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Identification of the main contributors to blood culture contamination at a tertiary care academic medical center

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SUMMARY

Background: Blood culture contamination poses an issue to all hospital systems worldwide because of the associated costs of extended length of stays, unnecessary antibiotic therapy, and additional laboratory testing that are preventable with proper handling and collection techniques.

Methods: In our study, multiple units, staff, and collection methods were compared to determine the primary culprits of contamination from a tertiary care academic medical center, which includes a pediatric hospital and both adult and pediatric emergency departments.

Results: Over 33 months, 2,083 out of 88,322 total blood cultures collected were contaminated, with an overall contamination rate of 2.4%. A moderate positive correlation was found between the monthly total number of cultures and monthly contamination rate ($r = 0.411$ $P < .01$). The most notable factors associated with contamination were found to be phlebotomy teams (2.7%) ($P < .01$), peripheral draws (2.3%) ($P < .01$), adult emergency departments (2.6%) ($P < .01$), and pediatric intensive care units (2.7%) ($P < .01$). A positive correlation was present between the number of hospital beds per unit and unit contamination rates ($r = 0.429$ $P < .01$).

Conclusion: Our results were used to make recommendations for decreasing the rate of blood culture contamination in this institution, which includes acknowledgement of an overwhelmed staff and mandatory periodic training on acceptable aseptic technique and contamination awareness. Understanding the factors contributing to blood culture contamination can aid efforts to reduce contamination rates.

Introduction

Blood cultures are one of the most crucial clinical tests performed on patients because the results from this diagnostic test

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can determine if microorganisms are present in the bloodstream. Blood cultures are ordered when a patient is suspected of having sepsis, a condition resulting from dysregulation of the immune response which can cause organ failure and death [1]. Unfortunately, blood culture collection comes with risks, as some results may be inaccurate, appearing as a false positive result. False positive blood cultures, typically due to contamination of the culture, can lead to inaccurate diagnosis of a bloodstream infection and administration of unnecessary antimicrobial therapy compromising antimicrobial stewardship efforts [2], increased risk of *Clostridioides difficile* infection, increased risk of infections due to antibiotic-resistant organisms, and increased workload for staff and laboratorians [3]. Contamination may originate from skin microflora introduced into the culture due to poor aseptic technique and/or poor skin disinfection prior to blood collection [4]; from poor technique, poor hub disinfection, or extensive manipulation of an indwelling catheter if used to collect blood [5]; or sample mishandling in the laboratory [6]. According to CLSI guidelines, the contamination rate for a healthcare facility should be no more than 3%, but despite constant advances in medicine, contamination is a persisting problem [7]. The most common contaminants of blood cultures are the coagulase-negative Staphylococci, microflora found on the skin, most likely due to insufficient antiseptic technique. However, these bacteria can cause severe bloodstream infections, especially in immunocompromised patients, making it important but difficult to differentiate a contaminated culture from a bacteraemia [8]. With blood culture contamination (BCC) comes increased costs, unnecessary antibiotic treatment, and prolonged hospital stays [9].

Numerous factors are thought to be promoting these increasing BCC rates, as previous studies propose that insufficient staffing of dedicated phlebotomy teams, increased use of preexisting catheters to perform draws, and high patient volumes are the primary contributors of contamination [10—12]. BCC rates are frequently elevated in emergency departments (ED), due to the urgency of the majority of cases presented, patient dehydration, argumentative/combative patients, and unclean patients. One study by Robertson *et al*. found that the contamination rate of their ED BCC was 11.7%, significantly higher than that of any other department in the hospital, which averaged to about 2.5% [13]. BCC is also believed to be more common in pediatric patients, as blood cultures are so frequently used in febrile children to detect any sources of bacteremia, although more research is necessary to determine the cause(s) of increased contamination in pediatric departments [14]. Our study aims to examine BCC rates from a tertiary care academic medical center over a 33-month period to identify potential factors affecting contamination rates. Recommendations to reduce BCC rates will be made after identifying the factors contributing to BCC. Further, our multifaceted consideration of potential contributing factors will allow us to frame recommendations in a manner that specifies boundary conditions (e.g., do differences in BCC rates between ICU and ED patients hold for both pediatric and adult units?).

