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Thank you for your assistance.
A prime reason for ensuring proper collection of blood cultures is to maximize the identification of true pathogens.
False-negative blood culture results are primarily caused by improper blood volume and number of sets.
Improper collection of blood cultures may lead to contamination of the sample (ie, false-positive result).
False-positive results are avoided with evidence-based interventions that may be implemented as a bundle.
Contamination of the blood culture sample may lead to over-reporting of central line–associated bloodstream infections.
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
Blood culture collection
Blood culture contamination
Central line associated bloodstream infection
Bacteremia
Venipuncture

Background: Blood cultures are an essential diagnostic tool in detecting microorganisms causing bacteremia and severe sepsis. A multidisciplinary task force of health care professionals at Stony Brook University Hospital conducted a literature review to understand the reasons for optimizing procedures and to identify best practices before the establishment of a new hospital-wide blood culture collection policy and procedure.

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
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. 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 (CLABSI) events. Improper BC collection impacts the interpretation of epidemiologic CLABSI events, conditions that are mandated by law in the United States to be reported to federal and select state agencies.

BACKGROUND

This article reports the findings of a project aimed at identifying evidence-based best practices in the preanalytical collection and handling phase5 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 phlebotomists/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, cardiology, 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, has accounted for a 32% increase in hospitalizations in recent years, and is the leading cause of admission to a hospital for adults aged 45–84 years after an ED visit. 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 the HACEK group.

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 healthcare worker performing the procedure. BC is defined by The College of American Pathologists (CAP). The CAP defines a BC set as typically consisting of a blood sample collected from a single procedure (eg, one venipuncture) and then inoculated into one aerobic and one anaerobic bottle. BCs are considered to be contaminated if >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 (CoNS), Staphylococcus epidermidis, Propionibacterium acnes, Corynebacterium sp (diphtheroids), and Bacillus sp. The contamination rate (%) is calculated as follows:

\[
\text{Contamination rate} = \frac{\text{Number of contaminated blood cultures}}{\text{Total number of routine blood cultures accessioned}} \times 100
\]

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%. A 5-year study examining BCC in institutions participating in the CAP Q-Trak 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. Based on the Q-Trak 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 ≤3.0%.” 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%. 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. 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 $18–$19 million. 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 PFBCs 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 Enterobacteriaceae,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 bacteraemia 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 often 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.30 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 organisms27 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, whereas CoNS is the most commonly reported organism in NHSN CLABSI events, accounting for 20.5% of all organisms30; 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,9,20 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 miscategorizing 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.”37 Other researchers have suggested the use of innovative algorithms to facilitate in the differentiation of true pathogens from contaminants.38

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 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.39-42 Additional reference materials included microbiology laboratory standards43 and clinical publications and guidelines identified via the National Guideline Clearinghouse44-46 and textbook chapters47 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 combina-
tion 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 re-
view 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 venipunc-
ture 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 intravas-
cular catheters.52 The 9 studies53-60 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 intra-
vascular 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) rec-
ommends 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.54 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.60

Hand hygiene

Proper hand hygiene using either a soap and water procedure or
an alcohol-based hand sanitizer is a cornerstone in infection pre-
vention 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 perform-
ing BC collection include decontaminating hands “...before
having direct contact with the patient...” “...before inser-
ting...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.”66

Prepackaged kits

Provision of supplies for BC collection procedures does not
equal to providing optimal practice. Issues such as time con-
straints and training insufficiencies may lead collectors to
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 signifi-
cant. 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 combi-
nation 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 anti-
septic 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 de-
creases of 43% and 64% at 2 EDs.69

