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Association of a Clinical Practice Guideline With Blood Culture Use in Critically Ill Children

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IMPORTANCE Sepsis and septic shock are common and, at times, fatal in pediatrics. Blood cultures are often obtained when clinicians suspect sepsis, yet are low-yield with a false-positive rate up to 50%.

OBJECTIVES To determine whether a novel, 2-part, clinical practice guideline could decrease the rates of total blood cultures and cultures collected from central venous catheters in critically ill children and to examine the effect of the guideline on patient outcomes.

DESIGN, SETTING, AND PARTICIPANTS A retrospective cohort study was performed to determine the effect of a new clinical practice guideline on blood culture practices in a 36-bed, combined medical/surgical pediatric intensive care unit of an urban, academic, tertiary care center from April 1, 2013, to March 31, 2015. All patients admitted to the pediatric intensive care unit with length of stay of 4 hours or more were evaluated (4560 patient visits: 2204 preintervention, 2356 postintervention visits).

INTERVENTIONS Two documents were developed: (1) fever/sepsis screening checklist and (2) blood culture decision algorithm. Clinicians consulted these documents when considering ordering blood cultures and for guidance about the culture source.

MAIN OUTCOMES AND MEASURES Primary outcome was the total number of blood cultures collected per 100 patient-days.

RESULTS Of the 2204 children evaluated before the intervention, 1215 were male (55.1%); median (interquartile range) age was 5 (1-13) years. Postintervention analysis included 2356 children; 1262 were male (53.6%) and median (interquartile range) age was 6 (1-13) years. A total of 1807 blood cultures were drawn before the intervention during 11 196 patient-days; 984 cultures were drawn after the intervention during 11 204 patient-days (incidence rate, 16.1 vs 8.8 cultures per 100 patient-days). There was a 46.0% reduction after the intervention in the blood culture collection rate (incidence rate ratio, 0.54; 95% CI, 0.50-0.59). After the intervention, there was an immediate 25.0% reduction in the rate of cultures per 100 patient-days (95% CI, 4.2%-39.7%; $P = .02$) and a sustained 6.6% (95% CI, 4.7%-8.4%; $P < .001$) monthly decrease in the rate of cultures per 100 patient-days. Significantly fewer cultures were collected from central venous catheters after vs before the intervention (389 [39.5%] vs 1321 [73.1%]; $P < .001$). Rates of episodes defined as suspected infection and suspected septic shock decreased significantly after the intervention, but patients meeting these criteria underwent cultures at unchanged frequencies before vs after the intervention (52.1% vs 47.0%, $P = .09$, compared with 56.7% vs 55.0%, $P = .75$). In-hospital mortality (45 [2.0] vs 37 [1.6]; $P = .23$) and hospital readmissions (107 [4.9] vs 103 [4.4]; $P = .42$) were unchanged after the intervention.

CONCLUSIONS AND RELEVANCE A systematic approach to blood cultures decreased the total number of cultures and central venous catheter cultures, without an increase in rates of mortality, readmission, or episodes of suspected infection and suspected septic shock.

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Blood cultures are a cornerstone in the evaluation of patients with sepsis because detection of a bloodstream infection identifies the cause of sepsis and allows a clinician to target antimicrobial therapy. Standards or guidelines are not available to guide appropriate indications for drawing blood cultures.[1] Fever often prompts clinicians to obtain a blood culture, but not all patients with fever have bloodstream infection. Blood cultures are generally perceived to be low-risk, whereas unidentified bacterial sepsis has high morbidity and mortality.

However, the yield of blood cultures drawn from hospitalized patients is low.[2] Literature on adult patients has found that only 5% to 15% of blood cultures obtained from febrile patients are positive.[3] As many as 50% of positive blood cultures are falsely positive, most often attributable to contamination.[2,4] In addition, there is a lack of uniformity about the optimal source for blood cultures. Previous work has suggested that blood cultures drawn from central venous catheters (CVCs) are at increased risk of being falsely positive.[1,5] Related literature demonstrated a decrease in false-positive blood cultures froms peripheral venipuncture rather than CVCs in adults.[6] False-positive cultures contribute to patient harm via additional hospital days, unnecessary antibiotics, and increased costs.[7]

Given the increased attention in the United States to early recognition and treatment of sepsis, clinicians must weigh 2 potential conflicting harms: delayed diagnosis and inappropriate testing. Recognizing the importance of balancing the unintended consequences of inappropriate testing and the need to promptly evaluate patients with suspected infections, our objective was to describe a quality improvement project at an academic tertiary care pediatric intensive care unit (PICU) implemented to reduce unnecessary blood culture use. The project's goal was to guide clinicians in the appropriate use of blood cultures for patients whose clinical characteristics raised concern for bacteremia while decreasing the number of unnecessary blood cultures collected: an endeavor to establish microbiologic stewardship in the PICU.