Methods

Data collection

Our study was conducted by observing 88,322 blood cultures from a 700-bed tertiary care academic medical center collected between June 1, 2018 and March 31, 2021. This medical center has two adult inpatient towers serving different patient needs (30 total units), a pediatric hospital (16 total units) with its own ED, a Level 1 trauma center, and a chest pain ED. A blood culture is defined as one blood specimen submitted for culture from one blood draw, regardless of how many bottles (BD BACTEC™ Plus Aerobic, Anaerobic, and Peds Plus™) the specimen is inoculated into. All blood cultures drawn through a peripheral vein or indwelling line were included in our data. In all hospital units excluding EDs, trained phlebotomists collected 11,325 (18.5%) of the blood cultures from peripheral sites only, and nursing personnel of varying skills ranging from certified medical assistants to registered nurses collected the remaining 49,733 cultures (81.5%). Laboratory data distinguished the method by which nurses collected blood, either from a peripheral site or indwelling line, total cultures drawn, and the number of contaminated cultures separated by hospital unit. All hospital departments excluding EDs and intensive care units (ICUs) are identified as acute care. This data was used to quantify the possible correlation between the total number of blood draws and the overall contamination rate and to compare the contamination rates of cultures collected by either nurses or phlebotomists, peripheral and line draws, and adult and pediatric departments using statistical analysis. The number of hospital beds per unit was compared with unit blood culture contamination rates to determine if a correlation was present between the two.

The protocol for blood culture collection at this facility requires an order from a clinician after clinical evaluation of the patient. A false-positive result was categorized by the presence of a non-pathogenic organism in a single blood culture that was introduced into the culture during specimen collection or laboratory processing, not truly present in the patient's bloodstream (Ref: CLSI M47-A) [7]. Examples of these microbes include but are not limited to *Bacillus* spp., *Corynebacterium* spp., *Cutibacterium* spp., *Staphylococci* spp. (not including *S. aureus* and *S. lugdunesis)*, and *Micrococcus* spp., all which are natural skin microflora. The recovery of the same potential contaminant from two blood cultures drawn within two hours of each other were considered pathogens and not included in these data.

Statistical analysis

In order to examine differences in BCC rates by characteristics, we conducted a series of chi-square analyses. As these comparisons were between a dichotomized dependent variable (contaminated or not contaminated) and dichotomized independent variables (nurse vs. phlebotomist, peripheral vs. line, and adult vs. pediatric department), chi-square tests were chosen and P values $< .05$ were considered statistically significant differences in observed distributions from expected distributions. Correlation coefficients are reported where applicable to describe linear relationships between variables (e.g., BCC rate and number of cultures obtained).

Results

During the study, 2,083 cultures were considered contaminated, representing 2.36% of all cultures collected (88,322). All units of the hospital and EDs collected an average

of 2,676 cultures per month. Over the 33-month period, a moderate positive correlation was found between the total number of cultures drawn each month and the monthly contamination rate (Figure 1). This finding was found to be significant using Pearson's correlation coefficient ($r = 0.411$, $P < .01$).

Units with more patient beds had statistically significant increases in blood culture contamination rates ($r = 0.429$, $P < .01$) (Figure 2).

While phlebotomists typically have lower BCC rates than nurses, in our study, phlebotomists were significantly more likely to have higher rates (2.7%) than nurses (2.2%) (X^2 (1) = 10.677, $P < .01$) (Table 1). In addition, the likelihood of contamination in cultures drawn by nursing personnel from a peripheral site was significantly higher (2.3%) than that of cultures drawn by nursing personnel from an indwelling line (1.3%) (X^2 (1) = 28.746, $P < .01$) (Table 1).