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 con-
taminants in BCs originate from the skin of the patient.43,45,46,61
Skin, however, cannot be sterilized during antiseptic procedures
because approximately 20% of bacteria are imbedded in sweat
pores, hair follicles, and other structures within deep layers of the
epidermis and dermis.43 It therefore becomes crucial, regardless of
the antiseptic used, that it be used in a manner to maximize bac-
terial 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 appli-
cation boundary for each product is dictated by the quantity of the
active ingredient; simply stated, a product applied to an area
measuring 3 × 3 in will be less efficacious if the recommendation
is to apply the product to a 1- × 1-in skin section. Aqueous-based
products are usually applied in concentric circles, from center to
erouter 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 approxi-
ately 30 seconds.”84,85 Appropriate drying time is reflective of
efficacy (ie, the time necessary for maximum antiseptic effect before
<table>
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<th>Lead author (year)</th>
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<th>Setting</th>
<th>Study period (no)</th>
<th>Persons drawing blood</th>
<th>Kit contents</th>
<th>Preintervention BCC rate (%)</th>
<th>Postintervention BCC rate (%)</th>
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<tr>
<td>Trautner (2002)</td>
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<td>68</td>
<td>1 hospital</td>
<td>Physicians, medical students, health care technicians</td>
<td>Kit 1: 2% CHG, 70% IPA; kit 2: 2% IT, 70% IPA</td>
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<td>Schifman (1993)</td>
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<td>1 hospital</td>
<td>Physicians, nurses</td>
<td>10% acetone, 70% IPA pad, 10% PI swab</td>
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<td>Hospital, 4 hospitals</td>
<td>Physicians</td>
<td>70% IPA, 2% IT</td>
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<td>71</td>
<td>2 emergency departments</td>
<td>Nurses, phlebotomists</td>
<td>Large 2% CHG, 70% IPA applicator</td>
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<td>Weinbaum (1997)</td>
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<td>72</td>
<td>Hospital, 2 adult units: unit A (medical) and unit B (medical-surgical)</td>
<td>Unit A: house staff (without kits), phlebotomists (with kits), house staff (with kits); unit B: house staff (without kits), phlebotomists (with kits)</td>
<td>Isopropanol with IT</td>
<td>NS</td>
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<td>Emergency department</td>
<td>Medical and nursing staff</td>
<td>Large 62% ethyl alcohol wipe</td>
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<td>1 hospital</td>
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<td>Alcohol</td>
<td>NS</td>
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*BC, blood culture; BCC rate, percent blood contaminated cultures/total no. of cultures (%); CHG, chlorhexidine gluconate; IPA, isopropyl alcohol; IT, iodine tincture; N, no; NS, not stated; PI, povidone iodine; Y, yes.

*Contaminates cultures/total number of positive BCs sets (%).
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.\(^{11}\)

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 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, 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

