**Abstract:**
Emergency departments are a primary site for evaluation of pediatric patients presenting with fever. Part of this evaluation may include the collection of blood cultures to rule out infection from a bacterial pathogen. Many of these samples, however, yield results that are not representative of a true bacterial infection, causing undue burden on patients and their families and adding considerable costs for the health care system. Reducing the rate of false-positive blood cultures may be achieved through quality improvement methodology. Strategies for the reduction of blood culture contamination, including process improvement and targeted education, are discussed in this review.

**Keywords:**
blood culture; quality improvement; contaminant; process improvement

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1522-8401


# Impact of Blood Culture Contamination on Patients and Health Care Systems: A Review of QI Strategies Within the ED

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Approximately 20% of emergency department (ED) visits and hospitalizations in the pediatric population are for the evaluation and management of fever.[1] Although viral infections are more commonly implicated as the cause of a febrile illness, concern for a bacterial source in certain at-risk individuals warrants further investigation. The standard method used to identify a blood-borne, bacterial pathogen is to collect a blood sample via venipuncture using sterile technique and instilling the sample into a blood culture bottle. Unfortunately, many of these cultures identify bacterial pathogens that are contaminants, creating a burden for the patient and the health care system. Data regarding the scope of this problem are

abundant, with some sources citing the percentage of contamination among collected blood cultures reaching as high as 50%.[2] The process of blood culture collection itself is composed of multiple steps, and identification of the many points where contamination can occur is onerous, making isolation and eradication of the problem an individualized effort at each institution.[3]

Contaminated or false-positive blood culture results can prolong a hospital stay, trigger the administration of unnecessary antimicrobials, or may prompt a return ED visit with hospital admission, adding additional cost and inconvenience to the patient and occupying resources (hospital inpatient bed) which otherwise could have been available to another patient.[4] In many scenarios, empiric antibiotic administration occurs, placing the patient at risk for complications from unneeded therapy (allergic reaction, increased susceptibility to opportunistic infections, *Clostridium difficile* colitis). In some cases, false-positive results may lead to removal of central venous access lines for fear that they are the site of bacterial colonization.[5] In addition to the patient-related issues, new Medicare guidelines negating reimbursement for hospital-acquired infections may deeply impact revenue streams for institutions that are unable to address the problem.

## BACKGROUND

Thuler et al evaluated the impact of false-positive blood cultures on the management of febrile children presenting to their hospital system, concluding that false-positive blood cultures led to unnecessary repeat testing, hospitalization, and treatment of patients.[6] These investigators reviewed the medical records of children aged 1 month to 18 years presenting to a Montreal hospital for whom a blood culture was drawn. Of the nearly 10 000 blood cultures obtained from July 1991 and June 1992, 778 (7.8%) demonstrated growth. Of these 778 positive blood cultures, 403 were excluded based on study criteria due to inaccurate documentation, age criteria (<1 month of age or >18 years of age), unrecorded age, or unavailable medical records. Patients with underlying medical conditions in whom it was difficult to differentiate between a contaminant and an opportunistic infection (eg, malignancy, liver disease, congenital heart disease, immunodeficiency) were also excluded. Of the 375 positive blood cultures that met study criteria, 81 (21.6%) were false positives. The investigators evaluated and contrasted the health care experiences for the 81 patients with false-positive cultures and the 162 patients with true-negative cultures. Patients eventually determined to have a false-positive culture were more likely to be admitted at the time of presentation and started on empiric antibiotics vs those with true-negative blood cultures. Twenty-three of the children with false-positive cultures were not hospitalized, and of those, 6 patients (26%) were called back and admitted for a cumulative total of 10 patient days. An additional 15 patients were treated with antibiotics or had existing antibiotic regimens changed after the preliminary culture report was obtained, adding up to 51 patient days of unnecessary antibiotic therapy. Within that group, 2 patients developed a skin rash, presumed to be an allergic reaction, after administration of the antibiotic. Additional expenses incurred included additional blood culture sampling in each of the patients in whom a positive preliminary culture was reported; none of the follow-up cultures were positive. The expense generated by additional testing, hospitalization, and unnecessary therapies was not calculated as part of the study.

