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Major article

Multidisciplinary team review of best practices for collection and handling of blood cultures to determine effective interventions for increasing the yield of true-positive bacteremias, reducing contamination, and eliminating false-positive central line–associated bloodstream infections

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Key Words:
Blood culture
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Venipuncture

Background: A literature search was conducted using keywords for articles published in English from January 1990 to March 2015. Using criteria related to blood culture collection and handling, the search yielded 101 articles. References used also included Microbiology Laboratory standards, guidelines, and textbook information.

Results: The literature identified diverse and complex issues surrounding blood culture practices, including the impact of false-positive results, laboratory definition of contamination, effect on central line–associated bloodstream infection (CLABSI) reporting, indications for collecting blood cultures, drawing from venipuncture sites versus intravascular catheters, selection of antiseptics, use of needleless connectors, inoculation of blood culture bottles, and optimizing program management in emergency departments, education, and implementation of bundled practice initiatives.

Conclusion: Hospitals should optimize best practice in the collection, handling, and management of blood culture specimens, an often overlooked but essential component in providing optimal care of patients in all settings and populations, reducing financial burdens, and increasing the accuracy of reportable CLABSI. Although universal concepts exist in blood culture practices, some issues require further research to determine benefit. Institutions undertaking a review of their blood culture programs

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are encouraged to use a checklist that addresses elements that encompass the research contained in this review.

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Optimizing blood culture (BC) practices has 3 important benefits. Foremost, BCs are a critical diagnostic tool for the clinical determination of bacteremia, severe sepsis, and systemic inflammatory response syndrome caused by infection.[1] Therefore, maximizing the identification of true pathogens may, in some events, be life saving. The second benefit is the avoidance of contamination of the sample. Although identification of a true pathogen is the prime objective, errors in collection technique may result in the inadvertent introduction of bacteria into the blood sample, potentially leading to the detrimental care of the patient. The third benefit is to increase the surveillance accuracy of central line–associated bloodstream infections (CLABSIs) events. Improper BC collection impacts the interpretation of epidemiologic CLABSI events,[2] conditions that are mandated by law in the United States to be reported to federal and select state agencies.[3,4]

BACKGROUND

This article reports the findings of a project aimed at identifying evidence-based best practices in the preanalytical collection and handling phase[5] and program management component of BC processing as spearheaded by members of the Blood Culture Task Force of Stony Brook University Hospital. The task force was initially formed as a subgroup of the hospital-wide effort to reduce CLABSI, later expanded to include quality improvement in the identification of true pathogens and decreasing contaminant events. The task force was comprised of infection preventionists (IPs), advanced practice nurses and nurse educators representing all services, dialysis, and plasmapheresis personnel, the microbiology laboratory director, the laboratory quality systems manager, and the phlebotomy supervisor.

Stony Brook University Hospital is a 603-bed tertiary-care hospital located on Long Island, New York, with a large emergency department (ED) (93,000 visits per year), level 1 trauma, neurosurgery, medical and surgical oncology, hematopoietic stem cell transplantation, burn, cardiothoracic surgery, cardiac, medicine, and pediatric units, and a level 3 neonatal intensive care unit (ICU). Total admissions for calendar year 2014 were 37,072. Approximately 34,400 BCs are drawn per year by phlebotomists or nurses. The average hospital-wide blood culture contamination (BCC) rate is 1.74 since 2010.

REASONS TO OPTIMIZE BC COLLECTION AND HANDLING

Enhancing the recovery of true pathogens (ie, avoidance of false-negative BCs)

The identification of true pathogens and subsequent antibiotic sensitivities provide the clinician with vital information for providing optimal treatment. The need to properly obtain blood for microbiologic culture takes on even greater significance when institutions consider that sepsis is currently the most costly hospital condition ($20.29 billion) among inpatients,[6] has accounted for a 32% increase in hospitalizations in recent years,[7] and is the leading cause of admission to a hospital for adults aged 45-84 years after an ED visit.[8] Millions of other patients whose initial diagnosis is not primarily sepsis are considered for BC testing because of clinical findings of fever, increase in white blood cell counts, and other trigger conditions.

Failure to identify a pathogen causing true bacteremia is a false-negative event. Potential causes for false-negative blood cultures include inadequate volume of blood or insufficient number of sets collected, collection of samples after antibiotic therapy has started, and infections caused by organisms that are not readily recovered using routine BC methods. The first 3 causes are subsequently discussed in the discussion on BC bottles. Current automated BC systems are reliable for detecting traditional pathogens, such as staphylococci and enteric gram-negative rods, and fastidious organisms such as *Aggregatibacter spp., Cardiobacterium hominis, Eikenella corrodens*, and *Kingella spp*.

Reducing BC contamination (ie, avoidance of false-positive BCs)

BCC has been attributed to transfer of organisms from the patient's skin, immediate environment of the patient, supplies used to obtain or transfer the blood sample, or hands of the health care worker performing the procedure. BCC is defined by The College of American Pathologists (CAP).[9] The CAP defines a BC set as typically consisting of a blood sample collected from a single procedure (eg, one venepuncture) and then inoculated into one aerobic and one anaerobic bottle. BCs are considered to be contaminated if $\geq$1 of the following organisms are found in only 1 bottle in a series of BC sets (eg, 1 of 1, 1 of 2, 1 of 3 sets): coagulase-negative staphylococci (CoNS), *Micrococcus*, α-hemolytic viridans group streptococci, *Propionibacterium acnes*, *Corynebacterium* sp (diptheroids), and *Bacillus* sp. The contamination rate (%) is calculated as follows:

$$\frac{\text{Number of contaminated blood cultures}}{\text{Total number of routine blood cultures accessioned}} \times 100$$

The seminal study conducted by the CAP of 497,134 BC specimens obtained from 640 hospitals in the United States reported a mean contamination rate of 2.5%, with institutions ranging from <1% to >5%.[10] A 5-year study examining BCC in institutions participating in the CAP Q-Tracks program reported that among adult patients in 326 institutions, the mean contamination rate was 2.92%, whereas the neonatal rate was 2.08% in 254 participating hospitals.[11] Based on the Q-Tracks data, the Clinical and Laboratory Standards Institute (CLSI) recommends that "…laboratories should validate that their process is effective in minimizing contamination rates to an acceptable range, typically $\leq$3.0%."[12] This rate is currently considered the standard benchmark for BCC by the Clinical Microbiology Laboratories. Reported rates of BCC have ranged from 0.6% to >6%.[13]

Contaminated or false-positive blood cultures (FPBCs) are a common problem in health care institutions often leading to substantial financial and clinical consequences. Studies conducted since the early 1990s have estimated the cost of a contaminated sample to be from $4,500-$10,078.[13-16] Data from trials conducted at 2 hospitals that reported annualized outcomes underscore the potential national enormity of the detrimental impact of FPBCs: 1,372-2,200 extra hospital days with additional costs of approximately $1.8-$1.9 million.[15,17] Bates and colleagues identified increases of 80% for microbiology charges, 39% in intravenous antibiotic charges, and 14% in the length of stay in their multivariate analysis of 94 false-positive episodes among an adult hospital

population.[14] Similar findings of increased resource expenditures have been reported in studies of contaminated BCs in pediatric populations including readmission rates of 14%[18] and 26%.[19] Increased length of stay caused by contaminated BCs has been reported to range from 1-5.4 days.[15,16]