**Table 2**

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

<table>
<thead>
<tr>
<th>Lead author (year)</th>
<th>Reference</th>
<th>Antiseptic(s)</th>
<th>Study population</th>
<th>Phlebotomists</th>
<th>BCC rate (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trautner (2002)</td>
<td>68</td>
<td>2% alcoholic CHG (kit)</td>
<td>Medical inpatients</td>
<td>House staff, medical students, health care technicians</td>
<td>0.5</td>
</tr>
<tr>
<td>Trautner (2002)</td>
<td>68</td>
<td>70% IPA and 2% tincture of iodine (kit)</td>
<td>Medical inpatients</td>
<td>House staff, medical students, health care technicians</td>
<td>1.4</td>
</tr>
<tr>
<td>Schifman (1993)</td>
<td>60</td>
<td>70% IPA followed by 10% PI (kit)</td>
<td>Adult inpatients</td>
<td>House staff</td>
<td>2.2</td>
</tr>
<tr>
<td>Schifman (1993)</td>
<td>60</td>
<td>70% IPA followed by 10% PI (no kit)</td>
<td>Adult inpatients</td>
<td>House staff and phlebotomy teams</td>
<td>4.6</td>
</tr>
<tr>
<td>Wilson (2000)</td>
<td>70</td>
<td>PI and alcohol (no kit)</td>
<td>Adult inpatients (4 centers)</td>
<td>House staff and phlebotomy teams</td>
<td>5.5</td>
</tr>
<tr>
<td>Wilson (2000)</td>
<td>70</td>
<td>70% IPA and 2% iodine tincture (no kit)</td>
<td>Adult inpatients (4 centers)</td>
<td>House staff and phlebotomy teams</td>
<td>5.5</td>
</tr>
<tr>
<td>Little (1999)</td>
<td>88</td>
<td>70% IPA followed by 2% iodine tincture (kit)</td>
<td>Adult inpatients</td>
<td>Phlebotomy team</td>
<td>2.4</td>
</tr>
<tr>
<td>Little (1999)</td>
<td>88</td>
<td>10% PI (no kit)</td>
<td>Adult inpatients</td>
<td>Phlebotomy team</td>
<td>3.8</td>
</tr>
<tr>
<td>Calfee (2002)</td>
<td>89</td>
<td>70% IPA (no kit)</td>
<td>ED and inpatients</td>
<td>Not specified</td>
<td>2.93</td>
</tr>
<tr>
<td>Calfee (2002)</td>
<td>89</td>
<td>10% PI (no kit)</td>
<td>ED and inpatients</td>
<td>Not specified</td>
<td>2.50</td>
</tr>
<tr>
<td>Calfee (2002)</td>
<td>89</td>
<td>PI and 70% IPA (no kit)</td>
<td>ED and inpatients</td>
<td>Not specified</td>
<td>2.62</td>
</tr>
<tr>
<td>Calfee (2002)</td>
<td>89</td>
<td>2% iodine tincture (no kit)</td>
<td>ED and inpatients</td>
<td>Not specified</td>
<td>2.58</td>
</tr>
<tr>
<td>Mimoz (1999)</td>
<td>90</td>
<td>0.5% alcoholic CHG (no kit)</td>
<td>Adult ICUs</td>
<td>Nurses</td>
<td>1.4</td>
</tr>
<tr>
<td>Mimoz (1999)</td>
<td>90</td>
<td>10% PI (no kit)</td>
<td>Adult ICUs</td>
<td>Nurses</td>
<td>3.3</td>
</tr>
<tr>
<td>Suwanpimolkul (2008)</td>
<td>91</td>
<td>2% alcoholic CHG (no kit)</td>
<td>ED and inpatients</td>
<td>Medical students, residents, nurses</td>
<td>3.2</td>
</tr>
<tr>
<td>Suwanpimolkul (2008)</td>
<td>91</td>
<td>10% PI (no kit)</td>
<td>ED and inpatients</td>
<td>Medical students, residents, nurses</td>
<td>6.9</td>
</tr>
<tr>
<td>Madeo (2008)</td>
<td>93</td>
<td>2% alcoholic CHG (no kit)</td>
<td>ED and 2 medical units</td>
<td>Not specified</td>
<td>2.1</td>
</tr>
<tr>
<td>Nuntanarumit (2013)</td>
<td>94</td>
<td>1% CHG (no kit)</td>
<td>Neonates</td>
<td>Medical residents</td>
<td>0.6</td>
</tr>
