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Original Article

Mixed-methods multicenter assessment of healthcare workers' knowledge, perceptions, and practices related to blood culture utilization in hospitalized adults

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Abstract

Objective: To understand healthcare workers' (HCWs) beliefs and practices toward blood culture (BCx) use.

Design: Cross-sectional electronic survey and semi-structured interviews.

Setting: Academic hospitals in the United States.

Participants: HCWs involved in BCx ordering and collection in adult intensive care units (ICU) and wards.

Methods: We administered an anonymous electronic survey to HCWs and conducted semi-structured interviews with unit staff and quality improvement (QI) leaders in these institutions to understand their perspectives regarding BCx stewardship between February and November 2023.

Results: Of 314 HCWs who responded to the survey, most (67.4%) were physicians and were involved in BCx ordering (82.3%). Most survey respondents reported that clinicians had a low threshold to culture patients for fever (84.4%) and agreed they could safely reduce the number of BCx obtained in their units (65%). However, only half of them believed BCx was overused. Although most made BCx decisions as a team (74.1%), a minority reported these team discussions occurred daily (42.4%). A third of respondents reported not usually collecting the correct volume per BCx bottle, half were unaware of the improved sensitivity of 2 BCx sets, and most were unsure of the nationally recommended BCx contamination threshold (87.5%). Knowledge regarding the utility of BCx for common infections was limited.

Conclusions: HCWs' understanding of best collection practices and yield of BCx was limited.

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Introduction

Blood cultures (BCx) are commonly ordered in hospitalized patients for workup of fever, leukocytosis, or other abnormal clinical signs, yet most BCx (85%–95%) will not grow an organism, and among those that are positive, a significant proportion will demonstrate contamination with skin flora.[1–4] Studies have estimated that up to 60% of BCx collected in hospitalized adults might not be clinically indicated.[5,6] Conversely, a recent study of BCx utilization in Israel, estimated that ~24% of adult bloodstream infections (BSIs) were missed due to single BCx, lack of anaerobic bottles, or BCx not being performed.[7] These data *emphasize the need for BCx diagnostic stewardship.*

Ordering of BCx is influenced by both clinical (eg, clinical stability and underlying conditions of patients) and nonclinical, socio-behavioral, or process-related factors such as the ordering

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provider's healthcare role and years of work experience, shift of the day when BCx are under consideration, and sign-out instructions.[4,8–11] Previous surveys have suggested prescribers are unfamiliar with appropriate BCx indications.[8] Little is known regarding providers' knowledge or practices related to BCx collection. Our objective was to understand healthcare workers' (HCWs) perceptions toward the utility of BCx in different clinical scenarios, their practices related to BCx ordering and collection, and the potential facilitators and barriers to stewardship interventions to improve BCx stewardship.

Methods

Study design and settings

A mixed-methods study with a convergent parallel design was conducted as part of a larger QI project to optimize BCx practices among inpatient adults. We recruited 8 teaching hospitals through the Centers for Disease Control and Prevention's Prevention Epicenters Program and the Society for Healthcare Epidemiology of America (SHEA) Research Network to join the collaborative to implement a BCx stewardship QI project based on a prior pilot study.[5] Each participating hospital convened a local QI team composed of 1 or 2 individuals with a leadership position in either the antimicrobial stewardship or the infection control programs as well as 1 or more unit project champions/thought leaders from targeted ICUs and wards (eg, unit director, resident physician, nurse leader).

Johns Hopkins University (JHU) served as the coordinating center for all sites in the collaborative. The Johns Hopkins Medicine Institutional Review Board approved this work as Human Subjects Research under expedited review. Oral consent was required for the interviews. Participation in the survey was taken as consent.

Survey development and administration

A 31-item survey was developed using the Qualtrics survey system (Qualtrics, Provo, UT) to assess HCWs' knowledge regarding BCx indications, ordering and collection practices and perceptions about these practices, and perceived barriers to improving BCx utilization. A JHU team with expertise in infectious diseases (ID), QI, and diagnostic stewardship developed the survey, which was piloted by 3 ID physicians and modified based on feedback. Site leads received the final survey through an electronic link and distributed the link to key stakeholders including ordering providers and non-ordering HCW roles. Additionally, the project site leads posted QR codes that linked to the survey on common areas in units of interest. A minimum of 30 HCW responses were requested from each site. Surveys were distributed between March 8 and December 4, 2023.

Semi-structured interviews

During baseline assessment, we conducted a group interview with each participating hospital QI team as well as relevant stakeholders such as trainees, bedside nurses using an interview guide developed by JHU team based on the Consolidated Framework for Implementation Research framework. Questions focused on motivation to participate in a BCx stewardship QI, perceptions regarding existing BCx practices, prior/current efforts to improve BCx utilization, and barriers to a BCx stewardship QI intervention (Supplementary Material).

Data analysis

Survey data were analyzed using descriptive statistics to summarize respondents' answers by unit (intensive care unit [ICU] vs non-ICU), hospital, or healthcare role. Questions with a 5-point Likert scale were categorized into 3 groups by combining "strongly agree" and "agree" or "almost always" and "often" or "very likely" and "likely" and by combining "disagree" and "strongly disagree" or "unlikely" and "very unlikely" or "rarely" and "almost never".[4] Separately, we conducted a qualitative content analysis of the interview data.[12] Through an iterative process, 2 JHU study team members (AX, VF) independently reviewed each interview transcript to identify recurring phrases, ideas, and concepts and discussed to achieve consensus and create common themes. Two additional JHU study team members (SEC and AMM) reviewed and provided feedback on the node structure to ensure the credibility, dependability, and confirmability of the analysis.[13,14] Quantitative survey data and qualitative interview data were then triangulated to better understand HCWs' knowledge, attitudes, and perceptions regarding BCx practices. For each section, we present survey results first followed by the interview findings.