Key Points

Question Can a quality improvement initiative safely reduce unnecessary blood culture use in critically ill children?

Findings In this cohort study, introduction of education and decision support tools for caregivers was associated with a reduction in blood culture use, and focused attention on blood culture collection site was associated with fewer cultures being collected from central venous catheters after vs before intervention. In-hospital mortality, readmissions, and rates of episodes defined as "suspected infection" and "suspected septic shock" did not increase after intervention.

Meaning Education and decision support tools that standardize approach to fever can safely reduce blood culture use in hospitalized children.

Methods

Setting

The Johns Hopkins Bloomberg Children's Center, Baltimore, Maryland, is an urban, academic tertiary care center with a 36-bed combined medical/surgical PICU that admits patients from birth to 24 years, with an average of 2000 admissions per year. The PICU is the regional referral center for childhood trauma and burns, provides care for life-threatening medical illness, and is the site of varied types of perioperative care for children. The Johns Hopkins University Institutional Review Board approved this retrospective study with a waiver of informed consent.

Study Design and Population

We performed a retrospective cohort study to determine the effect of a quality improvement-based new clinical practice guideline on blood culture practices. All patients admitted to the PICU during the preintervention (April 1, 2013, to March 31, 2014) and postintervention (April 1, 2014, to March 31, 2015) periods with a unit length of stay of 4 hours or longer were included.

Quality Improvement Project

In early 2014, review of the PICU's blood culture practices revealed 2 notable observations: (1) frequently, multiple blood cultures were drawn from patients with fever (including cultures from multiple CVC lumens) and (2) frequently, blood scultures were collected from CVCs and not via peripheral venipuncture sites. These observations led to a focused collaboration between PICU and infectious diseases faculty to standardize clinician approach to blood cultures in critically ill children. Two documents were developed, piloted, and revised: the fever/sepsis screening checklist (**Figure 1**) and the blood culture decision algorithm (**Figure 2**). Together, these documents represented a new clinical practice guideline for the PICU. Recognizing that blood culture practices differ across medical specialties and patient populations, clinicians from other pediatric specialties, especially oncology, were engaged to revise the checklist and algorithm.

The proposed work flow (Figures 1 and 2) was as follows: if fever, hypothermia, or new clinical instability alerted the bedside caregiver to the possibility of systemic infection in the patient, the fever/sepsis screening checklist was consulted. A checklist-based approach was chosen based on robust literature demonstrating that checklists provide a systematic framework to drive behavior change and improve patient outcomes.[8] Before a blood culture was ordered, this document would guide the clinician to consider other possible sources of infection (eg, surgical site infection or tracheitis), to consider noninfectious sources of fever (eg, opioid withdrawal or surgery within the preceding 24 hours), and to carefully evaluate the individual patient's risk factors for bacteremia (eg, prolonged presence of a CVC or compromised immune system). The goal of the fever/sepsis screening checklist was not to remove autonomy from the bedside caregiver; rather, it was meant to support a standard structured approach to a patient with a new fever or change in clinical status. For example, after reviewing the checklist, the clinician may realize that systemic infection is low on the differential for a stable, febrile patient with

Figure 1. Fever/Sepsis Screening Checklist

Fever/Sepsis Screening Checklist – Pre Culture Review

Instructions: Please complete this form ***before*** ordering a blood culture. Bedside RN and frontline provider complete this together, ideally at bedside.