The clinical impact of contaminated BCs has also been described.[20] Studies indicate that 41%-50% of patients with FPBCs are likely to be treated with antimicrobials compared with those with true-positive results,[21-23] Exposure to inappropriate therapy with antibiotics increases the risk of developing complications, such as allergic reactions, development of antimicrobial-resistant bacterial strains, including carbapenem-resistant *Enterobacteraceae*,[24] and increased risk for *Clostridium difficile* infection.[25]

Positive BC results pose a vexing question for the clinician: is the result indicative of a clinically significant infection that requires treatment or is it an insignificant finding? Two large studies conducted a decade apart have examined the clinical significance of organisms that are commonly isolated from positive BCs in adults.[21,26] Episodes of bacteremia or fungemia were categorized as true bloodstream infection (BSI), contamination, or of uncertain clinical significance based on a review of clinical manifestations, other laboratory data, and imaging. Both studies provided similar findings. Organisms that were clinically significant in >90% of cases included *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Escherichia coli*, *Klebsiella pneumoniae* and other *Enterobacteriaceae*, *Pseudomonas aeruginosa*, *Bacteroides* spp, and *Candida* spp. In contrast, *Bacillus* spp, *Corynebacterium* spp, and *Propionibacterium* spp were contaminants in >90% of the findings.

Other groups of organisms were more difficult to categorize. For example, *Enterococcus* spp, *Acinetobacter* spp, and other nonfermenting gram-negative rods were significant in 60%-70% of cases, but 25%-30% were of uncertain significance. Viridans group streptococci were only significant in a third of cases. Interpretation of CoNS represents a special challenge. Although only 10%-15% of isolates are clinically significant, this is a relatively large number of cases because CoNS were 3-fold more common than any other organism.[26]

Reducing false-positive CLABSI

The National Healthcare Safety Network (NHSN) provides the primary surveillance definition for a BSI event in hospitalized patients that have a central venous access device (CVAD) for >2 calendar days on the date of the event.[2] For a case to be categorized as a laboratory-confirmed BSI 1, a recognized pathogen must be identified in ≥1 BC and the organism must not be related to an infection at another site. The document defines a recognized pathogen as an organism not included in the NHSN common commensal list.[27] Recognized pathogens, such as *S aureus* and *Enterococcus* spp, are often considered pathogenic by physicians when initially identified in BC samples. However, this determination has not been found to be always accurate.[28,29] In the aforementioned study by Weinstein et al, these 2 organisms were also found to be contaminants in 6.4% and 16.1% of events, respectively.[26] The NHSN does not require an IP to distinguish the recognized pathogen as a contaminant or a true pathogen; however, for epidemiologic purposes, this determination may be crucial. If no Centers for Disease Control and Prevention (CDC)–defined primary site of infection is identified as having been the source for seeding of the blood, as most often occurs when the organism is a contaminant, then the facility must conclude that the finding is a CLABSI, albeit a false-positive one, and report the event.

Similar misclassifications may occur under other NHSN CLABSI definitions. Events categorized as laboratory-confirmed BSI 2 or 3 require that the patient be identified with signs and symptoms (as denoted in the definitions) and positive laboratory results not related to an infection at another site. However, the organisms must be the same commensal organisms[27] cultured from ≥2 BCs drawn on separate occasions defined as blood obtained on the same or consecutive calendar days with 2 separate site preparations. However, the statement may not reflect actual practice. In clinical situations, the patient's venous condition, limited CVAD lumen access, the clinician's workload, or other factors, may restrict ideal BC draws from separate sites or at different times. Not all hospitals document the sites of draw or have the ability to do so in the medical record. Such factors may contribute to BCC and subsequent false-positive CLABSI events. The avoidance of BCC with common commensal organisms is imperative: while CoNS is the most commonly reported organism in NHSN CLABSI events, accounting for 20.5% of all organisms,[30] another study in which infectious disease specialists reviewed the data on 100 BC isolates with CoNS indicated a contamination rate of 85%.[31]

Furthermore, a secondary BSI may also be misidentified as a CLABSI when the true site-specific infection is associated not with the CVAD but with another concurrently indwelling intravascular device, such as an arterial or peripheral catheter.[32,33]

Although there are well-established microbiology laboratory standards for BCC,[9,26] no gold standard exists for determining true infection versus contamination of BCs that would assist IP analysis of potentially reportable events.[14] Such limitation may be a contributory factor in the variability in identifying NHSN reportable CLABSI.[34-36] Freeman et al best state the potential consequences of misclassifying contaminant events as BSIs: "…hospitals may incur financial penalties under CMS regulations if their rate of central line infections appears high…furthermore, nonspecific definitions will result in inflated public reporting of infection rates."[28] Other researchers have suggested the use of innovative algorithms to facilitate in the differentiation of true pathogens from contaminants.[37]

REVIEW OF THE LITERATURE

The evidence presented in this article was generated using a literature search for articles and other publications that addressed best practices in BC collection and handling; occurrence of false-negatives and the effect on the recovery of true pathogens, false-positives, and the effect on CLABSIs; and quality improvement programs. The search was conducted using Medline, PubMed, and Ovid for articles published in English (January 1990-March 2015) using the keywords *blood culture*, *blood culture collection*, *blood culture contamination*, *true pathogen*, *central line-associated bloodstream infection*, *bacteremia*, and *venipuncture*. The initial screening yielded 6,791 articles. The reference lists of the articles identified in the initial screening added an additional 18 articles. After exclusion of articles that did not address the criteria, the number of publications was reduced to 101. Among the included articles were reviews and meta-analyses on BC best practices.[13,38-42] Additional reference materials included microbiology laboratory standards[12,43] and clinical publications and guidelines identified via the National Guideline Clearinghouse[44-49] and textbook chapters[50] culled by expert authors and organizations based in the United States and abroad. The following categories have been addressed in the reviewed literature as elements for an effective BC quality improvement program.

OPTIMAL STRATEGIES IN COLLECTION AND HANDLING

Clinical indications for BCs

BCs should be obtained for specific clinical indications.[47] An in-depth review of the literature by Willems et al indicates that BCs

should be obtained in any patient with fever (≥38°C), hypothermia (≤38°C), leukocytosis, an absolute granulocytopenia, or a combination of these markers. Specific conditions in which BCs need to be drawn include sepsis, meningitis, suspected catheter-related bacteremia, infectious endocarditis, arthritis, osteomyelitis, and fever of unknown origin. BCs may be performed selectively in patients with pneumonia or skin-soft tissue infections.[51] The review also provides a listing of indications for follow-up BCs.