Results

Cohort characteristics

Characteristics of survey and interview participants are displayed in Table 1. Three-hundred and fourteen HCWs from 8 hospitals located in California, Nebraska, Michigan, Tennessee, Pennsylvania, Maryland, Virginia, and North Carolina took the electronic survey; 282 reported their affiliation with a median number of respondents per hospital of 35 (range 16–58). Most survey participants were physicians (67.4%, of which 45.8% were physicians in training), followed by nurses (15.6%) and advanced practice practitioners (14.5%). Most indicated they were involved in ordering BCx only (73.7%), with 8.5% involved in ordering and collecting BCx and 16.7% in collecting BCx only.

Semi-structured group interviews were conducted with 36 participants averaging 5 participants per hospital. Most participants were physicians (53% attendings and 8% residents), followed by the grouped category of bedside nurses, infection preventionists, and phlebotomists (31%).

Perceptions about blood culture ordering practices

Half (52.2%) of survey participants perceived that there were too many BCx ordered in their units, and 65.3% agreed that they could safely reduce the number of BCx obtained (responses by hospital are shown in Figure 1 and by unit in Table 2). Most respondents felt that clinicians have a low threshold to order BCx for isolated fever (84.4%) and that not all patients with a new fever should get BCx (72.3%). Fewer agreed that newly isolated leukocytosis triggered BCx in clinical practice (27.7%). There were variations in the temperature threshold respondents used to consider BCx, 45.5% used >100.4°F (38.0°C), 29.8% used >101.0°F (38.3°C), and 12.1% reported different thresholds depending on the patient population. This lack of standardization regarding BCx indications and temperature thresholds to obtain BCx was confirmed by interviewees who reported lower temperature thresholds were used for immunocompromised patients and those requiring extracorporeal membrane oxygenation support (quotes [Q] 1 and 2, Table 3).

Regarding the decision to order BCx, most reported a combination of practices (eg, making decisions on their own,

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Table 1. Characteristics of survey and semi-structured interview participants

Characteristics	Survey participants** N=282 (%)	Interview participants N=36 (%)
Race		
African American	7 (2.5)	1 (2.8)
Asian	39 (13.8)	6 (16.7)
White	213 (75.5)	26 (72.2)
Other/more than one race	3 (1.1)	2 (5.5)
Unknown/not documented	20 (7.1)	1 (2.8)
Ethnicity		
Hispanic	11 (3.9)	2 (5.5)
Not Hispanic	256 (90.8)	33 (91.7)
Unknown/not documented	15 (5.3)	1 (2.8)
Gender		
Women	173 (61.4)	21 (58.3)
Men	101 (35.8)	14 (38.9)
Other	8 (2.8)	–
Unknown/not documented	–	1 (2.8)
Years of experience, median (IQR)	4 (2, 9)	8 (4, 11)
Role		
Attending physician	103 (36.5)	19 (52.8)
Physician in training	87 (30.9)	3 (8.3)
Advanced practice practitioner	41 (14.5)	1 (2.8)
Microbiologist	–	2 (5.5)
Other*	51 (18.1)	11 (30.6)
Hospital		
Hospital A	28 (9.9)	6 (16.7)
Hospital B	42 (13.4)	3 (8.3)
Hospital C	32 (10.2)	3 (8.3)
Hospital D	16 (5.1)	4 (11.1)
Hospital E	58 (18.5)	3 (8.3)
Hospital F	39 (12.4)	6 (16.7)
Hospital G	18 (5.8)	9 (0.3)
Hospital H	49 (15.6)	2 (5.6)
Unknown	32 (10.2)	–
Region		
Northeast	42 (13.4)	3 (8.3)
Midwest	97 (34.4)	9 (25.0)
South	111 (39.4)	3 (8.3)
West	32 (10.2)	21 (58.3)

*Includes bedside nurse, phlebotomist, and infection preventionist. **314 individuals took the survey, and 282 completed questions related to demographics.

following sign-out instructions, consulting institutional guidelines). Although 74.1% of respondents indicated decisions regarding BCx were made as a team (74.1%), only 42.4% indicated these discussions occurred in daily practice. Notably, interviewees overwhelmingly agreed decisions to order BCx were predominately made by trainees (Q3, Table 3).

Factors influencing blood culture ordering

Most survey respondents indicated clinicians usually review the electronic medical record (EMR) (74.8%) but do not necessarily evaluate the patient (78.7%) prior to ordering BCx. Interviewees described bedside evaluation of the patient prior to ordering a BCx as particularly challenging at night due to the cross-covering provider being responsible for many patients. Interviewees felt less experienced trainees were more likely to order unnecessary BCx (Q4, Table 3).

