Quality Improvement

Enhancing Patient Safety: The Role of Interdisciplinary Teams in Reducing Blood Culture Contamination

Austin Patrick Eisenberg, DO[1]; Fady M Awad, DO[1]; Brian Watson, MD[1]; Mohammed Faris, MD[1]

Author affiliations are listed at the end of this article.

Correspondence to:
Austin Patrick Eisenberg, DO
(austin.patrickeisenberg@hcahealthcare.com)

Abstract

Background
Blood cultures are vital to diagnostic workups among many hospitalized patients, providing valuable information about bloodstream infections (BSIs), which cause roughly 250 000 deaths annually between North America and Europe. Despite advances in health care, blood culture contamination remains a substantial problem, with deleterious effects on patient mortality, patient and hospital costs, and microbial resistance. This article reviews the repercussions of blood culture contamination on the health care system and delineates evidence-based strategies to decrease contamination rates.

Methods
To reduce blood culture contamination rates, our health care facility undertook a quality improvement initiative. A task force was created, consisting of leadership from the laboratory, phlebotomy, nursing, pathology, internal medicine teams, emergency medical services, and others. Measures included comprehensive staff training, standardization of protocols and supplies across facilities, and the introduction of waste tubes and smaller-volume chlorhexidine applicators for skin preparation. Data on blood culture contamination rates were collected before and after implementation.

Results
Prior to the intervention, the average monthly blood culture contamination rate across our facilities was 3.76%. Following the intervention, this rate decreased significantly to 2.07%, representing a reduction of 44.95%. Statistical analysis revealed a strong association between the implemented interventions and the decreased contamination rates, with a chi-square value of 62.3, 1 degree of freedom, and a *P* value of less than .001. These results indicate that the interventions were highly effective. Furthermore, the reduced contamination rates were sustained in the subsequent months, consistently remaining below 2%.

Conclusion
The study demonstrated a substantial reduction in blood culture contamination rates through targeted interventions, highlighting the efficacy of combining evidence-based strategies with interdisciplinary teamwork to improve patient care outcomes.

Keywords
blood/microbiology; bacteremia; bacteremia/diagnosis; bacterial infections; blood culture; bloodstream infections; cross infection; equipment contamination; infectious disease; quality improvement

Introduction
Blood cultures are pivotal in identifying bloodstream infections and guiding clinicians in appropriate treatment decisions. However, contamination undermines the reliability of results, leading to misdiagnosis and potential harm to patients. This article briefly reviews the effects of blood culture contamination on the health care system and presents current evidence-based strategies to reduce its prevalence.

The presence of bacteria in the bloodstream is referred to as bacteremia, and persistent bacteremia, also known as bloodstream infections (BSIs), is linked with significant mortality.[1,2] Between North America and Europe, approximately 250 000 patients die annually due to BSIs.[2,3] The gold standard for diagnosing BSIs is obtaining blood cultures.[1] Despite advances in health care, contamination of blood cultures remains a substantial problem, with approximately one-third to one-half of positive blood cultures representing contamination.[4,5] The 2 general metrics used to define blood culture contamination are as follows: "the percentage of all positive blood cultures that yield organisms judged to be contaminants (ie, overall blood culture contamination rate), or the percentage of all blood cultures obtained that are contaminated."[5]

Blood culture contamination ranges from 2% to 10% during emergency department and inpatient care.[6] False positive blood cultures have many consequences, such as more protracted hospital stays and thus increased risk of nosocomial infections, exposure to unnecessary antibiotics, which in turn can result in increased antibiotic resistance, increased cost for the patient, and an increased strain on the laboratory, phlebotomy, nursing, and pharmacy teams.[4,7] The standard for blood culture contamination is less than 3%, as recommended by the Clinical and Laboratory Standards Institute.[8,9]