Drawing cultures via venipuncture versus intravascular catheter

Blood for BC testing should be drawn via peripheral venipuncture unless clearly necessary.[44] Snyder et al in 2012 conducted a systematic review of studies comparing bacterial colonization of BCs drawn either through venipuncture routes or from intravascular catheters.[52] The 9 studies[53-60] reported higher BCC rates ranging for samples drawn via catheters (range, 3.4%-13%) than from blood obtained by venipuncture (range, 1.2%-7.3%). Higher contamination rates occur at the time of central line insertion despite a maximal sterile technique.[61] Consideration should be made to drawing venipuncture samples on the opposite extremity of an infusion or avoidance after specific occurrences (eg, breast surgery with axillary node dissection or radiation therapy to that side, affected extremity from a cardiovascular accident).[49]

However, when clinically indicated, BCs obtained from intravascular catheters are associated with greater sensitivity and negative predictive value as concluded in a review of 6 published studies.[62] The Infectious Disease Society of America (IDSA) recommends that when catheter-related BSI is suspected, paired blood samples should be drawn from the catheter and a peripheral vein.[63] Patients presenting with fever and neutropenia should have at least 2 sets of BCs drawn, with a set collected simultaneously from each lumen of an existing CVAD, if present, and from a peripheral vein site; if no central line is present, culture sets should be drawn from separate venipunctures.[64] Obtaining BCs from a CVAD lumen that was not used for advancing the catheter over a guidewire may also decrease contaminant findings.[65]

Assuring optimal aseptic technique during BC collection is also critical when obtaining such samples from neonatal and pediatric patients because of the diversity of intravascular catheters used in such populations. Although peripheral vein samples are preferred, it is often necessary to draw blood from peripheral lines, umbilical catheters, CVADs, or arterial catheters.[66]

Hand hygiene

Proper hand hygiene using either a soap and water procedure or an alcohol-based hand sanitizer is a cornerstone in infection prevention practices. The assurance that proper hand hygiene occurs prior to BC collection procedures lowers the risk of introducing contaminant bacteria into BC bottles. Recommendations contained in the CDC's guidelines that apply to health care workers performing BC collection include decontaminating hands "…before having direct contact with the patient," "…before inserting…peripheral vascular catheters…or other invasive devices that do not require a surgical procedure," "…after contact with a patient's intact skin," "…after contact with body fluids…," "…after contact with inanimate objects…," and "…after removing gloves."[67]

Prepackaged kits

Provision of supplies for BC collection procedures does not equate to providing optimal practice. Issues such as time constraints and training insufficiencies may lead collectors to retrieve incorrect items stored in supply rooms or, conversely, fail to acquire a needed item. In theory, prepackaged kits enhance compliance with the use of specific items selected by key hospital personnel for the express purpose of BC collection. BC collection kits may contain a variety of items, including sterile drapes, tourniquets, antiseptics, BC bottles, sterile gauze, blood drawing device, and instructions that delineate the hospital policy.

Table 1 provides a summary of published studies that examined the effectiveness of prepackaged kits in reducing BCC rates.[68-78] Several findings are important to note. First, in 10 of 11 studies, the institutions converting to BC collection kits reported decreases in contamination rates; however, not all were statistically significant. Second, the kits were used by a wide variety of health care workers with likely different levels of experience in BC collection and associated time constraints in their functions. Third, the skin antiseptics used varied extensively from basic alcohol to combination products of chlorhexidine gluconate (CHG) and isopropyl alcohol (IPA). Although the findings are generally positive, there are several limitations that hinder accurate identification of effective variables. No study fully explained the contents provided by the practitioner (eg, whether there was provision of a separate antiseptic for the disinfection of BC bottle tops or a sterile drape). A meta-analysis conducted by Snyder et al of 7 studies did not favor prepackaged kits for reducing BCC.[52] Evidence exists however that a well-designed program with extensive education sessions can be successful for extended periods. Using a fully sterile procedure with a standardized kit that contained sterile gloves and with a large fenestrated drape to create a sterile field resulted in relative decreases of 43% and 64% at 2 EDs[79]

A recent cost analysis based on the 2013 study by Self et al compared 3 strategies: usual care in which nurses collected BCs without a standardized protocol, use of kits containing sterile gloves and drapes, or use of phlebotomy teams.[80] Based on a BCC rate of 1.68% when using a sterile kit, the authors determined that the annual savings were $483,219. The strategy of using sterile kits was less costly than usual care.

Antisepsis of skin

It is currently accepted that most organisms identified as contaminants in BCs originate from the skin of the patient.[13,39,46,81] Skin, however, cannot be sterilized during antisepsis procedures[82] because approximately 20% of bacteria are imbedded in sweat pores, hair follicles, and other structures within deep layers of the epidermis and dermis.[83] It therefore becomes crucial, regardless of the antiseptic used, that it be used in a manner to maximize bacterial kill.

Three key factors to determine when choosing antiseptics are area of coverage, method of application, and efficacy time. Each factor should be clearly defined by the manufacturer and delineated in hospital protocols and education programs. The suitable application boundary for each product is dictated by the quantity of the active ingredient; simply stated, a product applied to an area measuring 7×7 cm will be less efficacious if the recommendation is to apply the product to a 2×2 cm skin section. Aqueous-based products are usually applied in concentric circles, from center to outer edge, in the belief that such action prevents reintroduction of organisms to previously cleaned areas. This method of application has no scientific support.[43] Food and Drug Administration–approved CHG-IPA products better reflect the understanding that, as stated, significant numbers of bacteria reside in deeper layers of skin and therefore, after wetting the site, application should "…use gentle repeated back-and-forth strokes of the sponge for approximately 30 seconds."[84,85] Appropriate drying time is reflective of efficacy (ie, the time necessary for maximum antiseptic effect before

Table 1
Rates of Blood Culture Contamination in published studies using pre-packaged kits

Lead author (year)	Ref	Setting	Study period (mths)	Persons drawing blood	Kit Contents							Pre-intervention BCC rate (%)	Post-intervention BCC rate (%)
					Antiseptic	Alcohol pad for BC bottle tops	Sterile drape	Gloves	Needle device	BC bottle(s)	Instructions		
Trautner (2002)	68	One hospital	7	Physicians, medical students, healthcare technicians	Kit 1: 2%CHG/70% IPA Kit 2: 2% IT and 70% IPA	NS	NS	NS	NS	Y	Y	6.5	Kit 1: 0.5 Kit 2: 1.4
Schifman (1993)	69	One hospital	15	Physicians and nurses	10% acetone/70% IPA pad, 10% PI swab	N	N	N	N	Y	Y	4.6	2.2
Wilson (2000)	70	Four hospitals	NS	Physicians	70% IPA and 2% IT	NS	NS	NS	NS	Y	Y	5.5	5.5
Self (2014)	71	Two emergency departments	27	Nurses and phlebotomy	Large 2% CHG/70% IPA applicator	Y	Y	Y	Y	N	Y	Hospital A: 4.83 Hospital B: 2.51	Hospital A: 2.71 Hospital B: 0.91
Weinbaum (1997)	72	One hospital, two adult units: Unit A – medical Unit B - med/surg)	Unit A: 3,6,3 Unit B: 2,3	Unit A: House staff (without kits), Phlebotomists (with kits), house staff (with kits) Unit B: House staff (without kits), phlebotomists (with kits)	Isopropanol with IT	NS	NS	NS	NS	NS	NS	Unit A:8.4 Unit B: 4.8	Unit A:1.2,4.8 Unit B: 1.0
Madeo (2003)	73	Emergency Department	2	Medical and nursing staff	Large 62% ethyl alcohol wipe	NS	NS	NS	NS	Y	Y	24	8
Bamber (2009)	74	One hospital	4	Physicians	2% CHG	NS	N	N	Y	Y	Y	43*	25*
Dhillon (2009)	75	One hospital	12	Physicians	2% CHG	Y	Y	NS	N	Y	Y	8.7	3.0
Thomas (2011)	76	Two hospitals	12	physicians	2% CHG/70% IPA antiseptic sponge applicator	NS	NS	NS	Y	Y	Y	9.2	3.8
Weightman (2012)	77	One hospital	48	Phlebotomists, physicians, nurses	2% CHG/70% IPA	NS	NS	NS	Y	Y	Y	6.0	2.7
Marini (2013)	78	Pediatric emergency department	12	Nurses and clinical assistants	Alcohol	BCC rate, percent contaminated cultures/total no. of cultures (%)Y	N	N	N	Y	Y	2.1	1.4

BCC rate, percent contaminated cultures/total no. of cultures (%); CHG, chlorhexidine gluconate; IPA, isopropyl alcohol; IT, iodine tincture; N, No; NS, not stated; Y, yes.
*Contaminates cultures/total number of positive BCs sets (%).