Regarding HCW knowledge of BCx indications, 49% of survey participants received training on when to draw BCx. Although most survey participants correctly responded cellulitis was unlikely to be associated with bacteremia (69.0%), a lower proportion correctly indicated meningitis was likely associated with bacteremia (52.8%) (Suppl. Table 2). Most survey respondents correctly agreed that all patients with *Staphylococcus aureus* bacteremia but not all patients with uncomplicated *E. coli* bacteremia required repeat BCx to document bacteremia resolution (80.0% and 64.3%, respectively). A minority of survey participants had received feedback regarding BCx utilization for their units (21.7%), and more than half were unaware if there was an institutional policy addressing fever workup or BCx indications (Table 2). During interviews, only 3 institutions reported the existence of some guidance regarding BCx indications (eg, when to repeat for uncomplicated gram-negative bacteremia, when to order BCx for fever workup). Regarding nursing involvement in BCx ordering decision-making, interviewees reported that it was usually limited to specific scenarios such as upon activation of sepsis alerts in the EMR but that there had been increasing engagement of nursing in BCx stewardship (Q5 and Q6, Table 3).

Perceptions about blood culture collection practices

Survey responses related to BCx collection practices are presented in Tables 2 and 4. Only 59% of survey participants agreed that 2 sets of BCx increased the likelihood of bacteremia detection, and 32.5% correctly identified 8–10 mL as the recommended volume to fill in each bottle. Half of the survey participants agreed that central-line BCx were more likely to yield BCx contaminants compared to BCx obtained through peripheral venipuncture, and ~10% reported central-line BCx rarely occurred. Interview participants shared their institution's approach to minimize central-line BCx including requiring prior authorization and restricting to specific circumstances (Q7, Table 3), although most did not track the number of central-line BCx in clinical units, usually due to unreliable documentation of BCx source. They reported variation in their institutions' approach to diagnose catheter-related BSIs (eg, 2 sites performed cultures of catheter tips, and 1 site performed time to positivity) as well as increased engagement of nurses in discussing opportunities to draw peripheral BCx when central-line BCx were ordered (Q8, Table 3).

While 65.6% of survey respondents reported familiarity with strategies to prevent BCx contamination (BCC), most were unaware of the recommended BCC threshold in the United States (65.7% were unsure, and 11% selected a threshold other than 3% or 1%). Interviewees reported BCx were usually obtained by either phlebotomists or nurses, depending on patient location, and most hospitals provided collector-specific feedback regarding BCC

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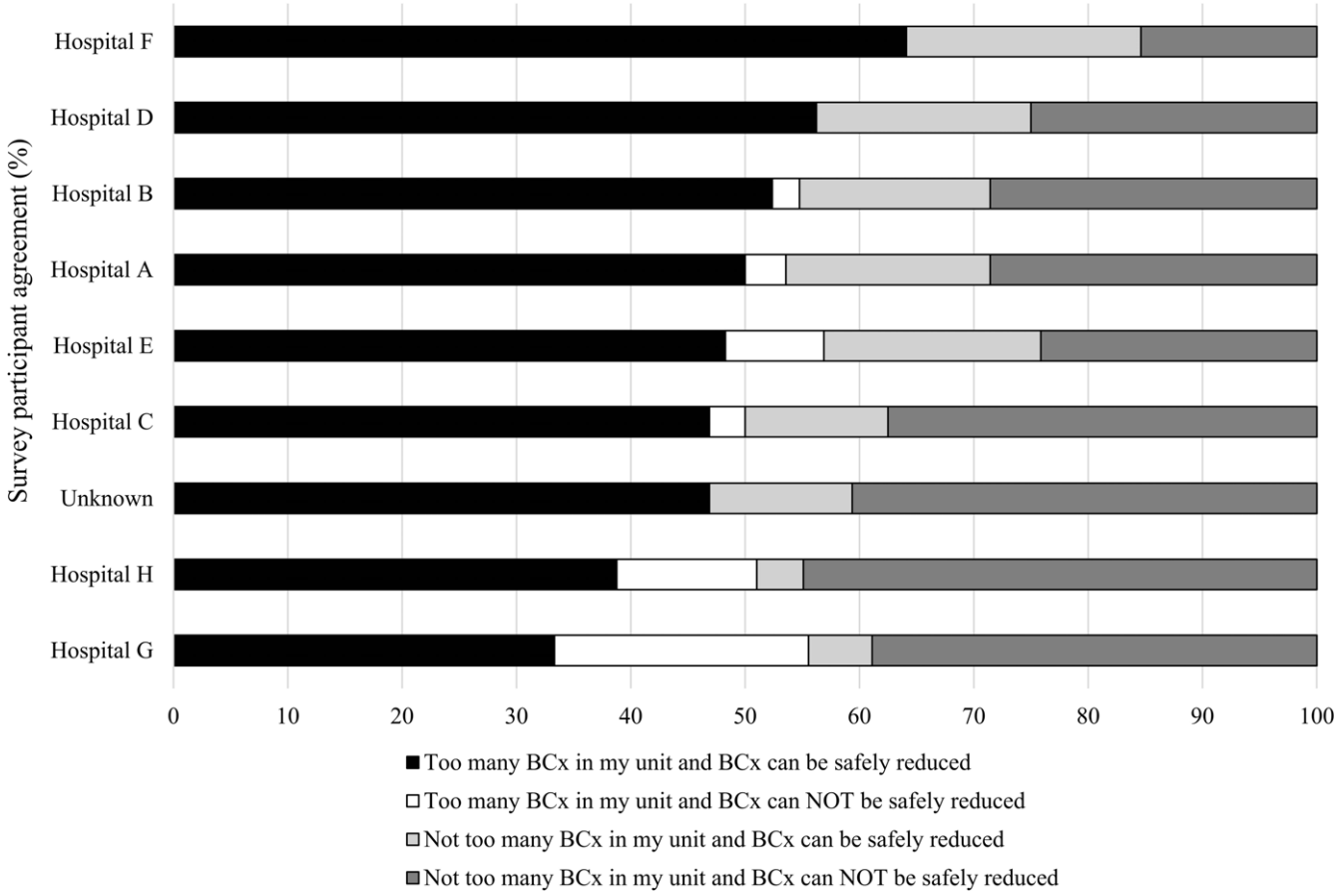

Figure 1. Participants' perceptions regarding blood culture (BCx) use and safety of reducing BCx use in their units by participating hospitals (n = 314 survey respondents).

results with re-training for repeat BCC. Interviewees reported a range of interventions to reduce BCC such as dedicated kits and blood diversion devices, although limited compliance with new protocols often compromised the sustainability of interventions.