The average BCC rate during the entire study period for all non-ED units was 2.3%, with an average of about 1850 total cultures collected monthly, and EDs had an average of 2.6%, with about 826 cultures collected monthly. In the EDs, a total of 27,264 cultures were collected from 24,144 adults (88.6%) and 3,120 children (11.4%). As expected, the adult ED had significantly higher BCC rates (2.6%) than all other adult acute care units (2.4%) (X^2 (1) = 4.1218, $P < .05$) (Table 2 and 3). Similarly, the pediatric ED had higher BCC rates (2.2%) than pediatric acute care units (1.3%) (X^2 (1) = 9.991, $P < .01$) (Table 2 and 3). Adult EDs also had higher BCC rates (2.6%) than adult ICUs (2.0%) (X^2 (1) = 15.616, $P < .01$), but no significance was found in pediatrics (Table 2 and 3). In addition, when comparing acute care and ICUs, a significantly higher BCC rate was found in adult acute units (2.3%) than ICUs (2.0%) (X^2 (1) = 4.477, $P < .05$), however pediatric ICUs had remarkably higher BCC rates (2.7%) than pediatric acute care units (1.3%) (X^2 (1) = 26.063, $P < .01$) (Table 2 and 3).

BCC rates were compared from adult and pediatric intensive care, ED, and acute care units (Table 2); the adult hospital as a whole had significantly higher rates (2.4%) than the pediatric hospital as a whole (2.0%) (X^2 (1) = 6.266, $P < .05$) (Table 2). When comparing acute care units, adult units showed notably higher rates (2.4%) than pediatric units (1.3%) (X^2 (1) = 22.593, $P < .01$) (Table 2). However, pediatric ICUs showed increased contamination (2.7%) when compared to adults (2.0%) (X^2 (1) = 8.187, $P < .01$) (Table 2). No statistical significance was found between rates in adult and pediatric EDs.

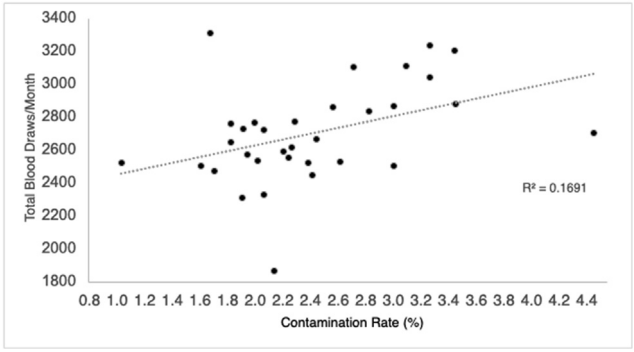

Figure 1. Relationship between the number of total blood cultures received and the rate of contamination. A positive correlation is present between total blood draws and their corresponding contamination rate over a 33-month period (r = 0.411, $P < .01$, N = 33). Cultures were collected from all adult and pediatric units in the hospital system, including emergency departments.

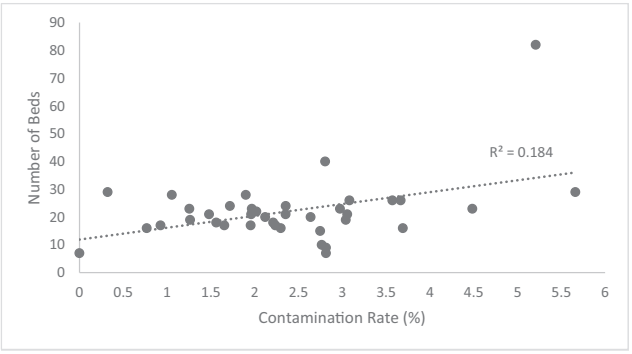

Figure 2. Correlation between the number of beds per unit and unit blood culture contamination rates. A positive correlation is present when comparing the number of patient beds per unit and the unit's blood culture contamination rate ($r = 0.429$, $P < .01$, $N = 38$ units). Units consisted of both adult and pediatric care as well as emergency departments.

Table 1
Contamination statistics for various staff groups and collection methods. Cultures were collected during a 33-month period from all units of the hospital, including pediatrics but excluding emergency rooms. Cultures drawn by nursing staff were collected by indwelling lines or peripheral draws. Chi-square analysis was used and $P < .05$ was considered significant

	Non-contaminated	Contaminated (%)	P - value
Phlebotomy	11,023	302 (2.7)	} < .01
Nursing	48,658	1,075 (2.2)	
Line	7,406	100 (1.3)	} < .001
Peripheral	41,252	975 (2.3)	

Discussion

Our data shows the factors leading to higher BCC rates were: the quantity of blood cultures drawn, the site where the blood culture is collected, the staff type collecting the blood culture, and the type of hospital unit of the patient. Previous research [4,9,10] has mostly focused on individual factors in each study, but here we are able to examine multiple contributing factors within the same study. Understanding the contributing factors to BCC is imperative to health care institutions for the purpose of accurately diagnosing patients, preserving hospital resources, and saving staff and patients time and money.