Screen initiated: Date _____ Time _____ Patient name _____
Nurse name _____ Provider Name _____

Blood culture may be warranted:

1. Signs of systemic infection
   a. Temperature: max min source? (*Rectal temp is contraindicated in neutropenic pt)
   b. Rigors
   c. Unexplained tachycardia
   d. Hypotension
   e. Poor perfusion
   f. Metabolic acidosis
   g. Elevated WBC from baseline
   h. Elevated or uptrending CRP
   i. Already on antibiotics but persistent fever or clinical symptoms?
2. Risk Factors
   a. Host Immune Status
      i. Neutropenic
      ii. Congenital immune deficiency
      iii. <6 mos after autologous BMT
      iv. <12 mos after allogeneic BMT
      v. Active GVHD
      vi. Steroids (>= 1mg/kg/day PDN equiv)?
      vii. Other therapy for GVHD
      viii. Lymphopenic (eg after ATG, alemtuzumab/ Campath, rituximab)
      ix. Asplenic (s/p splenectomy or functionally asplenic)
      x. Neonate?
   b. Central Line present AND concern for:
      i. Symptoms (eg hypotension) when infusing through the line
      ii. Line site inflamed, tender, purulent?
      iii. Line repaired?
      iv. Cuff exposed
      v. Consider duration of line – abx-coated PICC>56 days or abx-coated Cook >28 days?
      vi. Concern for line contamination? (eg hub in diaper, cap removed accidentally)
   c. Patient has these possible portals of infection:
      i. Mucositis
      ii. Skin ulcers/bullae/wounds
      iii. Active GVHD

Blood culture may not be warranted:

1. Consider other sources of infection on exam/history:
   a. Conjunctivitis
   b. Otitis media
   c. Pharyngitis
   d. Respiratory symptoms
   e. Increased trach or ETT secretions
   f. Urine color/consistency change/dysuria
   g. Diarrhea (>3 stools/24 hours)
   h. Superficial wound erythema/drainage/cellulitis without any of symptoms in item 1
2. Patient has non-infectious cause of symptoms
   a. Withdrawal – recent sedation weans? Elevated WAT score?
   b. Feeding intolerance causing tachycardia, emesis, diarrhea
   c. Surgery within last 24 hours
3. Negative blood cultures drawn within last 24-48 hours, and no clinical change in the patient other than fever

After completion of this tool, is a blood culture indicated?
_____

If yes, please now refer to Blood Culture Algorithm for source (peripheral vs central or both)