Perceived barriers and strategies to improving blood culture utilization

Barriers to reducing unnecessary BCx cited most frequently by survey respondents included concern for missing an infection (82.9%), lack of guidelines for when BCx are indicated (55.4%), and not receiving feedback on BCx utilization (51.2%). Creation of an electronic BCx algorithm in the EMR was perceived as the potentially most helpful strategy to improve BCx indications (selected by 60.6% of survey respondents), followed by integration of a BCx algorithm in institutional treatment guidelines (57.1%), and a bacteremia risk calculator based on patient data (55.1%) (Suppl. Table 4).

Interviewees reported frequent trainee turnover as a major challenge to sustainable changes in BCx practices (Q9, Table 3). Although they viewed a BCx algorithm very positively, they had concerns about its use at the point of care as trainees prefer clinical-decision support (CDS) tools in the EMR and most QI teams reported building CDS tools in the EMR can take a long time (Q10 and Q11, Table 3). Although most hospitals had prior experience with diagnostic stewardship initiatives (most commonly around urine cultures or *Clostridioides difficile* testing), interviewees found BCx stewardship to potentially be more challenging due to competing priorities such as the need to quickly obtain BCx to meet the Centers for Medicare & Medicaid Services SEP-1 core measure quality metric (Q13 and Q14, Table 3) and lack of incentives to avoid potential harm from unnecessary test utilization. They also viewed a multicenter QI intervention as an important nudge to implement a BCx stewardship program at their institutions. The primary reasons to participate in a BCx stewardship multicenter collaborative were the impact on patients (eg, avoiding adverse events associated with BCC) (Q15, Table 3), the potential to decrease central-line-associated BSI (CLABSI) (Q16, Table 3), and the need to protocolize BCx ordering (Q17, Table 3) and to reduce unnecessary nursing workload.

Discussion

Although studies have identified a need to improve when BCx are ordered and how they are collected,[1,2,15] little is known about HCWs' knowledge, perceptions, and practices related to BCx ordering and collection for hospitalized adults. We surveyed 314 and interviewed 36 HCWs working in adult ICUs or adult wards from 8 large academic hospitals from 4 regions in the United States. We found many HCWs did not understand when BCx are useful or what are the collection parameters that improve BCx sensitivity. Furthermore, there was a discrepancy in how HCWs perceived opportunities to improve BCx indications and whether BCx were overused. A summary of knowledge and practice gaps and barriers to improving BCx use is summarized in Table 5.

Diagnostic stewardship aims to optimize clinical management and healthcare resources.[16] The increasing rates of healthcare

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Table 2. Healthcare workers' perceptions regarding blood culture indications and practices. The table shows the proportion of respondents who strongly agreed/agreed with the statement stratified by unit (n = 314)

Survey statement	Overall N=314 (%)	ICU N=115 (%)	Non-ICU N=199 (%)
Blood culture decision-making process			
The decision-making process for ordering blood cultures in my unit is clear to me	125 (39.8)	48 (41.7)	77 (38.7)
There are too many blood cultures ordered in my unit	164 (52.2)	69 (60.0)	95 (47.7)
The number of blood cultures ordered in my unit can be reduced safely	205 (65.3)	79 (68.7)	126 (63.3)
Clinicians have a low threshold to order blood cultures if the patient develops a new isolated fever	265 (84.4)	97 (84.3)	168 (84.4)
Clinicians have a low threshold to order blood cultures if the patient develops new isolated leukocytosis	87 (27.7)	48 (41.7)	39 (19.6)
Clinicians usually evaluate the patient in person before ordering blood cultures	67 (21.3)	27 (23.5)	40 (20.1)
Clinicians usually review the electronic health record before ordering blood cultures	235 (74.8)	72 (62.6)	163 (81.9)
Temperature threshold used to order blood cultures			
• Temperature greater than 100.4°F (38.0°C)	135 (45.4)	43 (37.4)	92 (50.5)
• Temperature greater than 101.0°F (38.3°C)	89 (30.0)	42 (36.5)	47 (25.8)
• An increase in temperature of greater than 2°F (1.1°C) over baseline temperature	8 (2.7)	2 (1.7)	6 (3.3)
• Other	65 (21.9)	28 (24.3)	37 (20.3)
Blood culture indications			
All patients with a new fever should get blood cultures	87 (27.7)	32 (27.8)	55 (27.6)
All *Staphylococcus aureus* bacteremias need to have repeat blood cultures to document resolution of bacteremia	251 (79.9)	84 (73.0)	167 (83.9)
All *Streptococcus pyogenes* (Group A strep) bacteremias need to have repeat blood cultures to document resolution of bacteremia	184 (58.6)	65 (56.5)	119 (59.8)
All *Escherichia coli* bacteremias need to have repeat blood cultures to document resolution of bacteremia	112 (35.7)	39 (33.9)	73 (36.7)
All Candidemia need to have repeat blood cultures to document the resolution of fungemia	240 (76.4)	85 (73.9)	155 (77.9)
Blood culture accuracy			
Obtaining 2 sets of blood cultures will significantly increase the likelihood of bacteremia detection	186 (59.2)	67 (58.3)	119 (59.8)
Central-line blood cultures are more likely to yield false positive results than peripheral blood cultures	173 (55.1)	77 (66.9)	96 (48.2)
I am familiar with strategies to prevent blood culture contamination	206 (65.6)	98 (85.2)	108 (54.3)
I have received adequate training on how to draw blood cultures	101 (32.2)	60 (52.2)	41 (20.6)
I have received training on when to draw blood cultures	154 (49.0)	63 (54.8)	91 (45.7)

products and drug shortages in recent years related to climate change highlight the importance of stewardship initiatives.

