Contamination Rates of Blood Cultures Obtained by Dedicated Phlebotomy vs Intravenous Catheter

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Fever is the primary complaint in up to 20% of children presenting to emergency departments, and bacteremia is the source of fever in 1.5% to 2.3% of these patients. Blood culture is the criterion standard for identifying children with bacteremia; however, false-positive blood cultures are common and may add significantly to health care costs. High rates of contamination are common among pediatric patients, likely related to difficulties inherent to phlebotomy in young patients. To minimize the number of venipunctures in children, blood culture specimens are obtained simultaneously with intravenous catheter placement in many emergency departments. The impact of using intravenous catheters to obtain blood cultures is unclear. We hypothesized that the blood culture contamination rate would be less when blood culture specimens were obtained from a remote site rather than through a newly inserted intravenous catheter.

METHODS

A preintervention and postintervention observational study of patients who had a blood culture obtained as part of their routine emergency department course was conducted. Patients 18 years old or younger who presented to the emergency department at a free-standing tertiary care children’s hospital that evaluates more than 65,000 children annually and required a blood culture as part of their routine care were eligible. Patients with indwelling vascular catheters were excluded. All phlebotomy was performed by emergency department registered nurses. During the baseline phase, blood specimens for culture were obtained simultaneously with intravenous catheter insertion. During the postintervention phase, specimens were obtained by a separate, dedicated procedure.

RESULTS

A total of 4108 blood cultures were evaluated, including 2108 during the baseline phase and 2000 in the postintervention phase. The false-positive blood culture rate decreased from 9.1% to 2.8% (P < .001). A statistical process control chart demonstrated a steady-state process in the baseline phase and the establishment of a significantly improved steady state in the postintervention phase. Young age was associated with increased contamination rate in both the baseline and postintervention periods.

CONCLUSION

Blood culture contamination rates were lower when specimens were drawn from a separate site compared with when they were drawn through a newly inserted intravenous catheter.

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for specimen collection and inoculation were standardized and remained unchanged during the study. Nursing staff members were unaware of ongoing data collection and analysis. In cases where a positive blood culture was reported, the patient’s medical record was reviewed. Patients with indwelling devices (central venous lines, ventilator catheters) were excluded.

**Baseline Phase**

During the baseline phase (January 1, 1998- November 19, 1998), culture specimens were obtained through a newly inserted peripheral intravenous catheter using the standard over-the-needle approach. A sterile 5-mL syringe was attached to the catheter hub, and blood for both culture and for laboratory studies was withdrawn; the first portion of the sample was used for culture.

During the first 4 months of the baseline phase, focused efforts to decrease the contamination rate were implemented. Because these interventions failed to reduce the contamination rate, the standard technique was abandoned in favor of obtaining specimens from a separate phlebotomy site. Data from a 6-week implementation phase (November 20, 1998-December 31, 1998) were not included in the analysis.

**Postintervention Phase**

During the postintervention phase (January 1, 1999-December 31, 1999), culture specimens were obtained by venipuncture at a dedicated site. If a patient required an intravenous catheter, it was placed using the standard approach at a site distant from the blood culture venipuncture site. While laboratory specimens were sometimes obtained through the newly inserted intravenous catheter, all specimens for culture were obtained by phlebotomy dedicated to that procedure.

**Classification of Blood Culture Isolates**

Blood culture isolates were categorized as contaminants or pathogens. In all cases, Neisseria meningitidis, Streptococcus pneumoniae, Salmonella species, Haemophilus influenzae, and group A or group B β-hemolytic streptococci were considered pathogens. A contaminant was defined as a nonpathogenic microorganism. If pathogenicity was uncertain or variable, assignment was made in consultation with an infectious disease expert (J.R.B.), with consideration of patient demographics and the clinical setting. Assignment was made without knowledge of the intervention phase. Because the presence of even a single nonpathogenic species in the blood culture specimen represented improper phlebotomy technique, a specimen with multiple bacteria was considered contaminated.

Decisions regarding treatment and follow-up of patients were made by clinicians in the emergency department based on current practice. The institutional review board of the Children’s Hospital Medical Center of Akron approved the study protocol. Consent was not obtained from families. The intervention was adopted as our standard of care, and data was collected in a blinded database for analysis.