Table 2
Rates of BCC in published studies using various antiseptics at venipuncture sites

Lead author (year)	Reference	Antiseptic(s)	Study population	Phlebotomists	BCC rate (%)
Trautner (2002)	68	2% alcoholic CHG (kit)	Medical inpatients	House staff, medical students, health care technicians	0.5
Trautner (2002)	68	70% IPA and 2% tincture of iodine (kit)	Medical inpatients	House staff, medical students, health care technicians	1.4
Schifman (1993)	69	70% IPA followed by 10% PI (kit)	Adult inpatients	House staff	2.2
Schifman (1993)	69	70% IPA followed by 10% PI (no kit)	Adult inpatients	House staff	4.6
Wilson (2000)	70	PI and alcohol (no kit)	Adult inpatients (4 centers)	House staff and phlebotomy teams	5.5
Wilson (2000)	70	70% IPA and 2% iodine tincture (no kit)	Adult inpatients (4 centers)	House staff and phlebotomy teams	5.5
Little (1999)	88	70% IPA followed by 2% iodine tincture (kit)	Adult inpatients	Phlebotomy team	2.4
Little (1999)	88	10% PI (no kit)	Adult inpatients	Phlebotomy team	3.8
Calfee (2002)	89	70% IPA (no kit)	ED and inpatients	Not specified	2.93
Calfee (2002)	89	10% PI (no kit)	ED and inpatients	Not specified	2.50
Calfee (2002)	89	PI and 70% IPA (no kit)	ED and inpatients	Not specified	2.62
Calfee (2002)	89	2% iodine tincture (no kit)	ED and inpatients	Not specified	2.58
Mimoz (1999)	90	0.5% alcoholic CHG (no kit)	Adult ICUs	Nurses	1.4
Mimoz (1999)	90	10% PI (no kit)	Adult ICUs	Nurses	3.3
Suwanpimolkul (2008)	91	2% alcoholic CHG (no kit)	ED and inpatients	Medical students, residents, nurses	3.2
Suwanpimolkul (2008)	91	10% PI (no kit)	ED and inpatients	Medical students, residents, nurses	6.9
Madeo (2008)	93	2% alcoholic CHG (no kit)	ED and 2 medical units	Not specified	2.1
Nuntnarumit (2013)	94	1% CHG (no kit)	Neonates	Medical residents	0.0
Nuntnarumit (2013)	94	10% PI (no kit)	Neonates	Medical residents	2.9
Kiyoyama (2009)	95	70% IPA (no kit)	ED	Medical residents	0.42
Kiyoyama (2009)	95	70% IPA and PI (no kit)	Inpatients	Medical residents	0.46
Washer (2013)	96	Alcohol pad scrub followed by 10% PI (no kit)	3 medical-surgical units	Phlebotomy team	0.58
Washer (2013)	96	Alcohol pad scrub followed by 2% iodine tincture (no kit)	3 medical-surgical units	Phlebotomy team	0.76
Washer (2013)	96	2% alcoholic CHG (no kit)	3 medical-surgical units	Phlebotomy team	0.93
Gibb (1997)	97	PI followed by 70% IPA (no kit)	Adult inpatients	Phlebotomy team	1.4-2.6
Isaacman (1990)	98	2% PI followed by alcohol (no kit)	Pediatric ED	Trained hospital nurses	1.3
Marlowe (2010)	99	3.15% alcoholic CHG (no kit)	Pediatric ED	Nurses, phlebotomists, or physicians	1.7
Marlowe (2010)	99	10% PI (no kit)	Pediatric ED	Nurses, phlebotomists, or physicians	2.5
Barenfanger (2003)	100	Iodine tincture (no kit)	ED and inpatients	Phlebotomists, ED staff, nurses	2.7
Barenfanger (2003)	100	2% alcoholic CHG (no kit)	ED and inpatients	Phlebotomists, ED staff, nurses	2.9
Tepus (2008)	101	2% alcoholic CHG (no kit)	ED	Nurses, licensed practical nurses, ED technicians	2.2
Tepus (2008)	101	Iodine tincture (no kit)	ED	Nurses, licensed practical nurses, ED technicians	3.5
Strand (1993)	102	2% iodine tincture (no kit)	Adult ED	House staff, nurses, medical students, physician assistants	3.7
Strand (1993)	102	10% PI (no kit)	Adult ED	House staff, nurses, medical students, physician assistants	6.3
McLellan (2008)	103	2% alcoholic CHG (kit)	2 medical units	Junior doctors, doctor support workers	7.5
McLellan (2008)	103	70% IPA (kit)	2 medical units	Junior doctors, doctor support workers	8.9

NOTE. Modified with permission from Cambridge University Press.[68]
BCC, blood culture contamination; *CHG*, chlorhexidine gluconate; *ICU*, intensive care unit; *IPA*, isopropyl alcohol; *PI*, povidone iodine.

the procedure). Povidone iodine preparations require 1.5-2 minutes, whereas CHG-IPA products in typical sizes used for skin preparations prior to insertion of catheters or drawing blood have a 30-second drying requirement. When faced with time constraints, clinicians prefer shorter drying times. Also of note, tincture of iodine products is associated with allergic reactions, unlike CHG which does not need to be cleaned off the skin site.[12] The Food and Drug Administration has approved specific CHG products for premature infants or infants under 2 months of age, to be used with care because they may cause irritation or chemical burns.[86]

The most commonly used antiseptics in BC collection are alcohol-, chlorhexidine-, and iodine-based products. An extensive number of studies have been published that compared the efficacy of these skin antiseptics for prevention of BCC during venipuncture procedures. Calderia et al,[87] in a meta-analysis of 6 randomized control trials,[68,69,88-91] conducted between 1999 and 2008, concluded that alcohol-containing products were associated with low rates of contamination; all results involving alcoholic chlorhexidine solutions achieved rates ≤2%, whereas povidone-iodine–associated trials had contamination rates >3%. A review by Malani et al that included 4 of these trials resulted in the same conclusions.[92] Table 2 updates BCC outcomes as initially compiled by Trautner et al in 2002[68] and includes several additional trials.[70,93-103] The most widely studied alcoholic CHG concentration is 2%, with most findings below the desirable BCC rate of 3%. Despite several limitations of the cited studies (eg, variations in the definition of contamination and personnel drawing BCs, potential confounding effect of multiple interventions, lack of compliance monitoring to established protocols), it would appear that solutions combining IPA and CHG are superior products in health care for many patient populations in a wide variety of settings,[50,104] providing effective bacterial kill and a rapid drying time of 30 seconds.