Over 33 months, this tertiary care academic hospital had an average contamination rate of 2.4%, considerably below the current CLSI guidance of no more than 3% [7]. This result was unexpected, as other similar studies based on academic hospitals had BCC rates of between 4-6% [15–17]. A moderate positive correlation was found between the total number of blood cultures drawn and BCC rates, showing that times of increased patient volume or larger workloads will lead to

Table 2
Contamination rates in various hospital units in adult and pediatric hospitals. All cultures were collected by nursing staff over a 33-month period, phlebotomist draws are omitted. Acute statistics included surgical, specialty, and acute units. Chi-square analysis was used and $P < .05$ was considered significant

	Adult		Pediatric		*P*-value
	Not contaminated	Contaminated (%)	Not contaminated	Contaminated (%)	Adult vs. Peds
Total	62,370	1,517 (2.4)	12,846	264 (2.0)	< .05
Acute	22,553	542 (2.4)	5,416	72 (1.3)	< .001
ICU	16,310	338 (2.0)	4,379	123 (2.7)	< .01
ED	23,507	637 (2.6)	3,051	69 (2.2)	= .157

Table 3
Adult and pediatric hospital units. Comparisons were made between adult and pediatric units. Chi-square analysis was used and $P < .05$ was considered significant

	Adult	Pediatrics
Acute vs. ICU	< .05	<.001
Acute vs. ED	< .05	< .01
ICU vs. ED	< .01	= .154

heightened BCC rates. This conclusion is supported by other sources, as there was a strong correlation between ED overcrowding and BCC rates [18] as well as the number of occupied hospital beds and BCC [19]. With this knowledge, it is best for hospitals to plan for additional staffing or at least emphasize staff training on the importance and proper performance of aseptic technique during extended periods of overcrowding when possible, as our data shows that a higher rate of collection of blood cultures contributes to higher BCC rates.

The number of beds in a hospital unit determines the patient capacity that can be handled on the unit, and more patients result in heavier workloads for hospital staff. Our study found a significant positive correlation between the number of beds in a unit and the unit's BCC rate. Pertinent to this facility where nursing personnel draw approximately 80% of blood cultures, an investigation by Liu *et al*. found that nurse to patient ratios higher than 7:1 resulted in more frequent risks to patient safety [20]. BCC poses a risk to patient safety, as a contaminated culture often leads to unnecessary antibiotic treatment and prolonged hospital stays [3]. It is essential that larger hospital units are aware of the nurse-to-patient ratio to ensure that nurses do not become overwhelmed, as contamination can become more frequent.

A common measure that medical facilities take to reduce their BCC rates is the implementation of a phlebotomy team. The removal of phlebotomy teams from one institution resulted in an immediate 3% increase in BCC, emphasizing their significant impact on the accuracy of physician diagnoses and health care costs [10]. However, our results contradict most others, as the phlebotomists had significantly higher rates of BCC (2.7%) than nursing staff (2.2%). This was not predicted because phlebotomists receive more extensive training on the aseptic techniques required to obtain a blood culture, and the process becomes extremely repetitive [2]. Phlebotomists also performed far fewer blood draws than nurses, conflicting with other findings from our study that more draws lead to more contamination. Nursing staff also tend to have higher BCC rates due to the fact that they not only perform blood draws from multiple sites including indwelling catheters, but they also have numerous other clinical responsibilities, completely unrelated to culture collection [21]. Further studies would be necessary to identify the root cause of higher BCC rates from phlebotomy staff, but the majority of evidence concurs that phlebotomy teams are highly likely to reduce BCC rates for more facilities, although there are some exceptions, with this facility being an example.