Common organisms deemed to be contaminants are coagulase-negative *Staphylococci* (CoNS), *Propionibacterium spp*, *Micrococcus spp*, *Cutibacterium*, *Corynebacterium spp*, and *Bacillus spp*, other than *Bacillus anthracis*.[4,5] Common pathogens that should always raise concern for a true BSI include *Staphylococcus aureus*, *Streptococcus pneumoniae*, *Escherichia coli*, *Enterobacteriaceae*, *Neisseria spp*, *Haemophilus influenzae*, *Pseudomonas aeruginosa*, and *Candida albicans*.[4]

Blood culture contamination carries substantial consequences across many facets of the health care system. Our utmost responsibility is to patient care, and contaminated blood cultures increase the patient's length of stay, exposure to unnecessary antibiotics, cost, and overall mortality.[6,10-12] A study by Alhamadi et al demonstrated that blood culture contamination in hospitalized patients increased the length of stay by 5.4 days on average and increased the cost to the patient by roughly $7500.[12] In a study published in 2015 by Van der Heijden et al, patients were treated with antibiotics for an average of 7 days for a contaminated blood culture.[13] Exposure to unnecessary antibiotics has many unintended side effects. It increases the risk of drug reactions and organ toxicity, disrupts the host microbiome, and increases antimicrobial resistance.[13] Contamination also increases the workload for the laboratory, phlebotomy, nursing, and pharmacy teams.[5,6,11]

Numerous methods are commonly used in hospitals across the United States to decrease blood culture contamination. Notable examples include comprehensive training programs on proper blood collection techniques and aseptic practices, developing and enforcing standardized protocols for blood culture collection, creating quality assurance programs, utilizing chlorhexidine gluconate swabs for skin preparation, using continuously monitored blood culture systems, amongst many others.[5,13,14] By implementing several methods, our facility significantly reduced the percentage of blood culture contamination by greater than 40%, from an average of 3.76% of patients to 2.07%, and maintained this reduced percentage for 7 months and continued at this rate until the time of this writing.

Methods

During the fall of 2023, our facility began implementing numerous measures to reduce blood culture contamination. A quality improvement team was assembled with leadership from the laboratory, phlebotomy, nursing, pathology, internal medicine teams, emergency medical services (EMS), and others. Laboratory leaders collected blood culture data regarding blood cultures from our main hospital, stand-alone emergency departments, and patients brought in via EMS for the 6 months prior to the start of this project. Utilizing the hardware/software from MobiLab Solutions, blood cultures obtained were linked with the staff member who drew them. The data were separated by geographic location where it was drawn, whether the staff member was part of the phlebotomy, nursing, or another team, and who the staff member was. Microsoft Excel was used for the statistical data analysis, including the chi-

square analysis. Pre-intervention and post-intervention contamination rates were compared to assess the effectiveness of the implemented procedural changes.

The criteria our facility used to define blood culture contamination was as follows: the organism is commonly considered a contaminant, (ie, CoNS, *Propionibacterium spp*, *Micrococcus spp*, *Cutibacterium*, *Corynebacterium spp*, and *Bacillus spp*, other than *Bacillus anthracis*), and that the organism appeared in only 1 of 2 sets of cultures (ie, 1 aerobic and 1 anaerobic bottle). If the organism appeared in both blood culture sets (ie, all 4 bottles), it was considered true bacteremia.

Nursing and phlebotomy leadership provided facility-wide formal education for staff that routinely draw blood cultures. This included proper techniques and protocols, such as skin preparation and appropriate aseptic technique, venipuncture, the number of vials and blood volume to draw, and the use of a waste tube for the first 1-3 cc of blood drawn for each set of blood cultures. To facilitate a more accessible collection of blood cultures and adherence to new policies, collection kits were assembled, which included 2 sets of blood culture bottles (2 aerobic and 2 anaerobic) premarked to the appropriate fill line, two - 3 mL white top waste tubes, two - 1 mL chlorhexidine applicators, and 6 alcohol wipes.