<tr>
<td>Nuntanarumit (2013)</td>
<td>94</td>
<td>10% PI (no kit)</td>
<td>Neonates</td>
<td>Medical residents</td>
<td>2.9</td>
</tr>
<tr>
<td>Kiyoyama (2009)</td>
<td>95</td>
<td>70% IPA (no kit)</td>
<td>ED</td>
<td>Medical residents</td>
<td>0.42</td>
</tr>
<tr>
<td>Kiyoyama (2009)</td>
<td>95</td>
<td>70% IPA and PI (no kit)</td>
<td>Inpatients</td>
<td>Medical residents</td>
<td>0.46</td>
</tr>
<tr>
<td>Washer (2013)</td>
<td>96</td>
<td>Alcohol pad scrub followed by 10% PI (no kit)</td>
<td>3 medical-surgical units</td>
<td>Phlebotomy team</td>
<td>0.58</td>
</tr>
<tr>
<td>Washer (2013)</td>
<td>96</td>
<td>Alcohol pad scrub followed by 2% iodine tincture (no kit)</td>
<td>3 medical-surgical units</td>
<td>Phlebotomy team</td>
<td>0.76</td>
</tr>
<tr>
<td>Washer (2013)</td>
<td>96</td>
<td>2% alcoholic CHG (no kit)</td>
<td>Adult inpatients</td>
<td>3 medical-surgical units</td>
<td>0.93</td>
</tr>
<tr>
<td>Washer (2013)</td>
<td>96</td>
<td>PI followed by 70% IPA (no kit)</td>
<td>Adult inpatients</td>
<td>Phlebotomy team</td>
<td>1.4-2.6</td>
</tr>
<tr>
<td>Gibb (1997)</td>
<td>97</td>
<td>2% PI followed by 70% IPA (no kit)</td>
<td>Pediatric ED</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Isaacman (1999)</td>
<td>98</td>
<td>2% PI followed by alcohol (no kit)</td>
<td>Pediatric ED</td>
<td>Nurses, phlebotomists, or physicians</td>
<td>1.7</td>
</tr>
<tr>
<td>Marlowe (2010)</td>
<td>99</td>
<td>3.15% alcoholic CHG (no kit)</td>
<td>Pediatric ED</td>
<td>Nurses, phlebotomists, or physicians</td>
<td>2.5</td>
</tr>
<tr>
<td>Marlowe (2010)</td>
<td>99</td>
<td>10% PI (no kit)</td>
<td>ED and inpatients</td>
<td>Phlebotomists, ED staff, nurses</td>
<td>2.7</td>
</tr>
<tr>
<td>Barenfanger (2003)</td>
<td>100</td>
<td>Iodine tincture (no kit)</td>
<td>ED and inpatients</td>
<td>Phlebotomists, ED staff, nurses</td>
<td>2.9</td>
</tr>
<tr>
<td>Barenfanger (2003)</td>
<td>100</td>
<td>2% alcoholic CHG (no kit)</td>
<td>ED</td>
<td>Nurses, licensed practical nurses, ED technicians</td>
<td>2.2</td>
</tr>
<tr>
<td>Tepus (2008)</td>
<td>101</td>
<td>2% alcoholic CHG (no kit)</td>
<td>ED</td>
<td>Nurses, licensed practical nurses, ED technicians</td>
<td>3.5</td>
</tr>
<tr>
<td>Tepus (2008)</td>
<td>101</td>
<td>Iodine tincture (no kit)</td>
<td>Adult ED</td>
<td>House staff, nurses, medical students</td>
<td>3.7</td>
</tr>
<tr>
<td>Strand (1993)</td>
<td>102</td>
<td>2% iodine tincture (no kit)</td>
<td>Adult ED</td>
<td>House staff, nurses, medical students, physician assistants</td>
<td>6.3</td>
</tr>
<tr>
<td>Strand (1993)</td>
<td>102</td>
<td>10% PI (no kit)</td>
<td>Adult ED</td>
<td>House staff, nurses, medical students, physician assistants</td>
<td>6.3</td>
</tr>
<tr>
<td>McEllan (2008)</td>
<td>103</td>
<td>2% alcoholic CHG (kit)</td>
<td>2 medical units</td>
<td>Junior doctors, doctor support workers</td>
<td>7.5</td>
</tr>
<tr>
<td>McEllan (2008)</td>
<td>103</td>
<td>70% IPA (kit)</td>
<td>2 medical units</td>
<td>Junior doctors, doctor support workers</td>
<td>8.9</td>
</tr>
</tbody>
</table>