Provider signature _____

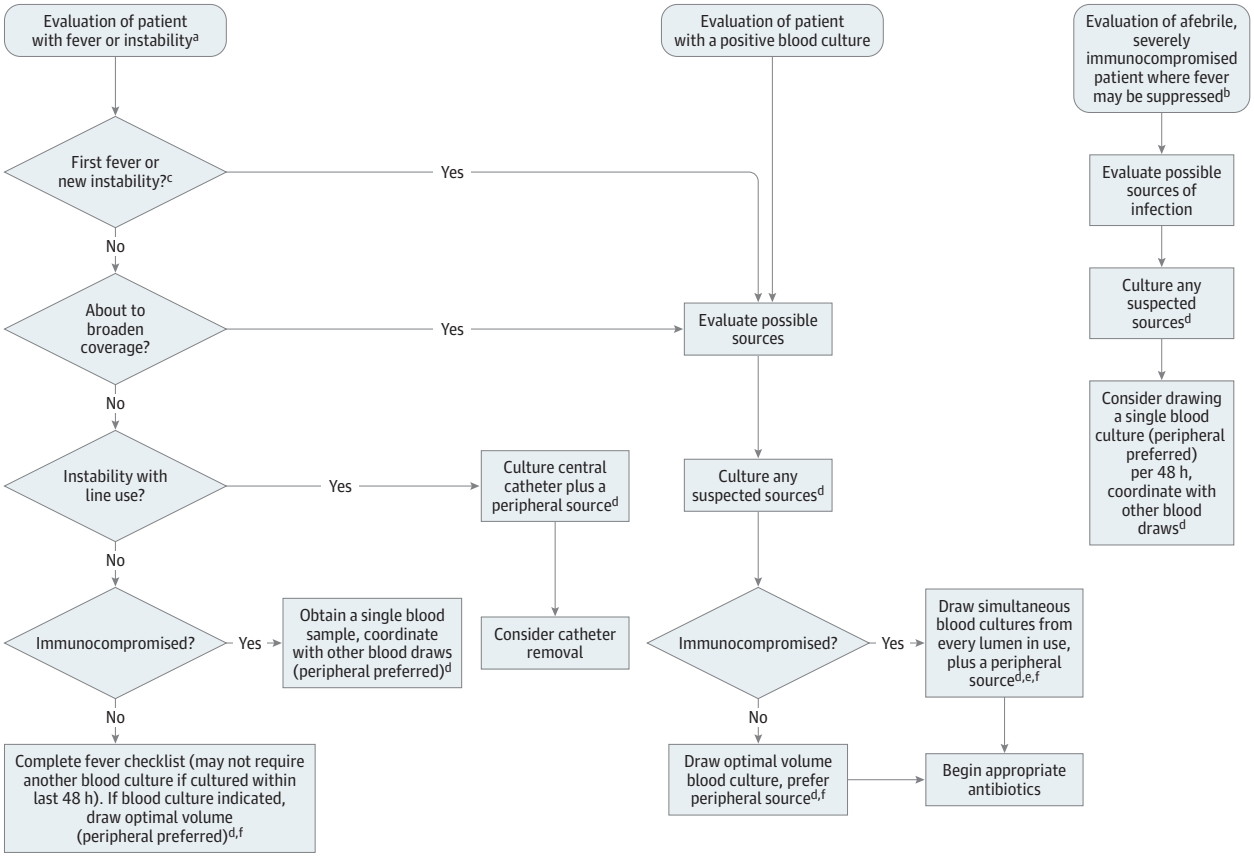
Please give to project coordinator

abx indicates antibiotic; ATG, antithymocyte globulin; Campath, alemtuzumab; Cook, manufacturer of catheters; CRP, C-reactive protein; BMT, bone marrow transplant; ETT, endotracheal tube; GVHD, graft-vs-host disease; PDN, prednisone; PICC, peripherally inserted central catheter; s/p, status/post; trach, tracheostomy; WAT, Withdrawal Assessment Tool; and WBC, white blood cell.

symptoms of withdrawal after recent narcotic weaning. If, after completing the fever/sepsis screening checklist, the clinician deemed it appropriate to obtain a blood culture, then he or she would consult the blood culture decision algorithm. This algorithm indicated whether to collect a specimen from peripheral venipuncture, a CVC, or both. In general, emphasis was placed on peripheral venipuncture as the first preference except for specific circumstances, such as prior positive culture from the CVC, clinical instability with use of the CVC line, or immunocompromised hosts with CVCs. The algorithm also clarified that obtaining blood cultures from arterial lines was not an acceptable surrogate for a peripheral specimen given the risk of contamination and false-positive results.[9] Recognizing that a peripheral site may be difficult or traumatic in some patients, after 2 unsuccessful attempts, clinicians were instructed to not delay antibiotic administration and to note on the checklist why a culture from a CVC was obtained. Initially during the pilot phase, the attending physician's signature on the checklist was required before drawing a CVC blood culture to emphasize the importance of multiple levels of review before entering a CVC. As the program became established, signed forms were no longer required.

After a brief pilot period in March 2014, the new program was instituted on April 1, 2014. A 4-part strategy for unitwide implementation was used. Copies of the checklist and algorithm were distributed electronically to PICU staff and paper copies were placed throughout the unit. The new blood culture practices were formally discussed at staff meetings and conferences. Individual attending physicians were given weekly electronic feedback about the number of blood cultures that were drawn from their patients. Briefly, copies of completed checklists were reviewed to ensure adherence to

Figure 2. Blood Culture Decision Algorithm



[a] Signs of instability include rigors, hypothermia, hypotension, tachycardia, mental status changes, poor perfusion, glucose instability, and metabolic acidosis.

[b] Examples of severely immunocompromised patients with masked signs of sepsis are a patient who is receiving corticosteroid therapy (≥1 mg/kg/d) after a bone marrow transplant, induction therapy for hemophagocytic lymphohistiocytosis, and reduction or induction therapy for Burkitt lymphoma.

[c] Fever is considered first or new if it occurs 48 hours or more after the last fever.

[d] After 2 unsuccessful peripheral attempts and 1 unsuccessful arterial attempt, consider a central culture.