**Data Analysis**

Data were analyzed using STATA Version 7.0 (Dallas, Tex, 2001). Univariate analysis was performed unless stated otherwise. Pearson χ² was used to analyze categorical data. Descriptive analysis of continuous data was performed. *P* < .05 was the level of significance.

Statistical process control methodology was also used to examine the impact of the intervention over time. A run chart was constructed showing the blood culture contamination rate for each month of the study ([number of contaminated specimens *× 100]/[number of blood cultures obtained]). The mean blood culture contamination rate and the upper and lower control limits were established based on the preintervention data, with control limits representing ±3 SD from the mean.

**RESULTS**

During the study, 4448 blood culture specimens were obtained. We excluded 289 specimens obtained during the 6-week implementation phase, 14 with incomplete data in the medical record and 37 because of the presence of central venous catheters, leaving 4108 emergency department visits for analysis (2108 in the baseline phase and 2000 in the postintervention phase). Overall, there were 324 positive blood culture specimens.

Patient demographics are presented in Table 1. There were no statistically or clinically important differences between patients in the baseline and in the postintervention phases.

During the baseline phase, 223 positive blood culture specimens were reported; of these, 32 specimens grew a pathogen. In the 191 blood culture specimens categorized as contaminated, 243 organisms were cultured (Table 2). The overall false-positive rate was 9.1% and the true-positive rate was 1.5%. In the postintervention period, there were 101 positive blood cultures; of these, 45 grew a pathogen. In the 56 contaminated specimens, 65 organisms were cultured (Table 2). The overall false-positive rate during the
Table 2. Blood Culture Contaminants in the Baseline and Postintervention Periods of Study

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>No. of Organisms (% of Total Contaminated Specimens)</th>
<th>Baseline*</th>
<th>Postintervention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coagulase-negative staphylococci</td>
<td>140 (73)</td>
<td>37 (67)</td>
<td></td>
</tr>
<tr>
<td>Streptococcus viridans</td>
<td>57 (30)</td>
<td>8 (14)</td>
<td></td>
</tr>
<tr>
<td>Corynebacterium species</td>
<td>13 (7)</td>
<td>7 (12)</td>
<td></td>
</tr>
<tr>
<td>Micrococcus species</td>
<td>13 (7)</td>
<td>5 (8)</td>
<td></td>
</tr>
<tr>
<td>Bacillus species</td>
<td>3 (1.6)</td>
<td>3 (5)</td>
<td></td>
</tr>
<tr>
<td>Propionibacterium acnes</td>
<td>4 (2)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Neisseria species</td>
<td>3 (1.6)</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>10 (5)</td>
<td>5 (8)</td>
<td></td>
</tr>
<tr>
<td><strong>Total No. of Organisms</strong></td>
<td><strong>243</strong></td>
<td><strong>65</strong></td>
<td></td>
</tr>
</tbody>
</table>

*There were 191 contaminated specimens growing 243 organisms in the baseline phase and 56 contaminated specimens growing 65 organisms in the postintervention phase of the study.

Figure 1. Statistical Process Control Chart Showing the Percentage of All Blood Cultures Growing Contaminants by Month, for the 2-Year Study Period

The upper and lower control limits (dotted lines) represent ±3 SD from the mean (dashed line). The mean, upper control limit, and lower control limit are calculated based on data in the baseline phase of the study.

Figure 2. Blood Culture Contamination Rate, by Age Category, During the Baseline and Postintervention Phases of Study

The postintervention period was 2.8%, with a true-positive rate of 2.3%. Using a 2-sample test of proportions, the contaminated blood culture rate in the postintervention phase is significantly decreased when compared with the baseline phase (P < .001). The increase in true-positive rates did not reach statistical significance (P = .20).

The statistical process control chart (FIGURE 1) shows 12 consecutive data points below the mean established in the baseline phase in the postintervention phase, indicating a special cause effect (the intervention) and a significant change in the measured outcome (the contamination rate).19

The contamination rates in the baseline and postintervention phases are higher the younger the child (FIGURE 2). For example, in the baseline phase, the contamination rate in patients younger than 12 weeks was 17%, compared with 4.5% in those older than 5 years.

COMMENT

The contamination rates were significantly lower when blood culture specimens were drawn from a separate and dedicated venipuncture site compared with through a newly inserted intravenous catheter in children seen in a busy emergency department. The low rates have been sustained since the end of the study.