Blood draws for cultures were drawn by fresh intravenous (IV) sticks using the new sterile methods documented previously but were also drawn from existing central venous catheters. Hospital policy prohibits blood culture collection from peripheral IV sites. Waste tubes were used to discard the initial 1-3 cc of blood and were sent down to the laboratory with the other vials to ensure they were being used. Waste tube usage was tracked with a goal of greater than 90% usage, with actual usage being roughly 98%. This study used all blood culture data obtained, including from medical and surgical intensive care units (ICUs), the primary emergency department, all freestanding emergency departments, medical and surgical floors, obstetric floors, and pediatric floors. The analysis included all adult and pediatric patients, although adult and pediatric contaminations were not separated within the data. Data were separated by hospital location, although not delineated by peripheral IV versus central venous catheter draw.

Before the start of this project, our facility had a dedicated phlebotomy team on the medical/surgical floors of our main hospital, which has been shown to decrease blood culture contamination.[6,12,14] Leadership from the phlebotomy department assembled a phlebotomy team specifically for the emergency department to assist nurses in blood draws.

This quality improvement project was reviewed by the facility's Institutional Review Board and was determined exempt from oversight.

Results

The implementation of new procedures commenced in the fall of 2023, and an assessment of the blood culture contamination rates was conducted for the periods before and after these changes. Training and re-education of staff members occurred throughout this time, with roughly 220 emergency department nurses, 30 phlebotomists, and 100 ICU nurses involved. Between March 2023 and August 2023, the average monthly blood culture contamination rate was 3.76% (±0.56%), with 409 contaminated cultures out of a total of 10 904 collected cultures during this period. Following the implementation of new procedures, from September 2023 to March 2024, the average contamination rate decreased to a monthly average of 2.07% (±0.69%), with 269 contaminated cultures out of a total of 13 092 collected cultures. This represents a notable 44.95% reduction in blood culture contamination rates following the implementation of the new procedures. This decrease in contamination rates is illustrated below in **Figure 1**, with month-by-month figures included in **Table 1**.

Before the implementation, the monthly average of positive blood culture was 1817 (±154), and 1870 (±148) post-implementation. Concurrently, the average monthly contaminations decreased significantly from a pre-implementation monthly average of 68 (±9) to a post-implementation monthly average of 34 (±11).

Statistical analysis demonstrated a strong association between the intervention and the reduction in contamination rates. The chi-

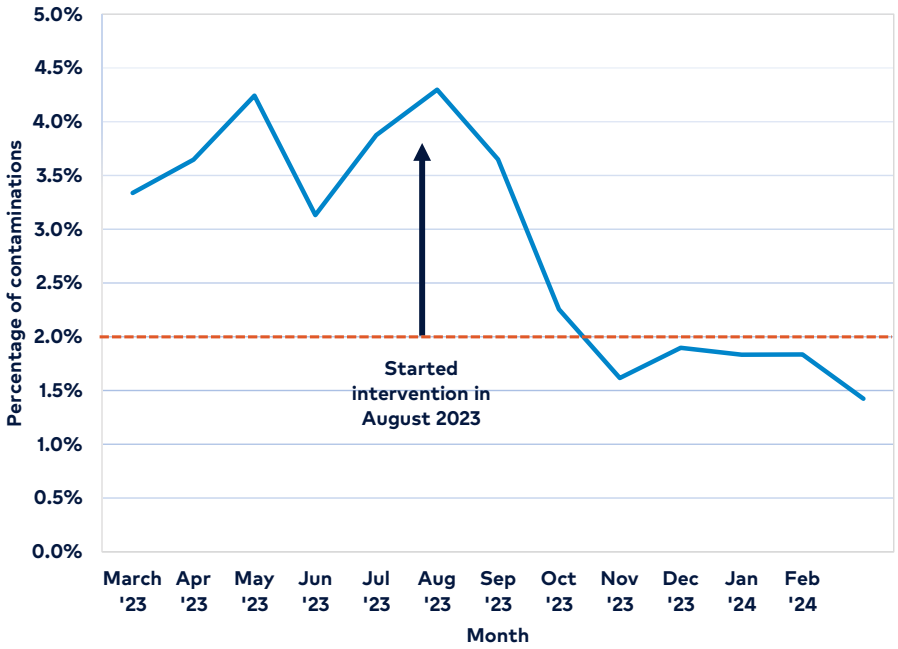

Figure 1. A line graph delineates the percentage of blood culture contamination per month for 12 months, with the solid blue line representing the trend of the percentage of contaminations per month. The horizontal orange line at 2.0% represents the goal maximum contamination rate.

square test yielded a value of 62.3 with 1 degree of freedom. According to the chi-squared distribution table, a chi-square value of 62.3 with 1 degree of freedom exceeds the critical value of 10.83 at the .001 significance level. Therefore, the corresponding *P* value is less than .001, indicating a highly significant result.