**NOTE. Modified with permission from Cambridge University Press.**\(^{89}\) BCC, blood culture contamination; CHG, chlorhexidine gluconate; ICU, intensive care unit; IPA, isopropyl alcohol; PI, povidone iodine.
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%, 41.3%, 53.0%, and no decrease. 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.

**Sterile gloves**

Although it is widely accepted that most FPBCs originate during the preanalytic phase of laboratory testing, specifically specimen collection, 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. Blood was drawn via venipuncture by interns drawing blood via venipuncture were randomly assigned to use either sterile gloves or optional sterile gloving when repalpating 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 NHSN53 with normal oral flora, such as *Streptococcus* spp (eg, *S salivarius, S mutans, S sanguinis*), 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 (personal communication).

**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. 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. 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.” The issue of drawing BCs from CVADs with NCs is not addressed by either the CDC or IDSA in intravascular catheter guides.

**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.

**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. The CLSI’s guideline recommends that 70% IPA be used for disinfection. Disinfection of the tops of the BC bottles is also supported by many other expert organizations. 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%). Iodine products should not be used because it may erode the stopper material, potentially introducing contaminants.

**Volume**

Drawing the correct volume of blood is the single most important factor in maximizing the yield of true pathogens. The quantity of pathogens recovered increases in direct proportion to the volume of blood that is recovered. 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. 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. Recommended volumes of blood for culture, based on pediatric patient weight, have been published. 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. 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. 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.