Investigators at a children's hospital in South Korea also examined the impact of blood culture contamination on hospitalized pediatric patients.[7] This was a retrospective medical record review of blood cultures obtained between 2006 and 2010. They recorded 40 542 blood cultures drawn, of which 610 were reported as positive. Of these, only 131 were true positives, with the remaining 479 determined to be contaminants, a false-positive rate of 1.2%. When the data were further analyzed by the location of sample collection and patient age, a false-positive rate of 2.1% was noted in children less than 1 year of age, with the ED representing the area with the highest rate of contamination, an observation frequently noted by other studies. They concluded that further study was needed to determine the reason behind the higher rates of contamination but proposed several explanations, including difficulty in obtaining specimens in young children and ED overcrowding.

A group of investigators in Taiwan evaluated the impact of ED overcrowding on blood culture contamination rates in the setting of a university hospital.[8] In this prospective study, adults 18 years or older with blood cultures obtained in the ED were enrolled between August 2007 and July 2008. Of the 11 491 patients with a blood culture drawn, 558 patients (4.86%) had bacterial growth reported. These patient records were then analyzed to differentiate true bacteremia versus contaminants. At the time of blood culture collection, the ED volume was scored by a study coordinator using the National Emergency Department Overcrowding

Study (NEDOCS) score, a validated scale for ED overcrowding. The NEDOCS score stratifies ED volumes based on overcrowding as follows: not busy and busy (0-60 points), extremely busy but not overcrowded (60-100 points), severely overcrowded (140-180 points), and dangerously overcrowded (180-200 points).[9] Patient comorbidities were also recorded and analyzed. Although their study reported an acceptable overall contamination rate (192 patients of the 558 or 1.67%), there was a high degree of correlation of contamination with ED overcrowding. ED overcrowding (NEDOCS score> 100 points) was independently associated with blood culture contamination, demonstrating an odds ratio of 1.58; $P = .04$. Their findings suggest that overcrowding may adversely affect clinical care, leading to an increase in blood culture contamination.

In a 2013 quality report, Hall et al evaluated institutional cost savings achieved after an intervention to reduce blood culture contamination rates.[10] They conducted a retrospective analysis of patients who had blood cultures collected during a 1-year period (July 2009 to June 2010), prior to an intervention aimed at addressing several observed inconsistencies in blood culture collection within their ED. During that time period, there were 149 contaminated cultures obtained, amounting to an estimated cost of $416 243 (an average of $2800 per contaminated culture) to their institution. This cost included additional days of hospitalization (90 days adding up to $267 840), return ED visits and repeat cultures (25 return visits adding up to $27 275 and an additional $17 480 in blood culture charges), antibiotic charges (516 occurrences amounting to $72 102), and additional charges based on patient-specific evaluations (radiology, lumbar puncture, echocardiogram, and PICC line placement) of $31 546. After initiating their intervention, the contamination rate dropped from 3.9% to 1.6%, a 59% relative reduction in contaminated cultures. By applying this rate reduction to the cost of the contaminants, these investigators estimated savings to the hospital of approximately $250 000 per year. Hall et al also highlight that opportunity costs to the hospital were not calculated as part of this study and would include adding to possible high census days and reduction of available hospital beds that may have led to ambulance diversion or capital expenditures to increase bed capacity to accommodate a falsely elevated census. This study did not address the cost to the families of these patients related to lost work days, added child care for other dependents, and psychological strain on the patients and their loved ones.

It is clear from these studies, and many others, that this problem is not only widespread but highly impactful to a number of stakeholders—the patient/family, the institution, insurance companies, and the involved medical staff. Patient safety, financial burden, and psychological stressors are all key risks associated with the presence of blood culture contaminants, making it a high-priority quality improvement and patient safety issue for the health care system.[11]

Many groups seeking to reduce blood culture contamination at their institutions have carefully considered the multifactorial sources of the problem. Weddle and colleagues addressed collection methods and techniques when examining the high rate of contaminants noted at their children's hospital.[12] As many of the bacterial contaminants involved species that colonize the skin, it was postulated that deviation from sterile prep procedures may be responsible for a large number of contamination cases. Factors addressed were skin preparation techniques, patient age, and skill or technique of the phlebotomist. Another factor that was addressed was the common practice of obtaining blood cultures at the time of placement of peripheral intravenous access, a phenomenon that is unique to pediatric patients in an effort to reduce the number of painful procedures. At this particular institution, an observational "prestudy" was performed, where practices were assessed and problem steps identified. The association of workload and contamination was also examined and more fully described in a follow-up publication. During the prestudy period, ED contamination rates were noted to be 2-3 times the current institutional rate (4%-11.2% vs 3% overall for the institution). A new policy outlining proper blood culture collection technique was instituted based on Centers for Disease Control and Prevention guidelines, which outlined the appropriate staff to perform the collection, how to correctly prep the skin, and which sites were optimal for specimen collection. A retrospective medical record review of a 12-month study period pre– and post–policy change did show that these interventions successfully lowered the rate of blood culture contamination from 6.7% to 2.3%. However, the investigators did note that additional interventions would be necessary to eradicate the problem. In addition, the poststudy data only reflected efforts noted 6 months after intervention, a time frame that did not account for any knowledge or skill attrition among the staff. Several other groups have published successful reductions in blood culture contamination rates after the initiation of educational protocols or policies. Park et al in Korea evaluated