The chi-square test assesses whether the observed frequencies of contamination rates differ significantly from what would be expected by chance alone. In this case, the high chi-square value strongly suggests that the observed reduction in contamination rates is not due to random variation but is a direct result of the implemented procedural changes.

Outcomes were further analyzed based on health care location, specifically the emergency department, ICU, and medical/surgical floors, to determine which location was most impacted by the interventions. The emergency department was expected to have the greatest impact due to the lack of phlebotomy support, a factor substantiated by multiple publications focused on this setting.[6,15,16] Data were analyzed based on the number of contaminated blood cultures against the number of *positive* blood cultures. Analyzing contamination rates based on the number of positive cultures, rather than total cultures, provides more meaningful insight. This approach focuses on relevant cases, where an infection is confirmed, reducing the noise from negative results. It enhances accuracy by targeting clinically significant cases, helps in pinpointing areas for improvement, and allows for better comparison across different departments. Although analyzing total cultures offers a broad overview, focusing on positive cultures ensures targeted and effective con-

Table 1. Percentages and Quantities of All Blood Cultures Deemed Contaminants From March of 2023 Through March 2024

Month	Mar '23	Apr '23	May '23	Jun '23	Jul '23	Aug '23	Sep '23	Oct '23	Nov '23	Dec '23	Jan '24	Feb '24	Mar '24
Total number blood cultures	1588	1809	1650	2043	1883	1931	1726	1774	1795	1951	2182	1908	1756
Total number contaminated	53	66	70	64	73	83	63	40	29	37	40	35	25
Percent contaminated	3.34%	3.65%	4.24%	3.13%	3.88%	4.30%	3.65%	2.25%	1.62%	1.90%	1.83%	1.83%	1.42%