Implementation of evidence-based algorithms to guide clinicians' decisions to order BCx, reduced BCx utilization by 20%–40% without increased mortality or readmissions in both adult and pediatric patients in US centers;[5,17–19] however, large-scale multicenter QI projects to improve BCx utilization in adult patients have not been conducted. Understanding HCWs' knowledge and practices about BCx can inform the development of effective interventions. In this survey, participants showed a strong perception that BCx could be safely reduced although overuse of BCx was felt to be less of a problem, despite most participants believing BCx are ordered reflexively for fever evaluation, a common driver of BCx orders. The perception of BCx overuse ranged from 39% to 64% among participating institutions, which is lower than the 75% estimate reported by hospitals in Switzerland.[20] This may be due to variation in practices as BCx inappropriateness based on indication can vary significantly between hospitals.[5,6] Factors that may be contributing to this discrepancy in how HCWs perceive BCx use in their units and HCWs' approach to fever may be multifactorial and related to their uncertainty about appropriate indications for BCx, unawareness of local BCx utilization rates, or response bias as most survey respondents were ordering providers. We also found knowledge gaps regarding parameters that influence BCx sensitivity (eg, adequate blood volume per bottle, number of sets, factors increasing blood culture contamination), even among those who are only involved with the collection of BCx. A major limitation to improving HCW knowledge around these issues according to interviewees was frequent staff turnover. Lack of professional society guidance on BCx indications likely contributes to HCW's knowledge gap in BCx indications. Incorporating education in pre-graduate training may help overcome this challenge. Our findings also emphasize opportunities to enhance multidisciplinary discussions about BCx, including better integration of nurses and the microbiology laboratory in BCx stewardship initiatives.[21]

Although several studies have shown a poor correlation between isolated fever or leukocytosis and bacteremia,[3] participants highlighted more data on special populations such as immunocompromised patients were needed to reduce unnecessary BCx in these populations. Participants identified guidance built in the EMR as the most potentially useful strategy to help guide BCx ordering decisions, yet they also acknowledged oversensitive EMR alerts for sepsis were perceived drivers of unnecessary BCx use as

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Table 3. Quotes from interviewed healthcare workers regarding perceived practices related to blood culture (BCx) ordering and collection