The statistical quality control methodology we applied provides a simple graphical display of process data that enhances our ability to understand outcomes that occur over time.17 This methodology has been used increasingly in the evaluation of processes occurring in the health care setting.18,20,21 The premise is that when a process achieves a steady state, it is likely to remain there until events cause it to shift to a new steady state.18,19

This study addresses a common problem that has been linked to substantial and unnecessary resource utilization.9,10,22-24 The contamination rate in our emergency department was resistant to change in spite of several specific interventions intended to address the problem. The sole procedural change was in the method by which blood culture specimens were obtained. During the baseline phase, the overall false-positive blood culture rate was 9.1% compared with a rate of 2.8% after the intervention, representing a decrease of 70%. While not statistically significant, the true-positive rate increased from 1.5% at baseline to 2.3% after the intervention. We believe that at least some of this increase is due to more selective ordering of blood cultures during the postintervention phase, when all cultures were obtained in response to other diagnostic tests obtained during the patient’s emergency department evaluation. Since it is easier to obtain blood for culture from an intravenous catheter, cultures may have been obtained more indiscriminately in the baseline phase.

Previous studies comparing contamination rates in specimens obtained through newly inserted intravenous catheters or by phlebotomy at a remote
site suggest that the 2 techniques are essentially equivalent. Smart and Baggo-ley failed to show a difference in the contamination rate in 940 adult patients randomized to phlebotomy by either venipuncture or by placement of an intravenous catheter. Isaacman and Karasic prospectively evaluated a convenience sample of 99 pediatric patients, each of whom had 2 blood cultures obtained, one by venipuncture and one through a newly inserted intravenous catheter. The authors demonstrated a low contamination rate with both techniques, concluding that newly inserted intravenous catheters offer an alternative to a separate venipuncture procedure in patients requiring blood culture. The small number of patients enrolled and the impact of the nursing staff's awareness of the study protocol may have biased the results.

On the other hand, a study by Ramsook et al suggested that blood culture contamination rates were decreased when using dedicated phlebotomy compared with those obtained through a newly inserted intravenous catheter. Importantly, this study demonstrated the highest contamination rates in patients younger than 3 months of age, regardless of the collection method used, a finding confirmed in our study. Because staff members were aware of ongoing data collection, the potential effect on their phlebotomy technique is unknown.

However, our study also has limitations; because medical records were reviewed only for those patients with positive blood cultures, detailed information about patients with negative blood cultures is not known. In particular, information about antibiotic pre-treatment is unknown. While it is likely that some patients were prescribed systemic antibiotic therapy prior to or during their emergency department evaluation, the rates of antibiotic pre-treatment in the baseline and postintervention phases of the study are likely to be similar and unlikely to affect the study's conclusions. In addition, this protocol was implemented in a single unit and may not be generalizable to other settings. Finally, no concurrent control group was included to account for secular temporal changes.

Obtaining blood cultures from a separate site requires the patient to undergo an additional procedure for phlebotomy, but the overall benefit in terms of costs associated with a high contamination rate is likely to be substantial. During the baseline period, there were 6 contaminated specimens for every true-positive blood culture, compared with a ratio of 1.2:1 after implementation of the intervention. If subsequent patient management is based on preliminary blood culture results, false-positive test results will result in repeat emergency department visits, unnecessary medical interventions, unnecessary antibiotic therapy, and even hospital admission. One study found that 26% of children followed as outpatients who had false-positive blood cultures were hospitalized unnecessarily, and that unnecessary use of antibiotics was significantly increased in the presence of false-positive blood culture results. Additional costs that are more difficult to quantify include staff effort and time required to arrange follow-up for patients, exposure of patients to unnecessary procedures, and cost and inconvenience related to repeat emergency department and/or hospital visits.

Author Contributions: Study concept and design: Norberg, Christopher, Ramundo, Berman. Acquisition of data: Norberg, Christophor, Ramundo, Berman. Analysis and interpretation of data: Norberg, Christophor, Bower. Drafting of the manuscript: Norberg, Christopher, Bower. Critical revision of the manuscript for important intellectual content: Norberg, Christophor, Ramundo, Bower, Berman. Statistical expertise: Christophor. Administrative, technical, or material support: Norberg, Christophor, Bower. Study supervision: Christophor, Ramundo, Bower.

REFERENCES