Universal decolonization

The importance of skin antisepsis is illustrated in the use of universal decolonization. A large cluster, randomized trial involving 74 adult ICUs in 43 hospitals was conducted to determine rates of BCC after implementation of 3 strategies to prevent health care–acquired infection.[105] Blood was obtained either by venipuncture or through an existing intravascular catheter. After a 6-month baseline

period, hospitals were randomly assigned to 1 of 3 strategies: arm 1 included methicillin-resistant *S aureus* nares screening and isolation of carriers; arm 2 included targeted decolonization whereby patients were screened, isolated, and decolonized if found to be carriers; and arm 3 required no screening but universal treatment of all patients with daily intranasal mupirocin for 5 days and daily bathing using prepackaged 2% CHG impregnated cloths for the entire duration of their ICU stay. Data using individual draws indicated BCC rates in the 3 intervention arms of the study as 3.3%, 3.2%, and 2.4%, respectively. Universal decolonization resulted in the greatest decrease in the BCC rate (41.3%), avoiding an additional 12.2 and 26.8 contaminated BC sets per 1,000 admissions compared with arms 1 and 2, respectively. Reducing the bioburden appears to be the primary reason for this dramatic result given that the protocol for using the 2% CHG cloths not only required application to the skin but also to the proximal 6 in of the line, connectors, and hubs. Four additional studies using CHG as a universal decolonization intervention reported BCC rate changes as follows: reductions of 58.1%,[106] 41.3%,[107] 53.0%,[108] and no decrease.[109] Current guidelines recommend the use of daily CHG baths for ICU patients to prevent CLABSI, which in turn may provide the additional benefit of reductions in venipuncture-related BCC.[110]

Sterile gloves

Although it is widely accepted that most FPBCs originate during the preanalytic phase of laboratory testing, specifically specimen collection,[5] no guideline or standard addresses the use of sterile gloves as a method to prevent such occurrences. The only study addressing this intervention was designed as a cluster randomized, assessor-blinded, crossover trial at a single hospital in medical wards and an ICU.[111] Interns drawing blood via venipuncture were randomly assigned to use either sterile gloves for all procedures or optional sterile gloves when re-palpating the vein after disinfection of the skin site. Significant differences were seen in the contamination rates: 0.6% in routine sterile gloving, and 1.1% when sterile gloves were optional. Although sterile gloving is a basic facet of aseptic technique, the use of sterile gloves has not been studied in BC collection from CVADs or other intravascular devices.

Masks

The use of masks during BC collection is not addressed in current guidelines or other publications that we could identify. Theoretically, organisms from the oral cavity may be transferred from the clinician onto a CVAD access port or patient skin surface during the collection of a blood sample. Evidence indicates that this does not occur. When comparing the top 10 pathogens associated with CLABSIs as reported to the NHSN[29] with normal oral flora, such as *Streptococcus* spp (eg, *S salivarius*, *S mutans*, *S sanguinis*),[112] there are no common organisms between the listings. Inquiries made to 2 leading authorities in the management of intravascular catheters, Mark Rupp, MD, and Lynn Hadaway, found no support for the use of a mask during BC collection from CVADs (R. Garcia, personal communication, January 2015).

Needleless connectors

Needleless connectors (NC) or mechanical valves were initially developed and became widely used as a means to eliminate the need for using needles and, therefore, potential needlestick injuries. However, NCs would eventually be identified with outbreaks of bacteremia caused by several factors, including the complex internal design that shielded colonizing bacteria from disinfection efforts and poor aseptic practices.[113,114] Obtaining blood for culture through an old NC has also been examined and found to be associated with contamination events, with 19 FPBCs reported in 1 study.[115] The current Infusion Nurses Society's standards of practice states that "when a sample for BC is drawn from the catheter, the used needleless connector should be changed prior to obtaining the sample."[49] The issue of drawing BCs from CVADs with NCs is not addressed by either the CDC or IDSA in intravascular catheter guides.[45,63]

Disinfection of CVAD hubs

To our knowledge, there are no published studies that have examined the effect of antiseptics on rates of BCC when performing scrub-the-hub techniques for disinfection of CVAD access hubs. There are currently no major guidelines that address disinfection of catheter hubs prior to drawing blood for testing.[44-46,49]

BC bottles

Disinfection

The rubber septa of BC bottles are not sterile even though they are manufactured with a lid that is removed prior to inoculation. One leading manufacturer of BC bottles specifies that the tops be disinfected, providing illustrated instructions emphasizing this point in the collection process.[116] The CLSI's guideline recommends that 70% IPA be used for disinfection.[12] Disinfection of the tops of the BC bottles is also supported by many other expert organizations.[46-48,50] The CAP Q-Probes study conducted in 640 hospitals determined that applying an antiseptic on bottle tops was associated with a significantly lower contamination rate (2.3%) when compared with those institutions that did not use this technique (3.4%).[10] Iodine products should not be used because it may erode the stopper material, potentially introducing contaminants.[13]

Volume

Drawing the correct volume of blood is the single most important factor in maximizing the yield of true pathogens.[12,43,50,117] The quantity of pathogens recovered increases in direct proportion to the volume of blood that is recovered.[23,118,119] However, a survey of persons who draw blood for culture indicated a high percentage who did not know the optimal volume of blood recommended for collection.[120] The CLSI recommends for adults drawing 20-30 mL from at least 2 separate venipuncture sites and inoculating 2 sets of BCs (a set consisting of 1 aerobic and 1 anaerobic bottle). For neonates, infants, and children, the volume should be no more than 1% of the patient's total blood volume.[12] Recommended volumes of blood for culture, based on pediatric patient weight, have been published.[43,50,121] Inadequate volumes may also have an effect on contamination. In a retrospective study of infants and children who had at least 1 BC drawn, it was reported that the rate of contamination was higher with lower blood volumes.[122] One factor that may contribute to underfilling of BC bottles is the amount of vacuum. Commercial bottles contain substantially more vacuum than is needed to adequately fill the bottles, ensuring rapid filling.[51,123] Obtaining blood for culture with a bottle in a horizontal position allows for only an estimate of the proper quantity. Although the bottle has a printed volume scale, it only helps if the bottle is maintained in a vertical position during filling. Educational efforts to address low volume events have been successful in laboratory quality control programs.[123]

Order of draw

To minimize contamination when collecting blood for multiple laboratory tests during a single procedure, blood for culture should be collected first.[12,124]

Distribution between aerobic and anaerobic bottles

BCs contain broth media that enhances the growth of bacteria that require oxygen to survive (aerobic) or organisms that grow in body sites where oxygen may be limited (anaerobic). Conflicting information exists on the issue of limiting the use of anaerobic bottles in BC testing.[12,125] Although the overall incidence of anaerobic bacteremia is low (approximately 4%) and may be decreasing,[126] the current recommendation states "…when less than the recommended volume of blood is drawn for culture, the blood should be inoculated into the aerobic vial first; any remaining blood should then be inoculated into the anaerobic vial."[12] Because most organism growth is recovered from aerobic bottles, it makes sense intuitively that the aerobic bottle be inoculated first to the recommended fill mark, followed by inoculation of the anaerobic bottle.