Perceptions about current BCx ordering practices	
Q1 (Attending physician)	*"Yeah, I don't think there's a good—from what I see anyway, I don't think there's a great structure in when they do it, it seems like it really is the primary team dependent on doing it. So, there is from what I can see pretty fair variability in when it's ordered, which to me is probably an area that I think we could improve upon. Basically, anyone who meets specific criteria like a white count tends to get them . . . But I think it really is provider dependent from what I see."*
Q2 (Attending physician)	*"There's a lot of confusion around collecting primary blood cultures versus when we should collect them for clearance of bacteremia. And it's really not standardized in how the decision-making occurs, it is typically by, I would say, a senior resident or their intern in the morning. The discussion will come up on rounds, but often at that point, the blood cultures have already been collected."*
Perceptions about current BCx ordering decision-making	
Q3 (Attending physician)	*"It's normally a decision that's made by trainees and how thoughtful that decision is, it really depends on the level of training of the trainee, like their PGY level. Not infrequently we come in and we realize the patient has had like three blood cultures in 36 hours just for recurrent fevers and without really thinking about "Is this blood culture really needed?" if we have one pending. But by the time the attending—rarely is the attending involved in that decision."*
Q4 (Attending physician)	*"I think that there's definitely a variation, I think, in terms of training level, like interns versus seniors, in terms of what that threshold is. So, some people might want to see a persistent fever, some people see one slight spike and immediately order blood cultures. So, I do think there's a good amount of variation."*
Q5 (Attending physician)	*"I think that we're increasingly seeing requests, especially from our nursing partners on the units, where in our medical ICU specifically, our nurses in our ICU very much want there to be a metric for providers to be ordering blood cultures at a reduced frequency than what they're currently doing."*
Q6 (Attending physician)	*"I think some nurses might prompt a trainee "Hey, we have fevers and hyp0tension. Do you want me to culture the patient?" That's variable. That's not something that all nurses do, but maybe some senior nurses or some nurses who have more experience with oncological care or neutropenic patients might prompt the trainee to consider blood cultures, but that's variable."*
Perceptions about BCx collection practices	
Q7 (Nurse)	*"I think a lot of times we're getting blood cultures ordered inappropriately. And/or they don't necessarily suspect that it's a line infection, but they still want us to draw blood cultures regardless, and just try and figure out where a possible infection is coming from. So they're kind of pan culturing and doing sometimes inappropriate things. And so we get a lot of line cultures a lot of times just to try and figure out what's going on with the patient."*
Q8 (Attending physician)	*"They [nurses] become involved once the order is placed. A lot of times it'll be the nurse that may question it of do you actually want the culture drawn from the line? Or can we get these peripherally? So sometimes it's the nursing staff really trying to drive it back to the peripheral and not trying to draw off the line."*
Perceived barriers and strategies to improving BCx utilization	
Q9 (Attending physician)	*"We have a large institution with many diverse teams and lots of people who impact patient care. And so I think that's one of the challenges is how do you get this out? And, particularly, how do you get this out to clinicians? I think for nursing we have, I think, a pretty good structure for providing education. I feel confident that our nurses will understand this and know about it. I am less confident in our ability to educate physicians just because it's such a large and diverse group."*
Q10 (Medical resident)	*"I think having an algorithm to help kind of guide decision making is going to be really, really helpful, and also kind of help in terms of our coordinated care with nursing staff, because we'll have an algorithm that all of us can kind of follow and look at together. So, I'm really excited about it, and I think also, part of the project is to decrease kind of unnecessary utilization of antibiotics. I just had a patient last night, actually, that was started on an antibiotic for something that I think was probably a contaminant for a blood culture that didn't need to be drawn."*
Q11 (Attending physician)	*"I think something that may facilitate the use [of a BCx algorithm] is if we can build some of this into our electronic medical record with some advice. That would be fantastic. That's something that is much more challenging and time-consuming and not a tool that we control. . . . if we can even build just a little bit of decision support into it I think it would help to influence providers."*
Q12 (Microbiologist)	*"We do have a policy. I sit on the sepsis committee, I'm the chair of diagnostics subcommittee, and we actually have a meeting next week, because as a system, not every hospital has a collection policy. And even the physicians that are on the sepsis committee aren't aware of the policy. So I'm not sure how well everybody knows that. And I think we're going to start sort of getting some of that communication out. I can kind of just give you a little story that happened a couple years ago, and it's around pediatrics."*
Q13 (Attending physician)	*"They're concerned that an itchy nose could be the beginning of sepsis, and they wouldn't be showing it. Sorry, that's a little too far, but you know what I mean?"*
Q14 (Attending physician)	*"I think one of the things that is ongoing in a way within our inpatient units, as well as within our ER, just the sepsis bundles and the Sep-1 guidelines and things like that. And so certainly a lot of those BPAs that continue to fire the alerts on the computer, that continue to fire even for inpatients. It is not just in our ER. And so I think that is something that may potentially have conflicts, if you're getting a giant red alert that everyone has sepsis."*
Q15 (Phlebotomist)	*"The reason why I wanted to be involved was to see how our contamination rates for phlebotomy, how it impacts with other institutions or whatever other organizations that you work with and how we compare with those."*
Q16 (Attending physician)	*"They [unit] were very interested because they've had some recent CLABSI events that were actually coag-negative staph, and the person shouldn't have probably had blood cultures drawn at all, in reviewing the whole clinical scenario. So, it's not really sure that it was a true positive, and so I think they were especially interested in the blood culture stewardship idea."*

(*Continued*)

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Table 3. (*Continued*)

Perceptions about current BCx ordering practices	
Q17 (Attending physician)	*"I think healthcare personnel collectively probably don't understand the probability of a true bloodstream infection associated with whatever event or clinical change they're evaluating in the moment. I think we do a poor job of that. And so I thought this project was interesting in a way that it provides a little bit of a construct and formal way to think about it. I remember as a house staff member, that any fever kind of got pan-cultured, including blood cultures, and I never stopped to think about the utility of that, and whether there was actually going to be some potential harms, if those were negative. I was afraid of missing something. And so I think this algorithm provides a way that—it provides some guidance for healthcare providers about really critically evaluating what would be the true probability of having a blood stream infection related with the change that they're seeing in a patient. And so I found this an interesting thing to participate in. And I think there's a lot of room for improvement of diagnostic stewardship in general, but certainly with blood cultures and how I utilize them."*

Q, quote.

Table 4. Knowledge and practices related to blood culture (BCx) collection practices, stratified by BCx collection role (n = 279)

What is the recommended volume of blood per BCx bottle for adult patients?	**Overall N = 279 (%)**	**Collect only N = 47 (%)**	**Collect and order/order only N = 232 (%)**
• 1–5 mL	4 (1.3)	–	4 (1.7)
• 5–8 mL	36 (12.9)	5 (10.6)	31 (13.4)
• 8–10 mL	90 (32.3)	36 (76.6)	54 (23.3)
• >10 mL	42 (15.0)	3 (6.4)	39 (16.8)
• Unsure	107 (38.3)	3 (6.4)	104 (44.8)
How often are you able to collect the correct volume?			
• Always	6 (2.1)	5 (10.6)	1 (0.4)
• Often	71 (25.4)	15 (39.1)	17 (7.3)
• Sometimes	32 (11.5)	25 (53.2)	46 (19.8)
• Rarely	6 (2.1)	2 (4.3)	4 (1.7)
• Never	–	–	–
• I don't collect BCx	165 (59.1)	–	164 (70.7)
What is the national recommended BCx contamination threshold in the United States?			
• ≤1%	34 (12.2)	7 (14.9)	27 (11.6)
• ≤3%	29 (10.4)	4 (8.5)	25 (10.8)
• ≤5%	22 (7.4)	3 (6.4)	19 (8.2)
• ≤10%	11 (3.7)	3 (6.4)	7 (3.0)
• Unsure	195 (65.7)	30 (63.8)	154 (66.4)
How often are BCx drawn from the following sites in patients in your unit (assuming all sites are present)?			
Peripheral venipuncture			
• Most of the time/often	266 (94.3)	42 (89.4)	169 (96.5)
• Sometimes	6 (2.1)	1 (2.1)	5 (2.2)
• Rarely/never	7 (2.3)	4 (8.5)	3 (0.4)
Central venous catheter			
• Most of the time/often	53 (18.9)	6 (12.7)	47 (20.2)
• Sometimes	113 (40.5)	15 (31.9)	98 (42.4)
• Rarely/never	26 (9.3)	73 (63.5)	87 (37.5)
Dialysis catheter			
• Most of the time/often	16 (18.5)	1 (2.1)	15 (6.5)
• Sometimes	56 (20.1)	5 (10.6)	51 (21.9)
• Rarely/never	207 (74.2)	41 (87.9)	166 (71.5)