[e] Differential time to positivity is a useful way to distinguish catheter-related bloodstream infections from bacteremia unrelated to central catheter care. To be valid, equal volumes of blood must be obtained simultaneously from each lumen and a peripheral source and inoculated in the same culture media. Do not let difficulty obtaining a peripheral blood culture delay initiation of appropriate antibiotics (standard is <60 minutes from neutropenic fever to broad-spectrum coverage).

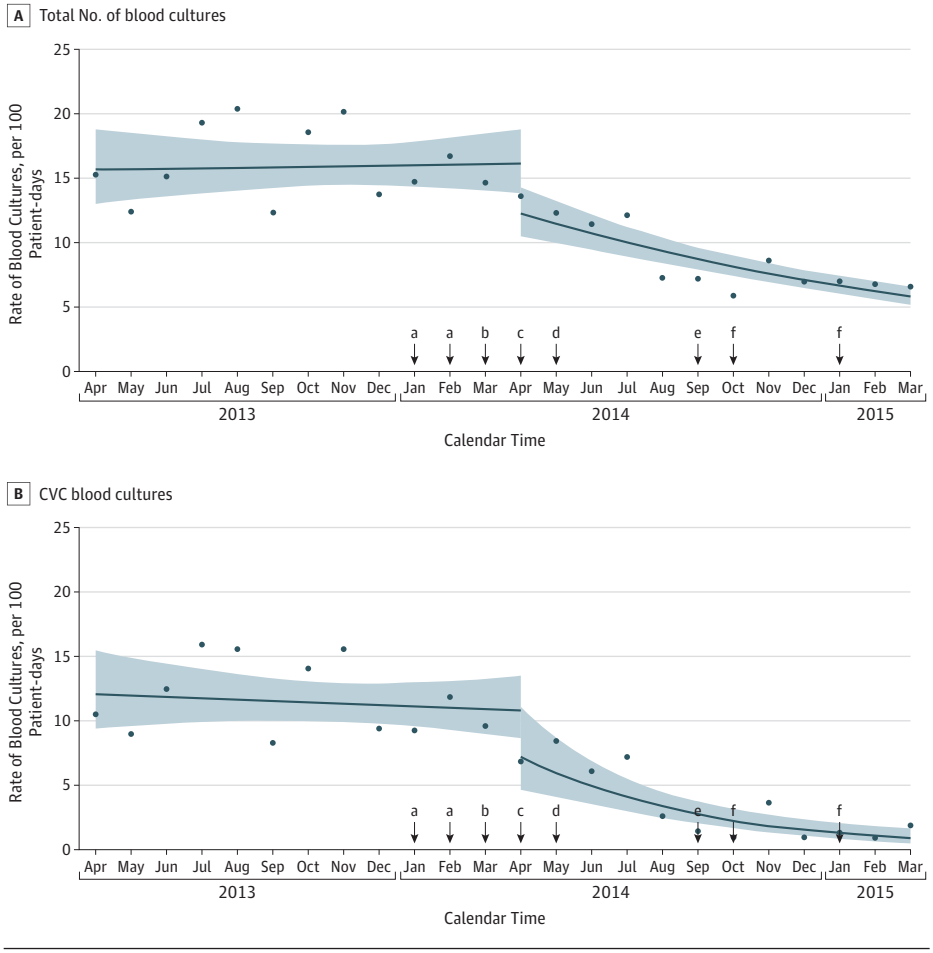
[f] Consider blood cultures from central catheter lumens and peripherally to distinguish catheter infections from bacteremia and to inform possible salvage of the central catheter. If considering catheter salvage, reculture every positive lumen daily until negative.

the new guidelines, although as blood culture rates began to decrease, adherence data were no longer collected. **Figure 3** illustrates the timeline of events in the implementation of this program, highlighting that multiple cycles of multidisciplinary communication and process refinement were required.