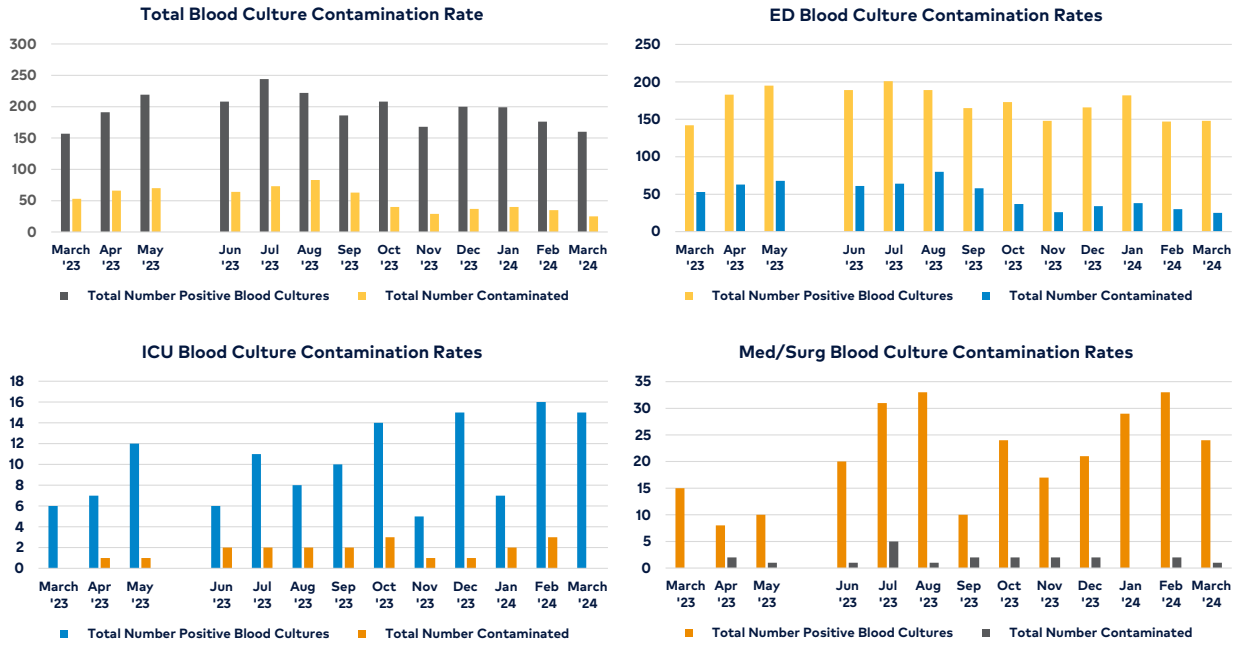

Figure 2. Bar graphs delineate the number of positive blood cultures versus blood culture contaminant per month for 13 months.

tamination control across different departments, as illustrated in **Figure 2**.

- Emergency Department: Of all positive blood cultures, the rate of contaminants decreased from 35.4% to 22.0%, indicating a 37.9% reduction.
- Intensive Care Units: Of all positive blood cultures, the rate of contaminants decreased from 16.0% to 14.6%, indicating an 8.5% reduction.
- Medical/Surgical Floors: Of all positive blood cultures, the rate of contaminants decreased from 8.5% to 7.0%, indicating an 18.5% reduction.

These results indicate that the emergency department saw the most significant improvement, likely due to the greater initial contamination rates and lack of dedicated phlebotomy support. While smaller, the observed reductions in the ICU and medical/surgical floors represent meaningful improvements in blood culture contamination rates.

The significance of these findings is substantial, as maintaining our facilities' contamination rates below 2% has important implications for patient care and hospital efficiency. Reduced contamination rates decrease the likelihood of false-positive results, which can lead to unnecessary treatments, increased health care costs, and prolonged hospital stays. By effectively reducing contamination rates to less than 2%, despite a national goal of less than 3%, the intervention enhanced the accuracy of blood culture diagnostics and improved overall patient outcomes and operational efficiency.

Discussion

A blood culture contamination reduction task force was established to address the issue of excessive blood culture contamination. Identifying and refining several flaws in the blood culture collection process have significantly contributed to a marked reduction in blood culture contamination rates. This discussion focuses on the key changes and implementations made in response to the identified flaws, emphasizing their impact on improving the overall integrity of blood culture samples.

One of our several changes involved using waste tubes during venipuncture for blood draws. By providing clear guidelines on when waste tubes were permissible and ensuring their proper application, the risk of introducing contaminants into blood culture samples was minimized, resulting in a more accurate representation of the patient's bloodstream.

The presence of different policies addressing blood culture collections, each with different recommendations for scrub time and drying time, highlighted the need for standardization. A key adjustment was made to the policy regarding chlorhexidine applicator volume and drying time. The applicator size was reduced from 3 mL to 1 mL, allowing staff to align its use with the chlorhexidine manufacturer's guideline of a 30-second scrub and a 30-second drying time. This standardization provided clarity for health care personnel and ensured a reliable and uniform approach to blood culture collection, reducing the likelihood of procedural errors.

To decrease blood culture contamination rates, staff underwent comprehensive training facilitated by nursing and phlebotomy leadership. This included formal education sessions on proper skin preparation, aseptic technique, and venipuncture procedures, emphasizing the use of fresh IV sticks and avoiding draws from existing IV sites or central venous catheters. Staff were also trained on the appropriate use of waste tubes to discard the initial 1-3 cc of blood, reducing contamination risks. Standardized protocols were established, including a 30-second scrub and drying time with chlorhexidine, to ensure uniform practices. Premade blood culture collection kits were provided, containing necessary supplies to support adherence to these protocols. Additionally, the MobiLab Solutions software was utilized to track staff involvement in blood draws, enhancing patient identification accuracy and accountability. Staff identified as needing further training received targeted support to improve compliance and technique, contributing to the overall reduction in contamination rates.

