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Cost Analysis of Strategies to Reduce Blood Culture Contamination in the Emergency Department: Sterile Collection Kits and Phlebotomy Teams

Wesley H. Self, MD, MPH^a, Thomas R. Talbot, MD, MPH^b, Barbara R. Paul, MD^c, Sean P. Collins, MD, MSCI^a, and Michael J. Ward, MD, MBA^a

^a Department of Emergency Medicine, Vanderbilt University School of Medicine, Nashville, Tennessee, USA

^b Departments of Medicine and Preventive Medicine, Vanderbilt University School of Medicine, Nashville, Tennessee, USA

^c Community Health Systems Professional Services Corporation, Franklin, Tennessee, USA

Abstract

Objective—Blood culture collection practices that reduce contamination, such as sterile blood culture collection kits and phlebotomy teams, increase upfront costs for collecting cultures but may lead to net savings by eliminating downstream costs associated with contamination. The study objective was to compare overall hospital costs associated with three collection strategies: usual care, sterile kits, and phlebotomy teams.

Design—Cost analysis.

Setting—This analysis was conducted from the perspective of a hospital leadership team selecting a blood culture collection strategy for an adult emergency department (ED) with 8,000 cultures drawn annually.

Methods—Total hospital costs associated with three strategies were compared: (1) usual care with nurses collecting cultures without a standardized protocol; (2) sterile kits with nurses using a dedicated sterile collection kit; (3) phlebotomy teams with cultures collected by laboratory-based phlebotomists. In the base case, contamination rates associated with usual care, sterile kits, and phlebotomy teams were assumed to be 4.34%, 1.68%, and 1.10%, respectively. Total hospital costs included costs of collecting cultures and hospitalization costs according to culture results—negative, true positive, and contaminated.

Corresponding Author / Reprints: Wesley H. Self, MD, MPH; 1313 21st Ave South, 703 Oxford House, Vanderbilt University Medical Center, Nashville, TN 37232; p: 615-936-8047; f: 615-936-3754; wesley.self@vanderbilt.edu.

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Results—Compared to usual care, annual net savings using the sterile kit and phlebotomy team strategies were \$483,219 and \$288,980, respectively. Both strategies remained less costly than usual care across a broad range of sensitivity analyses.

Conclusions—EDs with high blood culture contamination rates should strongly consider evidence-based strategies to reduce contamination. In addition to improving quality, implementing a sterile collection kit or phlebotomy team strategy is likely to result in net cost savings.

INTRODUCTION

The blood culture is an essential tool in clinical medicine for detecting bacteremia and guiding antibiotic therapy.¹ However, false positive blood cultures due to specimen contamination with skin bacteria are common and lead to patient morbidity and escalation of healthcare costs.² The negative consequences of blood culture contamination on medical costs and resource utilization have been well documented.²⁻⁸ Four studies during the past two decades have found that a contaminated blood culture is associated with, on average, several thousands of dollars in unnecessary costs among hospitalized adult patients.³⁻⁶ These increased costs are due to longer in-hospital lengths of stay,³⁻⁴ greater antibiotic use,^{3,4,7,8} increased diagnostic testing,^{3,4,8} and more invasive procedures.⁸

Emergency departments (EDs) are particularly susceptible to blood culture contamination, with many EDs in the United States having contamination rates higher than the 3% benchmark recommended by the Clinical and Laboratory Standards Institute (CLSI).⁹⁻¹⁴ The cause of high ED contamination rates is likely multifactorial, including frequent turnover of staff, fast-paced working environments, and the time pressure of collecting specimens prior to administering an initial dose of antibiotics.¹⁰⁻¹⁵

In many EDs, usual care for blood culture collection involves bedside nurses performing venipuncture or collecting blood from pre-existing catheters without a standardized process for specimen collection.¹⁰ Two alternative strategies that have shown promise in decreasing contamination rates are sterile blood culture collection kits for nurses to use at the bedside,^{10,11,14,15} and dedicated laboratory-based phlebotomy teams.^{6,16,17} Even though lower contamination rates from such strategies result in higher quality care,^{10,11,16,17} hospitals may be reluctant to adopt them due to concerns about their associated costs. Both sterile kits and phlebotomy teams have higher upfront costs compared to usual care; however, both strategies can lead to lower contamination rates, and therefore may ultimately lead to net cost savings by eliminating unnecessary downstream costs associated with contaminated cultures. The purpose of this study was to compare overall hospital costs associated with collecting ED blood cultures using three strategies: usual care, sterile kits, and phlebotomy teams.