Outcome Measures

Our primary outcome was the number of blood cultures drawn per 100 patient-days. Secondary demographic, clinical, and hospital utilization measures were collected to ensure unbiased before and after comparisons and to investigate other potential effects of the intervention. Secondary outcome measures included number of blood cultures drawn from CVCs vs peripheral venipuncture, patient length of stay, in-hospital mortality, hospital and PICU readmission within 7 days of discharge, number of episodes of suspected infection and suspected septic shock, number of blood cultures for episodes of suspected infection and suspected septic shock, and mortality in patients with suspected septic shock. Episodes of suspected infection and septic shock were detected by the presence of a set of clinical events occurring concomitantly (ie, within a 24-hour time window) during a PICU visit. The anchor time point for an episode was the time of a new (ie, first dose) broad-spectrum antibiotic (**Table 1**) or 48 hours or longer from prior administration of a broad-spectrum antibiotic. With the use of this anchor time, episodes were defined as (1) *suspected infection:* recorded temperature 38.5°C or higher or lower than 36.0°C within 24 hours (ie, before or after) of receiving a new broad-spectrum antibiotic, and (2) *suspected septic shock:* recorded temperature 38.5°C or higher or lower than 36.0°C and vasopressor

Figure 3. Rate of Blood Cultures Before vs After Introduction of a Quality Improvement Initiative to Optimize Blood Culture Use in the Pediatric Intensive Care Unit (PICU), and Timeline of Events Key to Implementation



A, Total blood cultures per 100 patient-days before and after intervention. B, Central venous catheter (CVC) cultures per 100 patient-days before and after intervention. Individual data markers represent blood culture rates per 100 patient-days displayed by month in the PICU; solid line represents predicted rate from the interrupted time series analysis with 95% CIs (blue-shaded area). The arrows indicate key dates in the development and implementation of the quality improvement initiative.

[a] Multidisciplinary discussions about blood culture practices in the PICU.

[b] Observations of repeated blood cultures in patients with persistent fever and cultures frequently drawn from CVCs.

[c] Weekly feedback about culture practices is distributed to PICU faculty and fever/sepsis screening checklist is distributed throughout the PICU.

[d] Engagement with multidisciplinary providers to create blood culture decision algorithm.

[e] Blood culture decision algorithm is implemented for all PICU patients.

[f] Refinement of blood culture decision algorithm in response to health care professional feedback.

administration within 24 hours of receiving a new broad-spectrum antibiotic.

It was then determined whether a blood culture was drawn within 24 hours of the new antibiotic administration time (ie, anchor time). Data on most secondary measures were collected retrospectively from the electronic medical record system (Sunrise Clinical Manager, version 15.3; Allscripts). Blood culture data were collected using infection surveillance software (TheraDoc, version 4.5.5; Premier).

Statistical Analysis

To measure the effect of this quality improvement program on blood culture use, we compared patients admitted to the PICU in the preintervention period of April 1, 2013, to March 31, 2014, with those in the postintervention period of April 1, 2014, to March 31, 2015. Demographic characteristics of patients in the preintervention and postintervention periods were compared using χ^2 tests. We measured the effect of the program on blood culture use by comparing blood culture rates per 100 patient-days in the preintervention and postintervention periods using a Poisson regression model and then using a quasi-experimental interrupted time-series model for the log-transformed monthly blood culture rates.[10,11] The interrupted time-series model estimates (1) the relative change in the blood culture rates per month during the preintervention period; (2) the immediate effect of the intervention, reported as the relative change in the blood culture rate comparing the first month of the postintervention period with the last month of the preintervention period; and (3) the sustained effect of the intervention, reported as the relative change in the blood culture rate per month during the postintervention period. To determine the robustness of our findings, we performed a sensitivity analysis by varying the start time of the intervention period in the interrupted time-series model.[12] Secondary outcomes were evaluated with Wilcoxon rank sum tests for continuous variables, χ^2 tests for categorical variables, and 2-sided Poisson tests for comparing independent incidence rates. Data were analyzed using StataSE, version 13.1 (StataCorp). The interrupted time-series models were fit using the *itsa* module in StataSE, version 13.1.

Results

During the study period, there were 4560 patient visits to the PICU, including 2204 before the intervention and 2356 after

the intervention. Patient demographics are described in **Table 2.** Before the intervention there were 1807 blood cultures drawn during 11 196 patient-days; after the intervention there were 984 blood cultures drawn during 11 204 patient-days (incidence rate, 16.1 vs 8.8 blood cultures per 100 patient-days), resulting in an overall 46.0% reduction in the collection rate of blood cultures comparing the postintervention and preintervention periods (incidence rate ratio [IRR], 0.54; 95% CI, 0.50-0.59) (Figure 3). Overall, there were fewer blood cultures collected from CVCs in the postintervention period compared with the preintervention period (389 [39.5%] vs 1321 [73.1%]; $P < .001$).