When comparing peripheral draws and central lines, relevant studies show that blood collection from central lines generally result in higher rates of contamination, likely due to the increased skin manipulation and time needed to complete the draw [4]. Our data analysis of draws found higher BCC rates in cultures collected from peripheral sites (2.3%) than in cultures collected from an indwelling line (1.3%), with peripheral draws used over five times (42,227) as often as line draws (7,506). The raised number of contaminated peripheral cultures may be a result of phlebotomy staff only collecting peripheral draws, while the nursing staff completed a combination of both peripheral and line draws. The most common cause of contamination of peripherally drawn cultures is inadequate skin preparation, causing coagulase-negative Staphylococci or other skin microflora to enter the sample when the skin is punctured [22]. Based on these findings, it may be recommended that additional training on aseptic technique and skin preparation for hospital staff can result in decreased BCC rates. This is supported by a 2014 study that found an extensive educational intervention on BCC in an ICU decreased contamination rates from 9.5% to just 3.7% in 19 months [23]. Another similar educational program in an ED contributed to a 7.4% decrease in contamination in only 6 months [13]. One method is not preferred over the other, as individual patient cases must be considered in order to choose the optimal method for blood collection, but the improvement from educational programs for hospital staff is demonstrably beneficial.

Numerous studies have demonstrated that BCC rates from EDs surpass those of other departments. One ED with a high BCC rate of 4.74% implemented a program that improved access to supplies and introduced educational sessions that assisted in lowering their BCC rates to 2.0% in only 12 months [24]. Our study showed higher BCC rates (2.6%) in the adult ED than adult acute units (2.4%), and similar results were found in pediatric acute (1.3%) and ED (2.2%) units. Min *et al*. compared the pediatric ED to all other general wards of the pediatric hospital, and found higher BCC rates in the ED (1.32%) than other wards (0.66%), but also found an increase in BCC with a decrease in children's age [14]. Other studies recommend that implementation of proper aseptic protocols and strong implementation of collection techniques with all necessary precautions will decrease BCC rates in EDs. Because microbes are

present in hair follicles, sebaceous glands, and deeper layers of the epidermis, topical antiseptics are unable to eradicate all of these microbes. Skin fragments can be dislodged during venipuncture, potentially resulting in contaminated cultures [25]. Diversion of the first portion of the blood and culturing of the remaining blood can significantly reduce false positive blood cultures to below 1%. Use of a commercially available initial diversion device implemented in this facility's adult ED almost 3 years prior to our study successfully reduced BCC rates from 4.5% to approximately 2% that was maintained until the beginning of our study.

In addition, BCC rates from the ICU were compared to rates in the ED, two departments in which patients heavily rely on indwelling catheters for administration of fluids and medication and are also at highest risk of bloodstream infections. Significantly higher BCC rates were present in the adult ED (2.6%) when compared to the ICU (2.0%), although no remarkable results were found in the pediatric hospital. When acute care and ICUs are compared, most studies find that ICUs have notably higher BCC rates than other hospital departments because orders for blood cultures are more frequent due to the escalated risk of sepsis for patients with indwelling central venous catheters, used in 48% of ICU patients [26,27]. Our results from the pediatric ICU support this claim with their heightened BCC rates, 2.7% in the ICU and 1.3% in all acute units. Other pediatric ICUs have also shown heightened rates of BCC, as a neonatal ICU study by Hashamizadeh *et al*. reported rates as high as 8.47% [28]. Pediatric BCC rates are expected to be elevated because of the many challenges associated with blood collection from anxious young patients, an almost inevitable difficulty. However, results from the adult hospital differed; the adult ICU had a BCC rate of 2.0%, significantly lower than acute care units (2.4%). This unexpected result could be due to extensive disinfection precautions used to manipulate a central venous catheter and the increased risk of sepsis posed to ICU patients with invasive devices [4,29]. It would also be interesting to monitor differences in infection control practices between units. It is possible that different units have varying levels of compliance with infection control practices due to differences in training, access to hand washing stations or hand sanitizer, frequency of hand hygiene, or staff: patient ratios. During the 33-month study period, this facility did not experience significant supply chain issues related to overall availability of blood culture bottles, antiseptics, PPE, and hand sanitizer, although a variety of hand sanitizers containing 70% alcohol were used. It is important to note that data collection spanned before and during the COVID-19 pandemic, which could have contributed to BCC rates due to staffing changes, increased patient loads, and changes in procedures.