whether reduction in contamination rates could be achieved through the introduction of a clinical skills test into the curriculum of residents at the time of their licensing boards within their institution.[13] They prospectively evaluated 3 cohorts of residents, the medical staff members responsible for blood sample collection in this hospital system, from 2009 through 2013. One group was trained with standard practice, another was given the clinical skills test during their licensing examination, and the last group was placed in an institutional education program regarding blood culture contamination rates. The contamination rates achieved by all 3 groups were measured, and although there was no statistical difference between the baseline group and the clinical skills test group (rates of 1.36% vs 1.35%, respectively), the rate among the group that received the institutional education program was 1%, a statistically significant change compared to the standard practice control group ($P < .0001$).

Although reeducation and institution-based policies have been effective in reducing occurrence, the rate of contamination still is not zero.[14] Studies addressing the collection equipment have sought to further explore its effects, if any, on the prevalence of contamination. Investigators in England assessed the impact of a preassembled blood culture collection kit on their rates of contamination.[15] These kits contained the skin prep materials, culture bottles, syringes, sterile needles, and gloves and were assembled at considerable cost to the institution. Although they did note a significant reduction in their contamination rate (9.2% to 3.8%) after introduction of the prepackaged kits, there were also a number of other interventions which were introduced at the same time—namely, a hand washing campaign and education of staff using videos, leaflets, and in-unit demonstrations—making it difficult to determine with certainty which of the interventions had successfully ushered in the reduction. Another group in New York examined the use of premade blood culture collection "bundles" on contamination rates from samples obtained through central lines.[16] The bundles included instructional materials, flushes, sterile personal protective equipment, and sterile collection bottles. The initial evaluation period of the study revealed high rates of contamination but in a very small sample size with 6 contaminated cultures out of 47 (12.77%). After bundle implementation, a high rate of contamination remained (6 false positives among 140 cultures or 4.29%), though significantly lower than preinitiation. Contamination rates were again evaluated several months after implementation, with no further improvement noted. Although there was a 61% decrease in contamination among samples drawn from central line access points using the preassembled kits and sterile equipment, the role that staff education played in this decrease was not singled out, and their contamination rates were still well above the national "accepted" rate of 2-3%.

Use of these kits and the training of additional staff to obtain samples in a prescribed way are not without expense, but does the cost incurred from the contamination justify it? Self et al conducted a cost analysis for the use of sterile collection kits and phlebotomy teams, comparing these to the costs generated from blood culture contamination.[17] Three hospital protocols were compared to generate a cost analysis: (1) usual care (ED and staff nurses collecting samples), (2) use of a preassembled kit with instructions by usual ED staff nurses, and (3) use of phlebotomists without the kits. Evaluation of samples collected by "usual care" netted the lowest upfront cost but the highest level of unwanted contaminants, with a cost of $16 000 in labor/materials but a hospital-wide cost of $32.3 million incurred by contaminants. The use of collection kits by ED staff nurses was associated with higher upfront materials costs but lower rates of contaminants, costing $39 040 in labor/materials and with a cost to the hospital of $31.8 million incurred by contaminants— an annual savings of $483 219 for the hospital. Use of phlebotomy teams was associated with the highest upfront costs for labor and training and low rates of contamination, with an outlay of $347 472 in labor and materials and hospital cost of $32 million incurred by contaminants, with an annual savings of $288 980. Based on this analysis, the data support the use of preassembled kits and instructional guidance with existing staff and justified the upfront expense of the kits for their hospital.