**Order of draw**

To minimize contamination when collecting blood for multiple laboratory tests during a single procedure, blood for culture should be collected first.
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. Although the overall incidence of anaerobic bacteremia is low (approximately 4%) and may be decreasing, 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.” 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. In all studies, rates of recovery increased with the number of BC sets obtained, ranging from 73% with 1 BC set to 89% when 3 sets were obtained. Single BCs should never be drawn from adults; the present recommendation is to draw 2–3 sets per episode. 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.

Timing

The timing of BC collection does not appear to be a significant factor in the recovery of pathogens; however, recommendations have been published for different clinical conditions. 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.

<table>
<thead>
<tr>
<th>Author (year)</th>
<th>Reference</th>
<th>No. of EDs</th>
<th>Population</th>
<th>Patient exclusions</th>
<th>Study period (mo)</th>
<th>Personnel drawing BCs</th>
<th>Interventions</th>
<th>Draw via separate venipuncture</th>
<th>Survey to identify defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weddle (2011)</td>
<td>53</td>
<td>1</td>
<td>Pediatric</td>
<td>Central lines, immunodeficiency, &lt;40 wk, or growing a pathogen</td>
<td>12</td>
<td>NS</td>
<td>Y</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Self (2014)</td>
<td>71</td>
<td>2</td>
<td>NS</td>
<td></td>
<td>27</td>
<td>Nursing and phlebotomy</td>
<td>Y</td>
<td>Y</td>
<td>Y</td>
</tr>
<tr>
<td>Self (2013)</td>
<td>79</td>
<td>1</td>
<td>Adult</td>
<td></td>
<td>22</td>
<td>Nursing and paramedics</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Madeo (2005)</td>
<td>136</td>
<td>1</td>
<td>NS</td>
<td></td>
<td>27</td>
<td>Medical staff</td>
<td>N</td>
<td>N</td>
<td>Y</td>
</tr>
<tr>
<td>Lin (2012)</td>
<td>137</td>
<td>1</td>
<td>NS</td>
<td></td>
<td>27</td>
<td>Nursing</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Hall (2013)</td>
<td>138</td>
<td>1</td>
<td>Pediatric</td>
<td>Central lines, immunodeficiency</td>
<td>28</td>
<td>Nursing</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Dennó (2013)</td>
<td>139</td>
<td>2</td>
<td>Adult and pediatric</td>
<td></td>
<td>21</td>
<td>Nursing</td>
<td>N</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Harding (2013)</td>
<td>140</td>
<td>1</td>
<td>Adult and pediatric</td>
<td></td>
<td>15</td>
<td>Nursing and phlebotomy</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Marini (2013)</td>
<td>78</td>
<td>1</td>
<td>Pediatric</td>
<td>Central lines, indwelling devices including orthopedic hardware</td>
<td>12</td>
<td>Nursing and clinical assistants</td>
<td>Y</td>
<td>N</td>
<td>N</td>
</tr>
<tr>
<td>Skalkos (2014)</td>
<td>141</td>
<td>1</td>
<td>Adult and pediatric</td>
<td></td>
<td>26</td>
<td>Pre: nurses; post: nurses and phlebotomy</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
<tr>
<td>Taneja (2014)</td>
<td>142</td>
<td>1</td>
<td>Adult</td>
<td></td>
<td>26</td>
<td>Pre: nurses; post: nurses and phlebotomy</td>
<td>N</td>
<td>Y</td>
<td>N</td>
</tr>
</tbody>
</table>

BC, blood culture; CHG, chlorhexidine gluconate; ED, emergency department; IPA, isopropyl alcohol; N, no; NS, not stated; PI, povidone iodine; Y, yes.

1 Eliminated in a modified procedure at hospital B.

Product changed from 2% CHG, 70% IPA applicator to 3.15% CHG, 70% IPA swabstick.

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. Although the overall incidence of anaerobic bacteremia is low (approximately 4%) and may be decreasing, 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.” 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.

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between 5-mL discard samples and the second sample obtained for diagnostic culture.\textsuperscript{13} 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.\textsuperscript{13} 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.\textsuperscript{13} 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.\textsuperscript{13}

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.\textsuperscript{13} Table 3 summarizes studies that have reported successful strategies in reducing contamination rates and other associated outcomes in EDs.\textsuperscript{13} 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.\textsuperscript{13} 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 antiseptic drying times.\textsuperscript{13} 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 1.5% in 2 EDs. 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.