Few studies have directly compared BCC rates between pediatrics and adults, but similar analyses show higher rates in pediatric patients, likely due to increased frequency of indwelling catheters in pediatric patients and complications that arise during insertion [8,30]. BCC rates were found to be higher in the pediatric ICU (2.7%) than they were in the adult ICU (2.0%), but no significant results were found when comparing adult and pediatric EDs. Our results also reflected elevated BCC rates in the adult hospital (2.4%) as opposed to rates in the pediatric hospital (2.0%). These results were also consistent throughout adult acute care units (2.4%) and pediatric acute care units (1.3%). Increased contamination rates in the adult hospital are most likely a result from insufficient antiseptic technique for skin preparation before skin puncture and blood collection, which can be decreased with more specialized training on aseptic technique.

Based on the findings that increased number of cultures, phlebotomy staff, peripheral draws, the adult ER, and pediatric ICU had the highest BCC rates in this institution, changes can be made to improve their rates, although it is important to note all contamination rates were well within the currently accepted 3% rate. However, when best practices for blood culture collection are rigorously followed, a BCC rate as low as 1% could be achieved, which would significantly enhance patient care and reduce healthcare costs (3). Educational interventions are proven to be effective in the reduction of BCC rates, as a study by Eskira *et al*. found that implementation of additional training courses in two institutions resulted in decreases in rates from 5.7% and 7.1%—1.95% and 6.7%, respectively [31]. For this facility, additional training for the phlebotomy staff specifically geared towards the aseptic technique used to perform peripheral draws would be beneficial as one of the leading causes of BCC is insufficient antiseptic contact time on the skin before puncture [32]. Consistent use of skin aseptic technique protocols by all staff collecting blood cultures may alleviate some of the variance in BCC rates between staff types. Specialized collection devices, such as initial diversion devices, may also be considered as a method of reducing contamination events [33]. Hand hygiene is also important in preventing BCC events. The World Health Organization launched its "Save Lives: Clean your Hands" initiative in 2009 [34]. The program aims to improve hand hygiene in healthcare workers to aid in prevention of HAIs, but would also reduce the rate of BCC. As part of this program the 5 moments for hand hygiene are stressed, which provide a defined list of times healthcare workers should perform hand hygiene. These 5 moments include before touching a patient, before aseptic procedures, after exposure, after touching a patient, and after touching patient surroundings. While performance of hand hygiene is universally recommended, its effectiveness is hard to assess in the reduction of BCC rates because hand hygiene is usually included in practice intervention "bundles" along with use of sterile gloves, blood culture collection kits, education/training, and other interventions (3). Supplemental instruction for the hospital staff may result in decreased BCC rates, as well as money and resources saved. Studies have shown adding instructional materials periodically may reduce contamination events [35]. Even short educational videos or more frequent email messaging can improve BCC rates. It is also imperative to maintain an acceptable patient-to-staff ratio, as the number of hospital beds as well as the number of cultures collected have an effect on BCC rates, which may be a result of overwhelmed staff, but additional research on the comparison between hospital staff and patient volume is necessary.

Several limitations of our study were presented during the research process, as the data that was collected restricted the variety of analyses to be performed. Differences in procedural methods and appropriate use of antiseptics between hospital units may have been present, especially regarding the adult and pediatric hospitals. An additional limitation is that BCC was identified based on the organism isolated and some cases could be wrongly identified as being contaminated but are indicative of true infections. In future studies, it would be beneficial to inspect the patient-to-staff ratio to determine when collection of blood cultures is optimal to prevent contamination. This is

especially important in overcrowded hospitals during the ongoing COVID-19 pandemic, when patient volumes have been at their peak [36]. Further research could survey various antiseptics and collection kits from several institutions that have provided their hospital staff with substantial, recurring training on proper blood culture collection technique necessary to effectively lower contamination rates.

Credit author statement

Brianna Sacchetti-methodology, formal analysis, writing-original draft, **Just in Travis**-methodology, formal analysis, writing-review & editing, **Lisa L. Steed**-conceptualization, methodology, data curation, writing-review & editing, **Ginny Webb**-methodology, formal analysis, investigation, writing-original draft, writing-review and editing, supervision, project administration, funding acquisition

Conflict of interest

The authors have no conflicts of interest to declare.

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