(*Continued*)

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Table 4. (*Continued*)

What is the recommended volume of blood per BCx bottle for adult patients?	Overall N = 279 (%)	Collect only N = 47 (%)	Collect and order/order only N = 232 (%)
Arterial line			
• Most of the time/often	6 (2.1)	1 (2.1)	5 (2.1)
• Sometimes	48 (17.2)	10 (21.3)	38 (16.4)
• Rarely/never	225 (80.6)	36 (76.6)	189 (67.7)
I have received adequate training on how to draw blood cultures			
• Strongly agree/agree	87 (31.2)	39 (83.0)	48 (20.7)
• Neutral	43 (15.4)	5 (10.6)	38 (16.4)
• Strongly disagree/disagree	149 (53.4)	3 (6.4)	146 (62.9)
I have received training on when to draw blood cultures			
• Strongly agree/agree	139 (49.8)	29 (61.7)	110 (47.4)
• Neutral	52 (18.6)	7 (14.9)	45 (19.4)
• Strongly disagree/disagree	88 (31.5)	11 (23.4)	77 (33.2)

Table 5. Summary of knowledge gaps, variability in practices, and commonly perceived barriers identified through the survey and semi-structured interviews conducted among healthcare workers (HCWs)

Knowledge gaps
• Misperceptions about common drivers of blood culture orders (eg, most people did not think isolated leukocytosis triggered blood cultures)
• Perception that blood cultures are not overused in their units
• Limited HCW understanding of the predictive value of fever for bacteremia
• Limited HCW awareness of blood culture quality indicators (eg, blood culture contamination rates) or national thresholds
• Limited HCW knowledge on the correct volume of blood per bottle (even among nurses and phlebotomists), or adequate number of sets for optimal bacteremia detection
• Misperceptions about the risk of blood culture contamination with central lines
Variability in practices
• Lack of standardization of temperature thresholds for fever workup, especially for special populations
• Limited training opportunities on best collection practices
• Inability to sustain interventions aiming to reduce blood culture contamination
• Variation in institutions' approach to diagnose catheter-related bloodstream infections
• Variation in institutions' approach to handling central-line blood draws
Barriers to improving blood culture utilization
• Concern for missing an infection
• Lack of guidelines
• Limited HCW awareness of blood culture utilization rates
• Limited awareness of the potential harms associated with overuse of blood cultures

many patients meeting sepsis criteria have noninfectious conditions, up to 75% based on published literature.[22] Another favored potential strategy was the development of a bacteremia risk score. Notably, bacteremia prediction tools have been developed for use in the emergency department setting but have not been widely implemented.[2] A recent study from Japan compared attending physicians' gestalt with 2 existing bacteremia prediction tools in adults hospitalized with a suspected infection.[23] Although physicians overestimated the probability of bacteremia compared to the prediction tools, they were less likely to miss a bacteremia case (22% of patients were identified as low risk of bacteremia by physician gestalt vs 53% by the Shapiro prediction tool with 4% of patients identified as low risk of bacteremia by physician gestalt vs 6% by the prediction tool developing bacteremia). Hence, while clinical-based algorithms are helpful, risk-score tools might be more efficient in reducing unnecessary BCx. More research is needed to define the utility of scoring tools based on users' years of clinical experience and in evaluating hospital-onset events.

We found variations in how institutions approached the diagnosis of CLABSI, central-line blood draws, and prevention of BCC. A previous study evaluating BCx practices among patients with central lines at a university hospital in Iowa showed central-line BCx were infrequent, and those who received them were more likely to have positive BCx for skin contaminants than those who did not.[24] These findings emphasize the need to better define the role of central-line BCx and their potential implications in patient care and hospital metrics in future updates to guidelines.

There are limitations to this study. Participating institutions were academic centers which may limit generalizability to non-teaching settings; however, they were located across the 4 US regions providing diversity to the sample. We were unable to calculate a response rate due to the distribution method (a link to the survey was both shared via email to relevant stakeholders and posted as QR codes in common areas in units of interest), which may have also led to selection bias. Additionally, 10% of respondents did not indicate their institution; however, based on the 282 respondents for which we had institution affiliation, 5 of

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the 8 participating institutions contributed a minimum of 30 responses per site. The target audience for this survey was unit staff in ICUs and wards, phlebotomists and HCWs from other areas with high BCx utilization such as emergency medicine and oncology were under and not represented, respectively. Finally, the study preceded the recent national BCx bottle shortage, which may have changed HCWs' perceptions and knowledge about BCx.

In summary, using mixed methods, we evaluated knowledge, perceptions, and practices related to BCx ordering and collection among HCWs of adult ICUs and wards from 8 academic centers in the US. We identified several opportunities for improvement including increasing HCWs' knowledge of BCx indications and collection practices, improving access to BCx quality indicators data such as BCC, and standardization of indications through CDS tools.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ice.2024.208.

