/ . Accessed 14 April 2024.
41. Adelfattah R, AI-Jumaah S, AI-Qahtani A, AI-Thawadi S, Barron I, AI-Mofada S. Outbreak of Burholderia cepacian bacteremia in a tertiary care centre due to contaminated ultrasound probe gel. J Hosp Infect, 2018;98:289-294.
42. Centers for Disease Control and Prevention. Multistate Outbreak of *Burkholderia cepacia* Infections Associated with Contaminated Ultrasound Gel. Available at: https://www.cdc.gov/hai/outbreaks/b-cepacia-ultrasound-gel/index.html . Accessed 14 April 2024.
43. American Institute of Ultrasound in Medicine. Guidelines for Cleaning and Preparing External- and Internal-Use Ultrasound Transducers and Equipment Between Patients as Well as Safe Handling and Use of Ultrasound Coupling Gel. Available at: https://www.aium.org/resources/official-statements/view/guidelines-for-cleaning-and-preparing-external--and-internal-use-ultrasound-transducers-and-equipment-between-patients-as-well-as-safe-handling-and-use-of-ultrasound-coupling-gel. Accessed 14 April 2024.
44. AIUM Disinfection of ultrasound transducers used for percutaneous procedures. Intersocietal Position Statement. J Ultrasound Med, 2021;40:895-897.
45. Peters N, Williamson F, Llewellyn S, Snelling PJ, Harris PNA, Stewart AG, et al. Comparison of low-level to high-level disinfection in eliminating microorganisms from ultrasound transducers used on skin. J Ultrasound Med, 2023;42:2525-2534.
46. Ultrasound Infection Prevention Toolkit. (Document development sponsored by Nanosonics) Available at: https://www.ultrasoundinfectionprevention.org/media/eqyfxkbr/ultrasound-iinfection-prevention-toolkit-tool-3.pdf. Accessed 14 April 2024.
47. Davis J. Peripheral vascular catheter–related infection: Dwelling on dwell time. Pennsylvania Patient Safety Advisory, 2014;11:30-36.
48. Blauw M, Foxman B, Wu J, Rey J, Kothari N, Malani AN. Risk factors and outcomes associated with hospital-onset peripheral intravenous catheter-associated *Staphylococcus aureus* bacteremia. Open Forum Infect Dis, 2019. Available at: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6441569/pdf/ofz111.pdf. Accessed 14 April 2024.
49. Kovacs CS. Hospital-acquired *Staphylococcus aureus* primary bloodstream infection: a comparison of events that do and do not meet the central line-associated blood stream infection definition. Am J Infect Control, 2016;44:1252–1255.
50. Zanella M-C, Pianca E, Catho G, Obama B, De Kraker MEA, Nguyen A, et al. Increased peripheral venous catheter bloodstream infections during COVID-19 pandemic, Switzerland. Emerg Infect Dis, 2024;30:159-162.
51. Steere L, Ficara C, Davis M, Moureau N. Reaching one peripheral intravenous catheter (PIVC) per patient visit with lean multimodal strategy: the PIV5Rights™ Bundle. JAVA, 2019;24:31-43.

52. DeVries M, Valentine M, Mancos P. Protected clinical indication of peripheral intravenous lines: successful implementation. JAVA, 2016;21:89-92.
53. Duncan M, Warden P, Bernatchez SF, Morse D. A bundled approach to decrease the rate of primary bloodstream infections related to peripheral intravenous catheters. JAVA, 2017; 23: 15-22.
54. DeVries M, Lee J, Hoffman L. Infection free midline catheter implementation at a community hospital (2 years). Am J Infect Control, 2019;47:1118-1121.
55. Puig-Asensio M, Marra AR, Childs A, Kukla ME, Perencevich EN, Schweizer ML. Effectiveness of chlorhexidine dressings to prevent catheter-related bloodstream infections. Does one size fit all? A systematic literature review and meta-analysis. Infect Control Hosp Epidemiol, 2020;19:429-454.
56. Zingg W, Barton A, Bitmead J, Eggimann P, Pujol M, Simon A, et al. Best practice in the use of peripheral venous catheters: A scoping review and expert consensus. Infect Prev Pract 2023;5:1-8.
57. Centers for Disease Control and Prevention. 2017 Updated Recommendations on the Use of Chlorhexidine-Impregnated Dressings for Prevention of Intravascular Catheter-Related Infections. Available at: https://www.cdc.gov/infectioncontrol/pdf/guidelines/bsi-guidelines-H.pdfc.gov. Accessed 14 April 2024.
58. Holinga G, McGuire JE. *In vitro* antimicrobial effects of chlorhexidine diacetate versus chlorhexidine free base dressings. J Wound Care, 2020;29(Sup5A):522-528.

Figure 1