METHODS

We performed a cost-consequence analysis from the perspective of a hospital leadership team selecting a protocol for collecting blood cultures in their ED.^{18,19}

Alternative Blood Culture Collection Strategies

Usual Care—Many EDs do not have specific protocols guiding nurses on how to collect blood culture specimens.¹⁰ Commonly, nurses collect these specimens using non-sterile gloves, alcohol skin antisepsis, and either peripheral venipuncture or a blood draw through an existing peripheral intravenous catheter.^{10,20} Training for ED nurses on blood culture collection frequently includes initial bedside mentoring by a senior nurse during orientation to the unit and annual training workshops.^{10,11} Individual-level feedback on contamination rates is not typical.^{10,11} This was considered the usual care collection technique in this study. Usual care was associated with the lowest upfront costs for materials and personnel, but also resulted in the highest proportion of cultures being contaminated.

Sterile Kits—Self et al¹⁰ recently described a process for collecting blood cultures using a fully sterile process with standardized use of a sterile blood culture collection kit. This kit includes sterile gloves, a 3 ml 2% chlorhexidine gluconate/70% isopropyl alcohol skin antisepsis device, a fenestrated drape, syringe, and butterfly needle. Converting blood culture collection from usual care to this sterile kit technique has been shown to significantly reduce contamination in EDs with historically high contamination rates.^{10,11} This strategy, which involved bedside ED nurses collecting cultures with standardized sterile kits, was associated with higher upfront material costs compared to usual care, and lower rates of contamination.

Phlebotomy Teams—Studies by Gander et al,⁶ Sheppard et al,¹⁶ and Weinbaum et al¹⁷ suggested that using dedicated laboratory-based phlebotomy teams with specific training in sterile technique for blood culture collection can reduce contamination in units with historically high contamination. Using this strategy, laboratory-based phlebotomists collected blood culture specimens instead of ED nurses. Compared to usual care, phlebotomy teams were associated with higher personnel costs due to the cost of training and staffing a phlebotomy team, and lower contamination rates.

Decision Analysis Model and Assumptions

We built a decision analysis model using TreeAge 2013 software (Williamstown, MA)²¹ comparing overall hospital costs associated with the usual care, sterile kit, and phlebotomy team strategies for ED blood culture collection (Figure 1). The base case for analysis consisted of an adult ED with 40 beds, 65,000 annual patient visits, and 4,000 patients undergoing blood culturing annually. We assumed that each patient had two blood cultures drawn during the ED visit (8,000 annual blood cultures). A patient was considered to have a contaminated culture if either culture collected in the ED grew a contaminant. Additionally, we assumed that each patient who had a blood culture drawn was hospitalized at the conclusion of the ED course.

For the purposes of assigning cost, patients were categorized into three blood culture outcome groups: bacteremia with at least one positive blood culture (true positive); no bacteremia with at least one positive culture (false positive; “contamination”); and no bacteremia with both ED cultures negative (true negative). For the purposes of this study, a series of two blood cultures was considered to have 100% sensitivity for detecting

bacteremia and thus no false negative results were considered in the model.²² Patients with both a contaminated culture and a culture growing a true pathogen were classified as a true positive. Patients with both ED blood cultures contaminated were assumed to have the same hospitalization costs as those with one contaminated culture. The cost associated with each terminal node in our model was calculated by summing the cost of collecting ED cultures according to the collection strategy being used (usual care, sterile kit or phlebotomy team) and the cost of the subsequent hospitalization according to the blood culture outcome group (true positive, false positive, true negative). The costs considered in this model were limited to the index ED visit and subsequent hospitalization.