In response to the identified issue of blood culture contamination, we utilized a software solution (MobiLab Solutions) to track staff involvement in blood draws. MobiLab Solutions allows staff members to scan a patient's wristband before drawing labs, and it will subsequently print patient-specific labels for the lab orders entered by a provider. When sent to the lab, these printed labels are adhered to the blood draw vials, increasing patient identification accuracy. This approach also allowed us to efficiently identify staff members responsible for each blood culture draw, enabling us to pinpoint recurrent instances of contamination. The utilization of MobiLab allowed staff to log in to the handheld device for individual blood draws and thus facilitated the recognition and monitoring of individuals who required additional training or support in adhering to our new blood culture collection protocols. By streamlining the process of logging blood draws, we gained valuable insights into individual performance and were able to address any patterns of repeated contamination effectively. Utilizing MobiLab has proven instrumental in improving accountability and promoting adherence to proper blood culture collection protocols among staff, ultimately contributing to the overall reduction in contamination rates.

Prior to the implementation, the average number of positive blood cultures per month was 1817 (±154), which increased slightly to 1870 (±148) after the implementation. Meanwhile, the average monthly contaminations significantly decreased from 68 (±9) before the implementation to 34 (±11) afterward. The effects of these implementations showed variation depending on the location within the hospital, with the emergency department seeing the largest decline in blood culture contaminants. Emergency departments saw a 37.9% decrease in contamination rate. Intensive care units saw a decrease of 8.5%, and medical/surgical floors saw a decrease of 18.5%.

While the observed decrease in contamination rates is indeed promising, it's essential to acknowledge that statistical significance remains a consideration, as indicated by the chi-square analysis. This recognition underscores the complexity of health care environments and the multifaceted nature of factors impacting blood culture outcomes. While the implemented changes have undoubtedly contributed to the reduction in contamination rates, other variables may also be at play, necessitating continued monitoring and data collection to ascertain the sustained effectiveness of the interventions over time. At the time of this analysis, contamination rates have consistently remained below 2.00% for 5 months. We anticipate that this trend will persist, establishing a new average contamination rate of less than 2%.

Besides the clinical implementations, the financial implementation of blood culture contamination is substantial. Patients with contaminated blood cultures had experienced an average hospital stay that was 5.4 days longer (95% confidence interval [CI], 2.8-8.1) and incurred higher hospital costs of $7502 (95% CI, $4925-$10 078) per patient. Additionally, pharmacy costs per patient increased by $95 and laboratory costs by $61.[12] A comparative study conducted in St. Louis, Missouri,[17] similarly demonstrated that patients with contaminated blood cultures had significantly higher total hospitalization costs, including a $4100 increase (95% CI, $740-$7400) in total costs, a $700 increase (95% CI, $20-$1400) in antimicrobial costs, and a $330 increase (95% CI, $140-$300) in laboratory costs. While the increase in length of stay in that study was not statistically significant, the economic burden of contaminated blood cultures underscores the importance of minimizing contamination through improved collection protocols.

Continuous data collection and analysis are imperative to gain a more comprehensive understanding of the continued effectiveness of our interventions. Extended monitoring will provide a clearer picture of the sustained impact of the implemented changes, facilitating a more accurate evaluation of the long-term effectiveness of our strategies in minimizing blood culture contamination rates. Continuous vigilance, data collection, and analysis will remain instrumental in refining our protocols and ensuring ongoing improvements in patient care and laboratory practices.

Limitations

Several limitations exist regarding this study, including that it was a single-center study with a limited data time frame, potential confounding variables, and outcome measures. Since this study was conducted within a single health care facility, this could limit the generalizability of the findings to other settings with potentially different resources, patient populations, pharmacy costs, and staffing structures. This study covered 6 months prior to intervention and 7 months after intervention. Although this study has demonstrated a consistent and significant decrease in contamination rates over a 7-month period, it may not capture the further sustainability of these implemented changes. Additionally, a longer follow-up may better assess long-term trends or cyclical variations in blood culture contamination rates.