Number of sets

Drawing multiple sets of BCs is another important factor in maximizing the recovery of organisms. Several studies examining the relation of the number of BCs and detection of bacteremia or fungemia have been published.[23,117,119] In all studies, rates of recovery increased with the number of BC sets obtained, ranging from 73% with 1 BC set to >99% when 3 sets were obtained. Single BCs should never be drawn from adults; the present recommendation is to draw 2-3 sets per episode.[12,43,50] These should be drawn from different sites over a 24-hour period. The number of positive sets among all sets obtained is one of the most valuable tools used to differentiate contaminants from true bacteremia.[13]

Timing

The timing of BC collection does not appear to be a significant factor in the recovery of pathogens[12]; however, recommendations have been published for different clinical conditions.[43] A large, multicenter study evaluating the timing of BC collection in relation to patient temperature elevations found no significant benefit to this practice. The authors concluded that emphasis should be placed on obtaining adequate volume, collection of appropriate numbers of sets, and use of aseptic technique.[127]

Transport

Once collected, BC specimens should be transported to the laboratory within 2 hours.[12,50] Specimens should be held at room temperature, but they should never be refrigerated or frozen because this may kill some of the microorganisms.[43]

Antibiotic neutralization

Ideally, BCs should be obtained prior to starting empirical antibiotic therapy to optimize the recovery of pathogens.[40,47,48] However, indications are that 28%-63% of patients suspected of bacteremia are on antimicrobials at the time BCs are collected.[41] In an attempt to increase organism recovery, manufacturers of continuous-monitoring BC systems have developed collection vials that contain antibiotic-absorbing resin media.[12,50,128] Institutions should contact the BC vial manufacturer to obtain specific listings of antibiotics that are neutralized.

Discarding the initial volume of blood

Discarding initial aliquots of blood for the purposes of minimizing dilution by infusate or contamination by other components, such as dextrose or potassium, is a common practice.[129] However, its purpose for reducing BCC is not addressed in current guidelines.[45,49,130] Several studies have tested the hypothesis that using a discard volume method (DVM) when collecting samples via venipuncture or through an intravenous catheter removes microorganisms that may in turn cause contamination. In 62 pediatric oncology patients with CVADs, there was no difference in BCC rates between 5-mL discard samples and the second sample obtained for diagnostic culture.[131] Dwivedi et al compared the contamination rates in 10-mL discard aliquots inoculated into aerobic bottles with 20-mL samples divided into two 10-mL aliquots inoculated into aerobic (standard vial) and anaerobic BC bottles obtained from adult oncology patients through Hickman or peripherally inserted central catheters.[132] The overall BCC rates for the discard and standard vials were 10.9% and 10.5%, respectively, suggesting that discarding the initial aliquot of blood obtained via an intravascular catheter does not reduce contamination rates. The findings from applying the DVM to BC collection from intravascular catheters appear to be converse to that when samples are obtained by venipuncture. In an 18-month trial that compared BCC rates in control and DVM samples obtained via venipuncture from adult hospitalized patients or patients seen in outpatient settings or the ED, the rate of FPBCs decreased from 2.8% to 1.0% among the aerobic samples.[133] Binkhamis and Forward in using the DVM over a 24-month study period reported 143 fewer contaminants and an overall reduction in BCC rates of 30.34%. Cost savings were estimated to be between $143,000 and $1.2 million.[134]

It may be hypothesized that the DVM is effective in lowering BCC rates when blood is obtained via venipuncture because the procedure may remove bacteria that remain on skin particles dislodged during such procedures; drawing blood via intravascular catheters does not involve skin contact with a needle and therefore the DVM provides no benefit in reducing contamination. Colonized catheters or accessories may however be the source of BCC when blood is drawn through such devices.

Labeling of BC bottles to identify health care worker and feedback

Labeling of BC bottles, either with electronically produced labels or via manual methods, enhances the ability of quality improvement personnel to detect important data points, such as time and location of collection, name of collector, and site (eg, right vs left arm venipuncture, specific catheter lumen[s]). Identifying and providing counseling to persons identified with higher contamination rates are a process improvement element of effective BC collection programs.

OPTIMAL STRATEGIES IN PROGRAM IMPLEMENTATION AND QUALITY IMPROVEMENT

ED interventions

It has been estimated that up to 50% of all BCs drawn in hospitals originate in an ED. Periods of increasing crowding in EDs have been associated with significant increases of BCC, suggesting that lapses in proper collection techniques by health care workers were contributory.[135] Table 3 summarizes studies that have reported successful strategies in reducing contamination rates and other associated outcomes in EDs.[53,71,78,79,136-142] A common practice in Pediatric EDs is to obtain a sample for BCs simultaneously when inserting a peripheral intravenous catheter (PIV). Such practice often occurs because of the difficulty in accessing veins in children and avoiding additional sticks. Two different approaches to drawing BCs in children with PIVs have been studied. Researchers faced with high rates of BCC in 1 pediatric ED of a Midwest tertiary children's hospital altered practice by requiring that BCs be obtained by a second venipuncture.[53] The revision in policy resulted in a decrease of the BCC rate from 6.7% to 2.3%. The number of recalled patients was reduced by 80%. Rather than require staff to draw a separate BC, Vanderbilt Children's Hospital elected to standardize a sterile BC collection process in patients having PIV placement, which included use of sterile gloves and adherence to

Table 3
Emergency department studies on reducing blood culture contamination

Author (year)	Reference	No. of EDs	Population	Patient exclusions	Study period (mo)	Personnel drawing BCs	Interventions	
							Draw via separate venipuncture	Survey to identify defects
Weddle (2011)	53	1	Pediatric	Central lines, immunodeficiency, <40 wk, or growing a pathogen	12	NS	Y	N
Self (2014)	71	2	NS	NS	27	Nursing and phlebotomy	N	N
Self (2013)	79	1	Adult		22	Nursing and paramedics	Y	Y
Madeo (2005)	136	1	NS	NS	NS	Medical staff	N	N
Lin (2012)	137	1	NS	NS	3	Nursing	Y	N
Hall (2013)	138	1	Pediatric	Central lines, immunodeficiency	28	Nursing	N	Y
Denno (2013)	139	2	Adult and pediatric	NS	21	Nursing	N	N
Harding (2013)	140	1	Adult and pediatric	NS	15	Nursing and phlebotomy	N	Y
Marini (2013)	78	1	Pediatric	Central lines, indwelling devices including orthopedic hardware	12	Nursing and clinical assistants	Y	N
Skalkos (2014)	141	1	Adult and pediatric	NS	NS	Nursing and phlebotomy	Y	N
Taneja (2014)	142	1	Adult	None	26	Pre: nurses; post: nurses and phlebotomy	N	Y

BC, blood culture; *CHG*, chlorhexidine gluconate; *ED*, emergency department; *IPA*, isopropyl alcohol; *N*, no; *NS*, not stated; *PI*, povidone iodine; *Y*, yes.
* Eliminated in a modified procedure at hospital B.
† Product changed from 2% CHG, 70% IPA applicator to 3.15% CHG, 70% IPA swabstick.

antiseptic drying times.[138] These revisions resulted in a BCC rate decrease from 3.9% to 1.6%, a 59% relative reduction. Excess charges caused by 149 contaminated cultures in the preintervention period were estimated to be >$416,000.

An intervention program designed to educate staff, standardize practices to include the use of a 2% CHG with 70% IPA skin antisepsis product, avoid repalpating the site with a nonsterile glove, and provide feedback to ED nursing staff resulted in the reduction in the rate of BCC from 12% to 2% and 1.5% in 2 EDs.[139] Several factors appeared to contribute to this result. Of note, the institution's IP recommended the use of a 1-step CHG-IPA product, which expedites skin antisepsis procedures (ideal in the fast-paced environment of an ED) and rewards staff with zero contaminations with annual certificates of excellence. Cost savings were estimated to be $2.5 million.