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References

1. 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:e00009–19.
2. Fabre V, Carroll KC, Cosgrove SE. Blood Culture Utilization in the Hospital Setting: a Call for Diagnostic Stewardship. *J Clin Microbiol* 2022;60: e0100521.
3. Fabre V, Sharara SL, Salinas AB, Carroll KC, Desai S, Cosgrove SE. Does this patient need blood cultures? a scoping review of indications for blood cultures in adult nonneutropenic inpatients. *Clin Infect Dis* 2020;71:1339–1347.
4. Woods-Hill CZ, Koontz DW, King AF, *et al.* Practices, perceptions, and attitudes in the evaluation of critically Ill children for bacteremia: a national survey. *Pediatr Crit Care Med* 2020;21:e23–e9.
5. Fabre V, Klein E, Salinas AB, *et al.* A diagnostic stewardship intervention to improve blood culture use among adult nonneutropenic inpatients: the DISTRIBUTE study. *J Clin Microbiol* 2020;58:e01053–20.
6. Siev A, Levy E, Chen JT, *et al.* Assessing a standardized decision-making algorithm for blood culture collection in the intensive care unit. *J Crit Care* 2023;75:154255.
7. Temkin E, Biran D, Braun T, Schwartz D, Carmeli Y. Analysis of blood culture collection and laboratory processing practices in Israel. *JAMA Netw Open* 2022;5:e2238309.
8. Fabre V, Milstone AM, Keller SC, Carroll KC, Cosgrove SE. Prescribers' knowledge, attitudes and perceptions about blood culturing practices for adult hospitalized patients: a call for action. *Infect Control Hosp Epidemiol* 2018;39:1394–1396.
9. Xie A, Woods-Hill CZ, King AF, *et al.* Work system assessment to facilitate the dissemination of a quality improvement program for optimizing blood culture use: a case study using a human factors engineering approach. *J Pediatric Infect Dis Soc* 2019;8:39–45.
10. Foong KS, Munigala S, Kern-Allely S, Warren DK. Blood culture utilization practices among febrile and/or hypothermic inpatients. *BMC Infect Dis* 2022;22:779.
11. Howard-Anderson J, Schwab KE, Chang S, Wilhalme H, Graber CJ, Quinn R. Internal medicine residents' evaluation of fevers overnight. *Diagnosis (Berl)* 2019;6:157–163.
12. Graneheim UH, Lundman B. Qualitative content analysis in nursing research: concepts, procedures and measures to achieve trustworthiness. *Nurse Educ Today* 2004;24:105–112.
13. Mays N, Pope C. Qualitative research in health care. Assessing quality in qualitative research. *BMJ* 2000;320:50–52.
14. Devers KJ. How will we know "good" qualitative research when we see it? Beginning the dialogue in health services research. *Health Serv Res* 1999;34:1153–1188.
15. Warren BG, Yarrington ME, Polage CR, Anderson DJ, Moehring RW. Evaluation of hospital blood culture utilization rates to identify opportunities for diagnostic stewardship. *Infect Control Hosp Epidemiol* 2023;44:200–205.
16. Fabre V, Davis A, Diekema DJ, *et al.* Principles of diagnostic stewardship: a practical guide from the Society for Healthcare Epidemiology of America diagnostic stewardship task force. *Infect Control Hosp Epidemiol* 2023;44:178–185.
17. Wang MC, Zhou KJ, Shay SL, *et al.* The impact of a blood-culture diagnostic stewardship intervention on utilization rates and antimicrobial stewardship. *Infect Control Hosp Epidemiol* 2024;45:670–673.
18. Seidelman JL, Moehring R, Gettler E, *et al.* Implementation of a diagnostic stewardship intervention to improve blood-culture utilization in 2 surgical ICUs: Time for a blood-culture change. *Infect Control Hosp Epidemiol* 2024;45:452–458.
19. Woods-Hill CZ, Colantuoni EA, Koontz DW, *et al.* Association of diagnostic stewardship for blood cultures in critically Ill children with culture rates, antibiotic use, and patient outcomes: results of the Bright STAR collaborative. *JAMA Pediatr* 2022;176:690–698.
20. Drager S, Giehl C, Sogaard KK, *et al.* Do we need blood culture stewardship programs? A quality control study and survey to assess the appropriateness of blood culture collection and the knowledge and attitudes among physicians in Swiss hospitals. *Eur J Intern Med* 2022;103:50–56.
21. Monsees EA, Tamma PD, Cosgrove SE, Miller MA, Fabre V. Integrating bedside nurses into antibiotic stewardship: a practical approach. *Infect Control Hosp Epidemiol* 2019;40:579–584.
22. Rhee C, Chiotos K, Cosgrove SE, *et al.* Infectious Diseases Society of America position paper: recommended revisions to the national severe sepsis and septic shock early management bundle (SEP-1) sepsis quality measure. *Clin Infect Dis* 2021;72:541–552.
23. Fujii K, Takada T, Kamitani T, *et al.* Diagnostic performance of physician gestalt for bacteremia in patients in the process of being admitted with suspected infection. *Clin Infect Dis* 2023;76:1074–1079.
24. Kovoor E, Kobayashi T, Sheeler LL, *et al.* Blood culture practices in patients with a central line at an academic medical center-Iowa, 2020. *Antimicrob Steward Healthc Epidemiol* 2022;2:e64.