Initiating a quality initiative directed at reducing blood culture contamination should take into account the unique barriers existing at that institution.[14] Once the need for improvement is identified, the next step is to assess current practices and assemble a quality improvement team, ideally one that includes members of all frontline staff disciplines who are involved with ordering and drawing of the samples, members of the hospital's or clinic's infection prevention staff, microbiology technologists, and hospital/clinic leadership. Barriers to achieving a high level of performance should be collected from several sources, including staff themselves, direct observations, and, when possible, patients and families. An example of a barriers assessment in the form of a fishbone diagram from

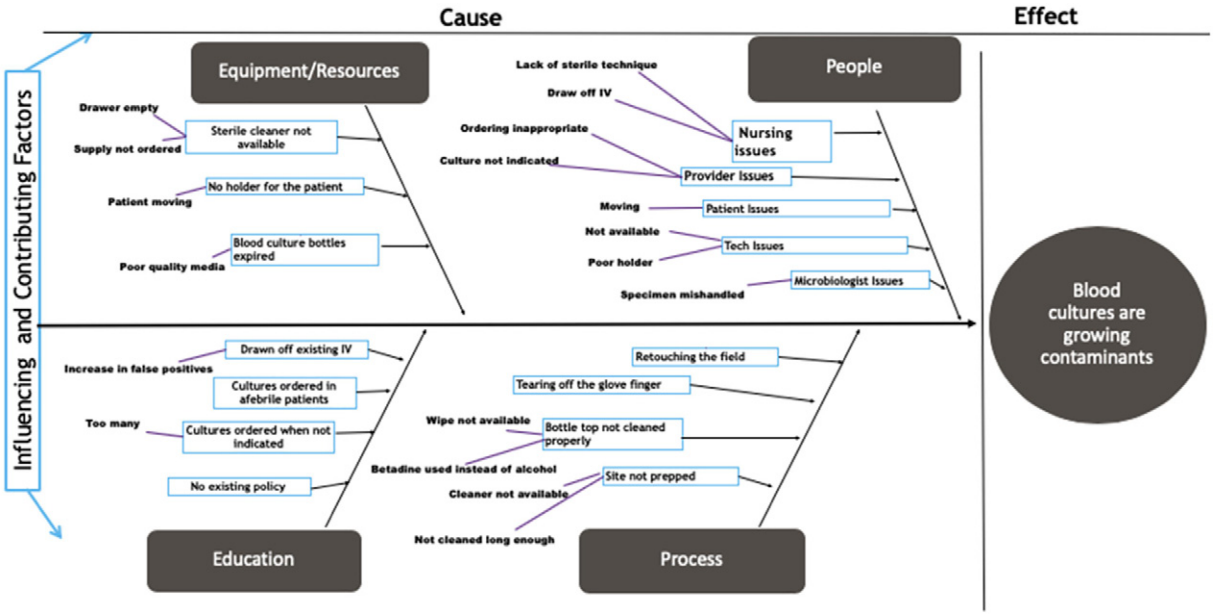


**Figure 1.** Fishbone diagram: blood culture contamination project.

our own institution's experience is pictured in Figure 1. A barriers assessment works from the perspective of the problem and what factors contribute to it. When developing interventions to drive improvement, the barriers assessment is key, as these issues are the key drivers of your project. An aim statement describes what it is you are hoping to achieve. In our team's case, we wanted to decrease the amount of blood culture contaminants we were getting each month. An aim statement is usually "SMART"—specific, measurable, achievable, realistic, and time-bound.[17] Using a key driver diagram and starting with your aim statement, barriers perceived to be the major drivers of the problem and their secondary contributors are listed. Interventions can then be directed toward solving these individual issues, making the desired improvement more likely because these smaller efforts are more achievable (Figure 2). Our group focused on developing a policy, educating staff on