Contamination rate refers to the proportion of blood cultures growing a contaminant. Most studies on blood culture contamination report a contamination rate, but not the proportion of patients with at least one contaminated culture.²³ The number of patients without bacteremia who have a contaminated culture, not the number of contaminated cultures, is the main driver of increased costs related to blood culture contamination. Therefore, as part of calculations in our decision analysis model, we converted *contamination rate* to the proportion of non-bacteremic patients with at least one false positive (contaminated) culture using the following equation: (# non-bacteremic patients with 1 contaminated culture) = [(total cultures)(contamination rate) – (total cultures)(bacteremia prevalence)(contamination rate) – (total cultures)(1 – bacteremia prevalence) (contamination rate)²]. This conversion assumed that the risk of contamination was the same for each culture regardless of the presence of bacteremia and the contamination status of other cultures collected from the same patient. For example, the ED in the model base case collected 8,000 cultures annually from 4000 patients, had an 11% prevalence of bacteremia among patients undergoing blood culturing, and a contamination rate of 4.34%. Using these data, 347 cultures were contaminated annually in the base case ED. Of the 347 contaminated cultures, 38 were collected from patients with bacteremia and 13 were collected from nonbacteremic patients who had a second culture contaminated. Therefore, 296 individual patients without bacteremia had at least one contaminated culture.

Data Estimates and Sources

Table 1 contains point estimates, data ranges for sensitivity analyses, and references for each variable used in the model. Four studies published in the past two decades report hospitalization costs or charges associated with blood culture outcomes (true positive, false positive, true negative).³⁻⁶ Estimates for hospitalization costs in this model were calculated using sample-size-weighted average charges reported in these four studies.³⁻⁶ Hospital charges were converted to hospital costs using a 0.3 cost-to-charge ratio for the base case, which is a typical cost-to-charge ratio for diseases in which blood cultures are obtained in the ED, such as pneumonia and cellulitis.²⁴ Sensitivity analyses were completed with the cost-to-charge ratio ranging 0.2 to 0.5. All costs were converted to 2010-adjusted dollars using the consumer price index.²⁵ The difference between hospital costs among patients with a false positive culture compared to those with negative cultures was expected to be a primary driver of the model. The base case point estimate for this cost difference was \$2,844.

Contamination rate point estimates for the usual care and sterile kit strategies were estimated at 4.34% and 1.68%, respectively.¹⁰ The contamination rate using a phlebotomy team was estimated at 1.10%.^{6,16,17}

The cost of materials needed for usual care (point estimate: \$2.00 per culture) and sterile kit (point estimate: \$4.88 per culture) strategies was estimated based on costs paid for these materials in 2010 at our home institution (academic medical center in the United States). In 2010, a cost analysis was conducted at our home institution to estimate the cost of staffing a phlebotomy team for collecting blood cultures in an ED with approximately 8,000 blood cultures collected per year. This team was assigned to the ED 24 hours per day to collect blood specimens. An annual cost of \$331,472 for a phlebotomy team was estimated based on staffing the team with 2 phlebotomists per 8 hour shift (8.4 full time equivalents (FTE) with an annual cost of \$39,461 per FTE). We conducted a broad sensitivity analysis on the annual cost of staffing a phlebotomy team, ranging from \$50,000 to \$500,000. We assumed the material costs for each blood culture collected was the same for the phlebotomy team and usual care strategies (point estimate: \$2.00 per culture).

RESULTS

Base Case

Using the base case point estimates, the usual care strategy resulted in the highest overall cost and the sterile kit strategy had the lowest cost (Table 2).

The usual care strategy resulted in 296 patients with a contaminated culture annually, resulting in \$841,824 in hospital costs directly due to contamination (296 patients with a contamination episode * \$2,844 in additional hospital costs associated per contamination episode). The overall cost associated with the usual care strategy was \$32,346,975 (cost of blood culture collection plus hospital costs associated with each patient who had blood cultures collected according to blood culture result—negative, true positive, and contaminated).

Compared to usual care, the sterile kit strategy cost an additional \$23,040 in upfront material costs annually to pay for the sterile kit materials. The sterile kit strategy resulted in 118 patients with a contaminated culture, resulting in \$335,592 in hospital costs directly due to contamination and overall costs of \$31,863,756. Net savings using the sterile kit strategy compared to usual care was \$483,219 annually.

Compared to usual care, the phlebotomy team strategy was associated with an additional \$331,472 annually in culture collection costs due to the personnel costs of staffing a phlebotomy team. This strategy resulted in 77 patients with a contaminated culture, resulting in \$218,988 in hospital costs directly related to contamination, and an overall cost of \$32,057,995. The net annual savings using the phlebotomy team strategy compared to usual care was \$288,980.

Sensitivity Analyses

We conducted sensitivity analyses on all the variables in our model with the ranges listed in Table 1.