Mistakes 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 × 4 in] applicator for skin antiseptic, 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 pre-intervention 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%.

**Personnel**

The use of dedicated phlebotomy teams has been found in many studies to reduce BCC. In both the CAP Q-Ticks and Q-Probes studies, the BCC data indicated a statistically significant support for the use of dedicated phlebotomy teams 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. A meta-analysis of 5 trials representing broad sampling for reducing BCC, has evolved into a standard practice in healthcare.

**Compliance monitoring**

The only study identified in the literature concerning compliance with hospital protocol on BC collection was published in 2008. 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. The use of bundles for reducing BCC has been described in 4 recent studies. Roberts used a context-input-process-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 3.0%. Other unique aspects integrated into bundles include the use of standardized nursing protocols and changing NCs prior to drawing blood, 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. 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. 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>
<thead>
<tr>
<th>Policy element</th>
<th>Comment</th>
<th>Reference</th>
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<tbody>
<tr>
<td>Establish clinical indications for BCs</td>
<td>Consider adding selection list to EMR</td>
<td>CLSI11, ASM11, CDC44, ENA46, NHS47, IDSA63</td>
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<tr>
<td>Establish clinical indications for follow-up BCs</td>
<td>Consider adding selection list to EMR</td>
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<tr>
<td>Use a procedure checklist outlining critical elements in the process</td>
<td>A checklist can be used to identify adherence to established policy and for re-emphasis of accepted practice</td>
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<tr>
<td>Educate all persons collecting BCs</td>
<td>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</td>
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<tr>
<td>Program should start with assessment and intervention in the ED</td>
<td>EDs are associated with higher numbers of BCs and rates of BCC; EDs admit patients to all hospital services</td>
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<tr>
<td>Use a dedicated phlebotomy team when possible for collecting samples via venipuncture</td>
<td>Phlebotomy teams are associated with lower contamination rates; coverage should be provided for the ED in at least a part-time capacity</td>
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<tr>
<td>Draw blood cultures before administration of antibiotics</td>
<td>Antibiotics may suppress growth of true pathogens</td>
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</tr>
<tr>
<td>Collect via venipuncture rather than intravascular catheter</td>
<td>BCs collected via venipuncture are associated with lower blood culture contamination rates</td>
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<tr>
<td>Select a different venipuncture site for each BC set</td>
<td>Improves ability to recognize contaminants; second site draw requires separate hand hygiene procedure and new supplies</td>
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<tr>
<td>For suspected CRBSI, draw a set from catheter paired with a set obtained from a peripheral vein site</td>
<td>The definitive diagnosis of CRBSI requires a positive peripheral blood culture with concordant microbial growth</td>
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</tr>
<tr>
<td>Perform hand hygiene with soap and water or sanitizer prior to donning gloves</td>
<td>Hand hygiene solution packets may be provided in BC kits</td>
<td></td>
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<tr>
<td>Use a BC collection kit</td>
<td>Prepackaged kits enhance the standardization of the established hospital procedure</td>
<td></td>
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<tr>
<td>Use a closed blood collection system</td>
<td>Reduces potential for introducing microorganisms</td>
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<tr>
<td>After identifying collection site, disinfect the rubber septum of the BC bottles using 70% alcohol or an alcoholic chlorhexidine solution</td>
<td>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</td>
<td></td>
</tr>
<tr>
<td>Perform skin antisepsis: use either alcohol or tincture of iodine or an alcoholic CHG solution</td>
<td>Studies indicate that an alcoholic CHG solution is most effective in reducing BCC</td>
<td></td>
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<tr>
<td>Follow manufacturer’s instructions for application of antiseptic to skin</td>
<td>Maximal antiseptic effect is achieved when the solution is used as recommended</td>
<td></td>
</tr>
<tr>
<td>Follow manufacturer’s instructions for coverage area for specific product used</td>
<td>Maximal antiseptic effect is achieved when the solution is used as recommended</td>
<td></td>
</tr>
<tr>
<td>Follow manufacturer’s instructions for drying time for specific product used</td>
<td>Maximal antiseptic effect is achieved when the solution is used as recommended</td>
<td></td>
</tr>
<tr>
<td>Use of universal decontamination with 2% CHG cloths</td>
<td>Universal decolonization has been reported to reduce BCC in most studies</td>
<td></td>
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<tr>
<td>After skin disinfection, do not palpate the site again; if necessary use a sterile glove</td>
<td>Transfer of microorganism to the venipuncture site may occur when repalpating site with finger or when wearing nonsterile glove</td>
<td></td>
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<tr>
<td>Remove a needleless connector before drawing blood for culture from a catheter hub</td>
<td>Needleless connectors may harbor bacteria in internal mechanisms and therefore may be source of contaminant organisms</td>
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<tr>
<td>Disinfect the hub of the catheter lumen</td>
<td>Most effective disinfectant to use has not been studied; use a scrub the hub procedure using a disinfectant wipe (as per manufacturer’s instructions)</td>
<td>CLSI12</td>
</tr>
<tr>
<td>Collect appropriate volume of blood for adults and children</td>
<td>Collecting the correct volume of blood has direct impact on yield of true pathogens</td>
<td>ASM33, CDC34</td>
</tr>
<tr>
<td>Use diversion of initial volume when collecting blood via venipuncture</td>
<td>May prevent introduction of contaminant organisms contained on skin particles</td>
<td>ENA46</td>
</tr>
<tr>
<td>Inoculate BCs first before inoculation of other test vials</td>
<td>Minimizes risk of contamination when drawing blood for multiple tests</td>
<td>NHS47</td>
</tr>
<tr>
<td>Inoculate aerobic BC bottle first, anaerobic second (adults)</td>
<td>Important when volume of blood BC set is inadequate; most pathogenic organisms are identified from aerobic bottle</td>
<td>IDSA63</td>
</tr>
<tr>
<td>Collect 2-3 sets of BCs per episode (adults)</td>
<td>Maximizes the ability to identify true pathogens</td>
<td>Other reference</td>
</tr>
<tr>
<td>BC sets may be collected simultaneously</td>
<td>Evidence indicates that drawing BCs simultaneously does not affect microbial recovery</td>
<td>50,122</td>
</tr>
<tr>
<td>BCs should be inverted gently several times to prevent clotting</td>
<td>Clotting may inhibit recovery of organisms</td>
<td>128</td>
</tr>
<tr>
<td>Handle BC bottles at room temperature</td>
<td>Refrigeration or freezing may kill microorganisms</td>
<td>128</td>
</tr>
<tr>
<td>Transport BC bottles to laboratory within 2 h of collection</td>
<td>Increases ability to identify true pathogens</td>
<td>50,127</td>
</tr>
<tr>
<td>Use BC bottles with antibiotic binding agents</td>
<td>Optimizes recovery of organisms from samples taken from patients on antibiotics</td>
<td>128</td>
</tr>
<tr>
<td>Use a standard methodology (eg, CAP Q-Tracks) for calculating BCC as the standard and provide rates as feedback to all units</td>
<td>Establishes a baseline to gauge level of BC collection techniques</td>
<td>10</td>
</tr>
<tr>
<td>Use a laboratory baseline BCC rate of ≤3%</td>
<td>Identifies the need to implement quality improvement strategies</td>
<td>14,28,34-37</td>
</tr>
<tr>
<td>Provide tools to assist in interpreting positive BCs (eg, use of an algorithm)</td>
<td>Although there is no gold standard, institutions should review published information on this issue</td>
<td>71,78,97,136-147</td>
</tr>
<tr>
<td>Feedback to collector identified with contaminant BC</td>
<td>Private counseling has been reported to improve compliance with policy</td>
<td>138</td>
</tr>
<tr>
<td>Reward staff identified as collectors with zero BC contaminants</td>
<td>Rewards promotes positive accomplishments and assists in sustained improvement</td>
<td>148</td>
</tr>
<tr>
<td>Establish a compliance monitoring program</td>
<td>Periodically conduct monitoring to ensure elements of policy are at acceptable levels of compliance</td>
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</tr>
</tbody>
</table>

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. 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 suspected 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.

Acknowledgments

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