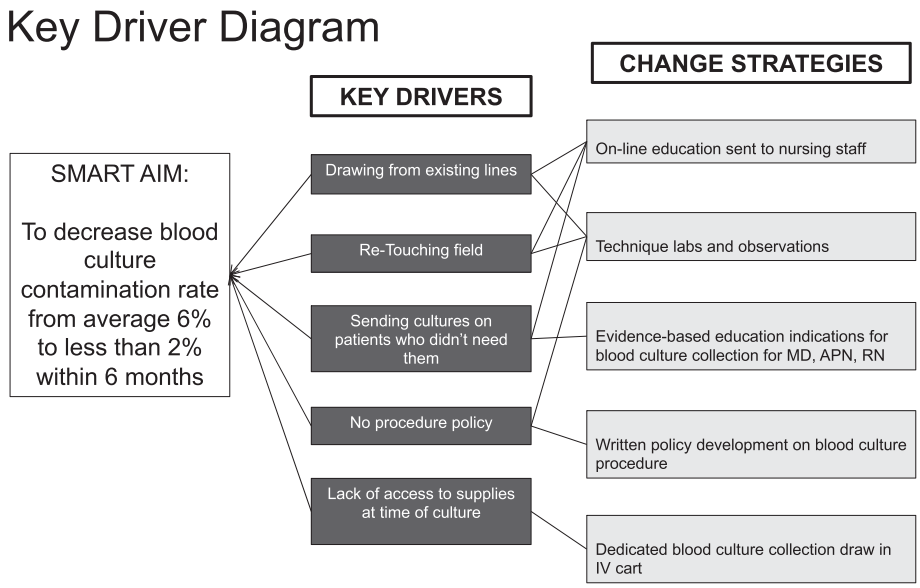


**Figure 2.** Key driver diagram: blood culture contamination project.

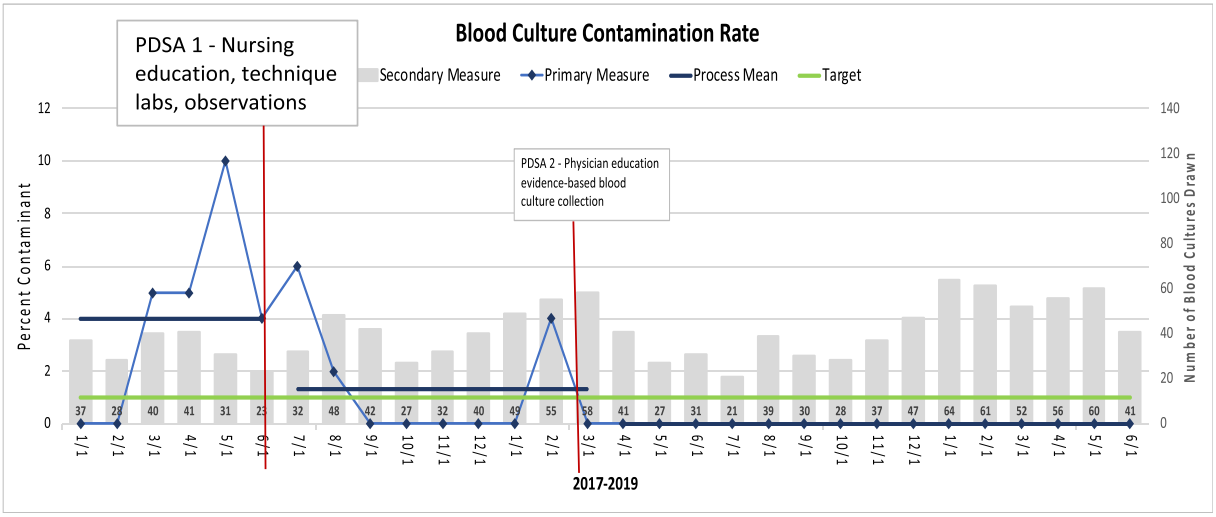


**Figure 3.** Data collection 2018-2019: blood culture contamination project.

appropriateness of testing (aimed at providers), and improving sterile technique and availability of supplies. After 2 cycles of improvement focused on tackling several of our most common issues, our group has achieved a measurable decrease in the occurrence of blood culture contamination (Figure 3).

## SUMMARY

Although the aforementioned studies show that multistep interventions have been successful in reducing the burden of blood culture contamination, there are still other factors that have not been widely considered. The most successful approaches —unit-wide education followed by periodic retraining, use of predesigned kits to eliminate variability, adoption of approved skin preparation techniques— involve a hospital-wide commitment to quality that stems from an acknowledgement of the problem and a willingness to solve it. Other sources of error that have been less widely addressed include development of on-boarding processes for new staff, which include training and competencies in blood culture collection technique, an evaluation of laboratory techniques for plating specimens once they reach the laboratory, and assessing the quality control of the blood culture bottle media itself.[18-23] In addition to methods directed at improving process or technique, indications for blood culture collection within the institution/group must be evidence based. A thorough evaluation of the group's collective practice may reveal practice variations not initially targeted with initial process improvements. Addressing and improving on these variations will further reduce the opportunity for contamination. Although it appears that a significant reduction in contamination has been achieved at multiple institutions through the above methods, there is still a long way to go in reaching zero as the acceptable false-positive rate. Changes in tolerance for hospital-acquired infections and removal of reimbursements for these cases may be the catalyst that further drives investigation into the remaining causes of this significant safety and quality problem within hospitals and emergency departments worldwide.

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