The threshold value for contamination rate using the sterile kit strategy that resulted in equivalent costs for the sterile kit and usual care strategies was 4.20% (Figure 2A). Thus, assuming a usual care contamination rate of 4.34%, the sterile kit strategy was overall less costly than usual care as long as the sterile kit contamination rate remained less than 4.20%. The contamination rate for the sterile kit strategy that would make the cost equivalent to the phlebotomy team strategy was 2.70% (Figure 2A).

In a sensitivity analysis of the hospital charges associated with a false positive (contaminated) culture, hospital charges associated with a negative culture and cost-to-charge ratio were held constant at \$22,849 and 0.3, respectively. The threshold value for hospital costs associated with a contaminated culture between the sterile kit and usual care strategies was \$23,280, equivalent to hospitalization charge and cost differences between a contaminated culture and negative cultures of \$431 and \$129, respectively, (Figure 2B). Thus, the sterile kit strategy resulted in lower overall costs as long as hospitalization costs associated with a contaminated culture remained above \$129. The threshold value between the phlebotomy team and usual care strategies was \$27,914, equivalent to hospitalization charge and cost differences of \$5,065 and \$1,520, respectively, between a contaminated culture and negative cultures.

The threshold value for the annual cost of staffing a phlebotomy team resulting in equivalent costs for the sterile kit and phlebotomy team strategies was \$137,233, with the phlebotomy team strategy resulting in lower overall costs below this threshold. Estimated costs to staff a phlebotomy team with one and two phlebotomists per shift were \$165,736 and \$331,472, respectively. Therefore, the sterile kit strategy resulted in lower costs than the phlebotomy team strategy even with one person staffing the team per shift. The phlebotomy team strategy remained less costly than the usual care strategy across the entire sensitivity analysis range of \$50,000 to \$500,000 for the annual cost of staffing a phlebotomy team. A twoway sensitivity analysis on the annual cost of staffing a phlebotomy team and the total number of cultures collected per year revealed that the phlebotomy team strategy was the least costly strategy if a one person-per-shift team (annual staffing cost of \$165,736) collected at least 9,221 cultures annually (Figure 3). However, at the base-case cost of using a two-person-per-shift team (annual staffing cost of \$331,472), the sterile kit collection strategy remained less costly than the phlebotomy team strategy through the upper limit for this analysis with 16,000 cultures collected per year. Costs for the two-person-per-shift team would have to be reduced in order to make this the preferred method.

A sensitivity analyses on the material costs for the sterile kits revealed a threshold value between the sterile kit and usual care strategies of \$65.28 and between the sterile kit and phlebotomy team strategies of \$29.16. Thus, if the purchase price of each sterile kit was less than \$29.16, which is well above the estimated cost of \$4.88 per kit, the sterile kit strategy resulted in the lowest overall hospital costs.

The sterile kit strategy was the least costly strategy across all sensitivity analysis ranges for the remaining variables, including: prevalence of bacteremia, material costs for usual care, cost-to-charge ratio, and hospitalization charges associated with a true positive blood culture.

DISCUSSION

Blood culture contamination in specimens collected in the ED continues to be a significant problem with direct adverse effects on patient care.² For EDs with high contamination rates, multiple studies have shown that implementing standardized practices for specimen collection with sterile blood culture collection kits or laboratory-based phlebotomy teams can significantly reduce contamination.^{6,10,11,14-17} This reduction in contamination leads to higher quality care due to elimination of diagnostic uncertainty created by contaminated cultures, which drives unnecessary antibiotic treatment, diagnostic studies, delays in surgery, and increased hospital length of stay.²⁻⁸ However, hospitals may be reluctant to adopt sterile blood culture collection kits or phlebotomy teams due to concerns about increased costs associated with these strategies. Our analysis suggests that implementing the sterile kit method or phlebotomy teams would actually result in significant net savings for many hospitals, with savings due to a reduction in contamination outweighing up-front costs associated with sterile kits and phlebotomy teams. Therefore, implementing either of these strategies in an ED with a contamination rate above the 3% blood culture contamination benchmark is expected not only to improve the quality of care, but also reduce the overall cost of care.