Despite efforts to implement standardized protocols and training, inherent biases or variations in adherence to new procedures among staff members may have influenced any results obtained from this study. A limiting factor is that the points in time when specific technique changes were implemented (eg, waste tubes) were not explicitly recorded. Thus, the actual effect of these techniques cannot be differentiated from the whole. Other unmeasured confounding variables, such as underlying disease severity, patient presentations, characteristics, or environmental factors, such as emergency department crowding, could also impact blood culture contamination rates. While the primary outcome of this study focused on blood culture contamination rates, other relevant endpoints, such as clinical outcomes (eg, mortality, length of stay, etc), the burden on staff, or patient satisfaction, were not assessed. Therefore, the full impact of contamination reduction efforts on patient care and health care utilization remains to be determined.

Implications

This study provides valuable insights into effective strategies for reducing blood culture contamination rates. These insights can inform clinical practice and quality improvement initiatives in health care facilities. Implementing comprehensive training programs, standardized protocols and supplies, and dedicated phlebotomy teams can enhance the integrity of blood culture results and optimize patient care. Health care institutions may consider allocating resources to improve blood culture collection practices and implement quality assurance programs to minimize contamination rates. While initial investments may be required, the potential cost savings associated with reduced unnecessary antibiotic use and health care-associated infections could outweigh the expenditures in the long run.

This study's success in reducing contamination underscores the importance of interdisciplinary collaboration among health care professionals, including laboratory staff, nurses, phlebotomists, and quality improvement teams. Establishing clear communication channels and

promoting teamwork are essential for implementing and sustaining effective interventions. Further research is warranted to validate the findings of this study in diverse health care settings and explore additional interventions for minimizing blood culture contamination. Longitudinal studies with extended follow-up periods and robust outcome measures are needed to assess the long-term impact and sustainability of contamination reduction strategies on patient outcomes and health care utilization. Additionally, qualitative research methods could provide deeper insights into the barriers and facilitators of implementing such interventions in clinical practice.

Conclusion

The comprehensive changes and implementations made in response to the identified flaws in our procedures collectively contributed to a significant 44.95% reduction in blood culture contamination rates. The chi-square analysis strongly supports that this reduction was not due to random chance but was likely a direct result of the procedural improvements. These adjustments underscore our commitment to evidence-based practices and highlight the potential for sustained improvements in patient care outcomes through the identification and targeted rectification of procedural flaws in blood culture collection processes. The highly significant results demonstrate that effective interventions can lead to substantial and reliable improvements in clinical practice, ultimately enhancing patient safety and care quality.

Acknowledgments

We would like to extend our deepest gratitude to the following individuals for their invaluable contributions to the blood culture contamination reduction task force: Tamara Cox, MSN, RN; Nora Bardocz BSN, RN; Nathan Holben, LPN; Chad Cox NREMT-P, FP-C; Ashton Lackey BSN, RN; Candace Burch MLS (ASCP)cm SM; Tommonica Dunham, MPH, MLS(ASCP)cm, BSMLS, BSB; Hope Wallace, BSMT (ASCP); Betsy Chase, RN, BSN, MBA, CIC; Tim Pollock Asst Director of Supply Chain; Katina Brown Phlebotomy Supervisor; Sally Ogot MS, CLS MLS (ASCP); Aurora Mitchell BSN, RN, CEN Each of these individuals brought unique skills and perspectives to the project, and their collaborative efforts were instrumental in significantly reducing blood culture contamination rates at our facilities. We sincerely appreciate their dedication and hard work to improve patient care. Without them, none of this would have been possible.

Conflicts of Interest

The authors declare they have no conflicts of interest.

The authors are employees of Grand Strand Medical Center, a hospital affiliated with the journal's publisher.

This research was supported (in whole or in part) by HCA Healthcare and/or an HCA Healthcare-affiliated entity. The views expressed in this publication represent those of the author(s) and do not necessarily represent the official views of HCA Healthcare or any of its affiliated entities.