A 3-part plan highlighted another ED effort to reduce BCC: identify via BC labeling and privately counsel phlebotomists or nurses associated with high contamination; identify and remove barriers associated with the practice of drawing BCs; and identify and correct misconceptions associated with proper BC collection.[140] Misconceptions that were addressed included alcohol as a sole skin antiseptic was sufficient, palpation of the vein site after antiseptic skin preparation with a gloved finger was acceptable, BC bottle stoppers are sterile and do not need to be cleaned, and 4 bottles can be drawn from the same venipuncture site. During 8 months of implementing corrective actions, the BCC rate dropped from 1.82% to 1.01%, a 45% reduction. The decrease represented 77 fewer contaminated results and a cost avoidance of $614,363.

A unique, 2-hospital ED study elevated BC collection protocols from a nonsterile process to one that required the use of a full sterile technique (cleaning of BC tops with alcohol; use of a sterile BC collection kit that contained a large 3-mL no-touch CHG-IPA [emphasizing coverage area of 5 $\times$ 4 in] applicator for skin antisepsis, fenestrated drape, butterfly needle, and a checklist outlining the procedure; and use of sterile gloves prior to creation of sterile field and for relocating vein), resulting in a 50.25% reduction in contamination at hospital A. Hospital B, identified in the preintervention period with a low BCC rate, and despite eliminating the use of the sterile drape, achieved a sustained reduction over 9 months in their rate from 2.51% to 0.91%.[71]

Personnel

The use of dedicated phlebotomy teams has been found in many studies to reduce BCC. In both the CAP Q-Tracks and Q-Probes studies,[10,11] the BCC data indicated a statistically significant support for use of a dedicated phlebotomy team over other personnel for drawing blood for culture. A review by Dawson found scientific support in 6 of 7 trials for the use of a phlebotomy team in reducing contaminant BCs.[39] A meta-analysis of 5 trials representing broad and diverse patient populations also was found to favor the use of phlebotomy teams in collecting BC specimens.[52] Worker skill, competency training, and procedure focus have been cited as reasons for these outcomes.[143] The phlebotomist's role in drawing blood for culture, however, is limited to venipuncture procedures.

Education and feedback

Monitoring of contamination rates, identification of collectors associated with contaminant cultures, and feedback to the individual is another method used to reduce BCC. Data collected over the 5-year Q-Tracks study indicated that continuous feedback to staff resulted in a median reduction in the BCC rate of 0.67%.[11] Providing basic education on elements for proper blood drawing technique with a no feedback component proved beneficial in 1 trial where BCC rates decreased from 5.7% to 1.95%.[144] Other

Interventions										
Education	BC drawing kit	Sterile drape	Sterile gloves	Cleaning tops of BC bottles	CHG-IPA skin prep	Counseling high-contamination individuals privately	Feedback to staff	Checklist	Preintervention rate (%)	Postintervention rate (%)
N	N	N	N	N	N	N	N	N	6.7	2.3
Y	Y	Y*	Y	Y	Y	N	Y	Y	Hospital A: 4.83; hospital B: 2.51	Hospital A: 2.71; hospital B: 0.91
Y	Y	Y	Y	Y	Y	N	N	N	4.3	1.7
Y	Y	N	N	NS	N	N	N	N	24	8
Y	N	N	N	Y	N	Y	Y	N	3.4	2.0
Y	N	Y	Y	Y	Y	Y	Y	N	3.9	1.6
Y	Y	N	Y	Y	Y	N	Y	Y	12	1.5
Y	N	N	Y	Y	Y	Y	Y	N	3.5	1.0
Y	Y	N	N	Y	N	Y	Y	Y	2.1	1.4
Y	N	N	Y	Y	Y†	N	Y	N	9.73	1.19
Y	Y	N	N	Y	Y	Y	Y	Y	6.0	4.6

published studies have witnessed significant declines in contamination rates after implementation of feedback processes often with retraining interventions. Rates in the preintervention period for these trials ranged from 1.82%-6.4%, whereas rates in the post-intervention period decreased in reported rates of 1.01%-2.6%.[97,137,140,145-147] Hospitals should ensure that the program includes documented competencies for phlebotomists and clinicians drawing blood for culture.

Compliance monitoring

The only study identified in the literature concerning compliance with hospital protocol on BC collection was published in 2008.[148] The authors devised a survey to assess compliance by staff collecting peripheral BCs and included 4 best practice criteria: fresh peripheral vein used for venipuncture, BC bottle septa cleaned with an antiseptic, venipuncture site prepped with alcohol, and avoidance of repalpating site after skin preparation. Analysis of 766 questionnaires indicated that when compliance with all 4 criteria was met, the contamination rate was 8%, but when the protocol was not followed the rate was considerably higher, 10.3%. Univariate analysis identified not using an antiseptic for skin preparation and using a site other than a peripheral site as being associated with significantly higher rates of contamination.

Bundled preventive practices

A bundle is a set of interventions composed of best practices that when implemented together support optimal outcomes.[149] The use of bundles for reducing BCC has been described in 4 recent studies.[147,150-152] Robert used a context-input-process and product model to create a useful framework for identifying needs and process components and focusing decisions on education and planning. Educational fact sheets outlining accepted practices in skin or intravascular hub disinfection, BC bottle tips, and other procedure elements were used in a 1-year intervention that resulted in BCC rates to be reduced from 4.8% to <3%.[150] Other unique aspects integrated into bundles include the use of standardized nursing protocols and changing NCs prior to drawing blood,[147] use of unit-based posters highlighting protocols and monthly BCC rates, modification of the electronic medical record to provide a BC order template, and provision of specimen labels to include site and time of draw.[151] Both studies reported sustained decreases in BCC rates.

The only study we identified that used a bundle approach to specifically reduce BCC in patients with CVADs was published in 2014.[152] Murphy et al introduced a BC bundle that included hand hygiene, a revised policy and procedure for procurement of blood specimens, proper labeling of vials, and use of a kit (outer kit containing prefilled saline syringes and an inner sterile kit with hand sanitizer, three 70% alcohol swabsticks, a 10-mL syringe, a needleless access device, a blood transfer device, and mask and gloves). Education was provided for all staff who obtain BCs. Rates of BCC were reduced from 8% in the preintervention phase to 4.2% after education and introduction of the bundle. These studies demonstrate that bundling practices, which individually have been studied as effective in reducing BCC, are significantly more effective in reducing contaminant organisms when grouped among a variety of populations and when obtained by venipuncture or intravascular catheters.

BC checklist

The use of procedural checklists for enhancing patient safety and lowering avoidable outcomes, such as health care–acquired infections, has evolved into a standard practice in health care.