Results of this study should be interpreted in the context of its limitations and assumptions. First, estimates for the key data points used in the cost model were obtained from the published literature; accuracy of the model is dependent on the validity of these published estimates. Second, potential negative consequences of using phlebotomy teams and sterile kits were not incorporated into this cost model. Negative consequences with cost implications have not been reported in the literature and are thought to be unlikely. A delay in obtaining cultures resulting in a delay in antibiotic administration is a potential concern with programs that increase the complexity of blood culture collection. However, delays associated with sterile kits properly stocked in the ED and with well-staffed phlebotomy teams are expected to be minimal. Third, the cost of extra training needed to teach bedside nurses how to properly use the sterile kits was not included in this model. Additional training needed before using the kits is expected to be minimal, with published reports describing brief workshops and on-line training videos for training nurses on the sterile kit technique.^{10,11} Fourth, the use of phlebotomy teams in the ED is likely to free up additional time for ED nurses to perform other tasks; we did not include potential savings from nurses having time for other tasks in this model. Fifth, the analysis was limited to adult patients because most of the published cost data were from adult studies. Sixth, this study was limited to an analysis of cost and did not consider effectiveness. In the base case, the phlebotomy team strategy resulted in 41 fewer patients with a contaminated culture compared to the sterile kit strategy with an additional cost of \$194,239 (\$4,738 per additional contamination episode avoided). Whether the higher cost of the phlebotomy team strategy is justified by its greater effectiveness was not considered in the current model.

Lastly, our base case assumed relatively high contamination using usual care, and therefore, results are only potentially generalizable to settings with high baseline contamination.

In summary, EDs with blood culture contamination rates higher than the 3% benchmark that convert the technique of blood culture collection from bedside nurses obtaining specimens without a standardized protocol to either a sterile blood culture kit or phlebotomy team strategy are expected to experience significant cost savings. Hospitals should strongly consider evidence-based quality improvement strategies to minimize blood culture contamination; lower contamination rates result in higher quality care and are likely to result in net cost savings even if these programs are associated with substantial up-front costs.

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Figure 1.

Decision tree modeling the cost implications of collecting ED blood cultures by the usual care, sterile kit and phlebotomy team strategies.

Figure 2.

One way sensitivity analyses, including (A) analysis with variation in the sterile kit strategy blood culture contamination rate, and (B) variation in the hospital charge for patients with a contaminated blood culture.

Figure 3.

Two-way sensitivity analysis on the annual number of blood cultures collected in the emergency department and the annual cost to staff a phlebotomy team.* *Usual care did not result in the lowest costs at any point along the ranges evaluated in this analysis.

Table 1

Base case point estimates, data ranges for sensitivity analyses, and data source for each variable in the decision analysis model.

Variable	Base Case Point Estimate	Sensitivity Analysis Range	Data Source
Point prevalence of bacteremia among ED patients undergoing blood culturing	11%	8.2%, 12.4	6, 10, 26
Hospital charges associated with negative blood cultures	\$22,849	\$10,000, \$30,000	3-6
Hospital charges associated with a true positive blood culture	\$53,693	\$30,000, \$70,000	6
Hospital charges associated with a false positive (contaminated) blood culture	\$32,330	\$20,000, \$40,000	3-6
Cost-to-charge ratio for hospital costs	0.3	0.2, 0.5	24
Cost of material to collect a culture by usual care method	\$2.00	0, \$5.00	Institutional Data
Cost of material to collect a culture by sterile kit method	\$4.88	\$2.44, \$7.32	Institutional Data
Annual cost to staff an ED phlebotomy team	\$331,472	\$50,000, \$500,000	Institutional Data
Contamination rate with usual care strategy	4.34	1.00%, 8.00%	10
Contamination rate with sterile kit strategy	1.68%	0, 4.34%	10
Contamination rate with phlebotomy team strategy	team strategy 1.10%	0, 4.34%	6, 16, 17
Total number of cultures collected in the ED annually	8,000	2,000, 16,000	Range from small to very large ED

Table 2

Annual hospital costs and nets savings associated with alternative ED blood culture collection strategies using base case point estimates.

Blood culture collection strategy	Blood Culture collection costs	Non-bacteremic patients with a contaminated culture	Total hospital costs *	Net savings compared to usual care
Usual Care	\$16,000	296	\$32,346,975	referent
Phlebotomy Teams	\$347,472	77	\$32,057,995	\$288,980
Sterile Kits	\$39,040	118	\$31,863,756	\$483,219

* Total hospital costs were calculated by summing the cost of collecting blood cultures (material costs for usual care and sterile kit strategy; material costs plus additional personnel costs for phlebotomy team strategy) and the hospitalization costs associated with each patient who underwent a blood culture.