Author Affiliations

1. Grand Strand Medical Center, Myrtle Beach, SC

References

1. Fabre V, Carroll KC, Cosgrove SE. Blood culture utilization in the hospital setting: a call for diagnostic stewardship. *J Clin Microbiol*. 2022;60(3):e0100521. doi:10.1128/JCM.01005-21
2. Kontula KSK, Skogberg K, Ollgren J, Järvinen A, Lyytikäinen O. Population-based study of bloodstream infection incidence and mortality rates, Finland, 2004-2018. *Emerg Infect Dis*. 2021;27(10):2560-2569. doi:10.3201/eid2710.204826
3. Goto M, Al-Hasan MN. Overall burden of bloodstream infection and nosocomial bloodstream infection in North America and Europe. *Clin Microbiol Infect*. 2013;19(6):501-509. doi:10.1111/1469-0691.12195
4. Hall KK, Lyman JA. Updated review of blood culture contamination. *Clin Microbiol Rev*. 2006;19(4):788-802. doi:10.1128/CMR.00062-05
5. Doern GV, Carroll KC, Diekema DJ, et al. Practical guidance for clinical microbiology laboratories: a comprehensive update on the problem of blood culture contamination and a discussion of methods for addressing the problem. *Clin Microbiol Rev*. 2019;33(1):e00009-19. doi:10.1128/CMR.00009-19

6. Gander RM, Byrd L, DeCrescenzo M, Hirany S, Bowen M, Baughman J. Impact of blood cultures drawn by phlebotomy on contamination rates and health care costs in a hospital emergency department. *J Clin Microbiol*. 2009;47(4):1021-1024. doi:10.1128/JCM.02162-08
7. Dempsey C, Skoglund E, Muldrew KL, Garey KW. Economic health care costs of blood culture contamination: a systematic review. *Am J Infect Control*. 2019;47(8):963-967. doi:10.1016/j.ajic.2018.12.020
8. CLSI. *Principles and Procedures for Blood Cultures; Approved Guideline*. Clinical and Laboratory Standards Institute; 2007. CLSI document M47-A.
9. Baron EJO, Melvin P, Yagupsky P, David F, Wilson DM. *Cumitech 1C, Blood Cultures IV*. ASM Press; 2005.
10. Rupp ME, Cavalieri RJ, Marolf C, Lyden E. Reduction in blood culture contamination through use of initial specimen diversion device. *Clin Infect Dis*. 2017;65(2):201-205. doi:10.1093/cid/cix304
11. Bates DW, Goldman L, Lee TH. Contaminant blood cultures and resource utilization. The true consequences of false-positive results. *JAMA*. 1991;265(3):365-369. doi:10.1001/jama.1991.03460030071031
12. Alahmadi YM, Aldeyab MA, McElnay JC, et al. Clinical and economic impact of contaminated blood cultures within the hospital setting. *J Hosp Infect*. 2011;77(3):233-236. doi:10.1016/j.jhin.2010.09.033
13. van der Heijden YF, Miller G, Wright PW, Shepherd BE, Daniels TL, Talbot TR. Clinical impact of blood cultures contaminated with coagulase-negative staphylococci at an academic medical center. *Infect Control Hosp Epidemiol*. 2011;32(6):623-625. doi:10.1086/660096
14. CLSI. *Principles and Procedures for Blood Cultures*. 2nd ed. Clinical and Laboratory Standards Institute;2022. CLSI guideline M47.
15. Sacchetti B, Travis J, Steed LL, Webb G. Identification of the main contributors to blood culture contamination at a tertiary care academic medical center. *Infect Prev Pract*. 2022;4(3):100219. doi:10.1016/j.infpip.2022.100219
16. Norberg A, Christopher NC, Ramundo ML, Bower JR, Berman SA. Contamination rates of blood cultures obtained by dedicated phlebotomy vs intravenous catheter. *JAMA*. 2003;289(6):726-729. doi:10.1001/jama.289.6.726
17. Little JR, Murray PR, Traynor PS, Spitznagel E. A randomized trial of povidone-iodine compared with iodine tincture for venipuncture site disinfection: effects on rates of blood culture contamination. *Am J Med*. 1999;107(2):119-125. doi:10.1016/s0002-9343(99)00197-7