Table 4
Checklist of elements to consider in a blood culture collection and handling policy

	Policy element	Comment	Reference						
			CLSI[12]	ASM[43]	CDC[44]	ENA[46]	NHS[47]	IDSA[63]	Other reference
☐	Establish clinical indications for BCs	Consider adding selection list to EMR					✓		51
☐	Establish clinical indications for follow-up BCs	Consider adding selection list to EMR							51
☐	Use a procedure checklist outlining critical elements in the process	A checklist can be used to identify adherence to established policy and for re-emphasis of accepted practice							153
☐	Educate all persons collecting BCs	Education sessions should provide information on adverse outcomes of contaminant samples, benefits of identifying true pathogens, effect on reportable CLABSIs, and best practice elements when obtaining BCs				✓	✓		11,97,137,140,145-147
☐	Program should start with assessment and intervention in the ED	EDs are associated with higher numbers of BCs and rates of BCC; EDs admit patients to all hospital services							53,71,78,79,136-142
☐	Use a dedicated phlebotomy team when possible for collecting samples via venipuncture	Phlebotomy teams are associated with lower contamination rates; coverage should be provided for the ED in at least a part-time capacity			✓	✓		✓	10,11,39,52,143
☐	Draw blood cultures before administration of antibiotics	Antibiotics may suppress growth of true pathogens				✓	✓	✓	40
☐	Collect via venipuncture rather than intravascular catheter	BCs collected via venipuncture are associated with lower blood culture contamination rates	✓		✓	✓	✓		52-60
☐	Select a different venipuncture site for each BC set	Improves ability to recognize contaminants; second site draw requires separate hand hygiene procedure and new supplies	✓						
☐	For suspected CRBSI, draw a set from catheter paired with a set obtained from a peripheral vein site	The definitive diagnosis of CRBSI requires a positive peripheral blood culture with concordant microbial growth						✓	
☐	Perform hand hygiene with soap and water or sanitizer prior to donning gloves	Hand hygiene solution packets may be provided in BC kits					✓		67
☐	Use a BC collection kit	Prepackaged kits enhance the standardization of the established hospital procedure							68-78
☐	Use a closed blood collection system	Reduces potential for introducing microorganisms					✓		
☐	After identifying collection site, disinfect the rubber septum of the BC bottles using 70% alcohol or an alcoholic chlorhexidine solution	The septa of BC bottles are not sterile; disinfection of the blood culture septa should be performed prior to the start of drawing blood (allows antiseptic to dry before inoculation); iodine should not be used to disinfect the septa; CLSI and ENA recommend using 70% alcohol; NHS recommends alcoholic CHG	✓			✓	✓		10,50
☐	Perform skin antisepsis: use either alcohol or tincture of iodine or an alcoholic CHG solution	Studies indicate that an alcoholic CHG solution is most effective in reducing BCC	✓		✓	✓	✓	✓	68-70,93-103
☐	Follow manufacturer's instructions for application of antiseptic to skin	Maximal antiseptic effect is achieved when the solution is used as recommended				✓		✓	84
☐	Follow manufacturer's instructions for coverage area for specific product used	Maximal antiseptic effect is achieved when the solution is used as recommended							84
☐	Follow manufacturer's instructions for drying time for specific product used	Maximal antiseptic effect is achieved when the solution is used as recommended				✓		✓	84
☐	Use of universal decontamination with 2% CHG cloths	Universal decolonization has been reported to reduce BCC in most studies							105-109
☐	After skin disinfection, do not palpate the site again; if necessary use a sterile glove	Transfer of microorganism to the venipuncture site may occur when repalpating site with finger or when wearing nonsterile glove	✓			✓	✓		111
☐	Remove a needleless connector before drawing blood for culture from a catheter hub	Needleless connectors may harbor bacteria in internal mechanisms and therefore may be source of contaminant organisms							49,115

☐	Disinfect the hub of the catheter lumen	Most effective disinfectant to use has not been studied; use a scrub the hub procedure using a disinfectant wipe (as per manufacturer's instructions)					✓	49
☐	Collect appropriate volume of blood for adults and children	Collecting the correct volume of blood has direct impact on yield of true pathogens	✓	✓				50,117-123
☐	Use diversion of initial volume when collecting blood via venipuncture	May prevent introduction of contaminant organisms contained on skin particles				✓		131-134
☐	Inoculate BCs first before inoculation of other test vials	Minimizes risk of contamination when drawing blood for multiple tests	✓				✓	124
☐	Inoculate aerobic BC bottle first, anaerobic second (adults)	Important when volume of blood BC set is inadequate; most pathogenic organisms are identified from aerobic bottle	✓			✓		125,126
☐	Collect 2-3 sets of BCs per episode (adults)	Maximizes the ability to identify true pathogens	✓	✓		✓	✓	23,50,117,119
☐	BC sets may be collected simultaneously	Evidence indicates that drawing BCs simultaneously does not affect microbial recovery	✓	✓				50,127
☐	BCs should be inverted gently several times to prevent clotting	Clotting may inhibit recovery of organisms						128
☐	Labeling (collector identification, date and time, site of draw)	Information assists in quality control management					✓	135,136,138-140
☐	Handle BC bottles at room temperature	Refrigeration or freezing may kill microorganisms	✓					
☐	Transport BC bottles to laboratory within 2 h of collection	Increases ability to identify true pathogens	✓	✓				50,127
☐	Use BC bottles with antibiotic binding agents	Optimizes recovery of organisms from samples taken from patients on antibiotics	✓					128
☐	Use a standard methodology (eg, CAP Q-Tracks) for calculating BCC as the standard and provide rates as feedback to all units	Establishes a baseline to gauge level of BC collection techniques	✓					10
☐	Use a laboratory baseline BCC rate of ≤3%	Identifies the need to implement quality improvement strategies	✓					
☐	Provide tools to assist in interpreting positive BCs (eg, use of an algorithm)	Although there is no gold standard, institutions should review published information on this issue						14,28,34-37
☐	Feedback to collector identified with contaminant BC	Private counseling has been reported to improve compliance with policy						71,78,97,136-147
☐	Reward staff identified as collectors with zero BC contaminants	Rewards promotes positive accomplishments and assists in sustained improvement						138
☐	Establish a compliance monitoring program	Periodically conduct monitoring to ensure elements of policy are at acceptable levels of compliance						148

ASM, American Society of Microbiology; *BC*, blood culture; *BCC*, blood culture contamination; *CDC*, Centers for Disease Control and Prevention; *CHG*, chlorhexidine gluconate; *CLABSI*, central line–associated bloodstream infection; *CLSI*, Clinical Laboratory Standards Institute; *CRBSI*, catheter-related bloodstream infection; *ED*, emergency department; *EMR*, electronic medical record; *ENA*, Emergency Nurses Association; *IDSA*, Infectious Disease Society of America; *NHS*, National Health Service.

Implementing the concept of a checklist to BC collection to increase procedural compliance is an emerging area of research. An innovative approach to decreasing BCC that met the NHSN definitions for a CLABSI was undertaken at a 500-bed university-affiliated hospital where nurses, phlebotomists, and intravenous therapy staff obtained blood specimens.[153] The program involved discouraging drawing blood samples from central lines; re-educating on venipuncture techniques; implementing a 2-nurse procedure whereby an ICU nurse obtained the specimen through a CVAD, whereas the other monitored adherence using a checklist; and using special kits containing all necessary items for drawing blood specimens from CVADs. This effort resulted in a decrease of cultures obtained from central lines from 10.9% to 0.4% and a sustained reduction in the BCC rate from 1.6% to 0.5%. The impact on reported CLABSIs is important to note: 3 of 10 events (30%) were suspected to represent contamination; a postintervention 7.5-month period detected no CLABSIs related to suspect contaminated BCs.

Table 4 is provided as a summary of the findings of this research and may be used by hospitals as a checklist to assess best practice elements in their BC processes.

CONCLUSION

The currently available body of research indicates that improper collection of BCs is associated with suboptimal treatment of patients, increased financial burdens, and potential over-reporting of CLABSI. Best practices in the collection and handling of BC specimens require a thorough understanding of a variety of issues, including appropriate indications for drawing BCs, criteria for drawing from venipuncture sites versus intravascular catheters, selection and appropriate application of antiseptics, collection methods in the presence of NCs, and proper use of BC bottles. BC practices can be optimized when programs include EDs, focused education, feedback of BCC rates to collectors, and implementation of bundled practice initiatives.

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