The interrupted time series analysis found that, before the intervention, the rate of blood cultures per 100 patient-days was not changing (IRR per month, 1.002; 95% CI, 0.98-1.04; $P = .83$). After introduction of the intervention, there was an immediate 25.0% reduction in the rate of blood cultures per 100 patient-days (95% CI, 4.2%-39.7%; $P = .02$). In the postintervention period, there was a sustained 6.6% monthly decrease in the rate of blood cultures collected per 100 patient-days (95% CI, 4.7%-8.4%; $P < .001$) (Figure 3). The sensitivity analysis with varying start dates for the intervention period confirmed that the immediate drop in blood culture rates correlated with the actual intervention start date.

There were decreases in the rates of suspected infection and suspected septic shock per 100 patient-days between the postintervention and preintervention periods (Table 2). However, the proportions of suspected infection occurrences during which blood cultures were drawn within 24 hours were not significantly different in the preintervention and postintervention periods (52.1% and 47.0%; $P = .09$) (Table 2). Similarly, the proportions of suspected septic shock occurrences

Table 1. Broad-Spectrum Antibiotics and Vasoactive Medications Included in the Analysis

Category	Medications
Broad-spectrum antibiotics: *New* defined as ordered during PICU admission and receipt of first dose or ≥48 h from any broad-spectrum antibiotic administration	Aztreonam arginine, cefepime hydrochloride, cefotaxime sodium, ceftazidime sodium, ceftriaxone sodium, gentamicin sulfate, imipenem sodium, meropenem sodium, piperacillin-tazobactam sodium, vancomycin hydrochloride
Vasoactive medications: Included if ordered within 24 h of the initiation of new broad-spectrum antibiotic therapy and temperature ≥38.5°C or <36.0°C, and ≥48 h from any vasoactive medication administration	Dobutamine hydrochloride, dopamine hydrochloride, epinephrine, milrinone lactate, norepinephrine bitartrate, phenylephrine, vasopressin

Abbreviation: PICU, pediatric intensive care unit.

Table 2. Demographic and Clinical Characteristics of Patient Visits Before and After an Intervention to Improve Blood Culture Use in a PICU[a]

PICU Visit Characteristic	No. (%) Before Intervention (n = 2204 Visits)	No. (%) After Intervention (n = 2356 Visits)	*P* Value
Demographics			
Age, median (IQR), y	5 (1-13)	6 (1-13)	.27
Male	1215 (55.1)	1262 (53.6)	.50
Race/ethnicity			
Black/African American	774 (35.1)	765 (32.5)	.07
White	966 (43.8)	1080 (45.8)	
Other	342 (15.5)	349 (14.8)	
Unknown	122 (5.5)	162 (6.9)	
Ethnicity			
Hispanic or Latino	104 (4.7)	133 (5.6)	.01
Clinical measures			
Patient-days	11 196	11 204	
Blood cultures drawn, No. (rate per 100 patient-days)	1807 (16.1)	984 (8.8)	<.001
Suspected infection, No. (rate per 100 patient-days)[b]	660 (5.9)	496 (4.4)	<.001
With blood cultures	344 (52.1)	228 (47.0)	.09
Suspected septic shock, No. (rate per 100 patient-days)[c]	205 (1.8)	159 (1.4)	.02
With blood cultures	117 (56.7)	88 (55.0)	.75
In-hospital mortality	45 (2.0)	37 (1.6)	.23
For suspected septic shock occurrences	25 (12.2)	16 (10.0)	.51
Hospital Utilization Measures			
Length-of-stay, median (IQR), d			
Hospital	5 (2-11)	4 (2-10)	.41
PICU	1.81 (0.9-4.2)	1.91 (1.0-4.0)	.04
7-d Readmission			
Hospital	107 (4.9)	103 (4.4)	.42
PICU	69 (3.1)	74 (3.1)	.98

Abbreviations: IQR, interquartile range; PICU, pediatric intensive care unit.

[a] Before: April 1, 2013, through March 31, 2014; after: April 1, 2014, through March 31, 2015.

[b] Suspected infection was defined as new initiation of broad-spectrum antibiotic therapy in the PICU and a temperature of 38.5C° or higher or lower than 36.0C° within 24 hours of the initial antibiotic dose. New initiation of antibiotic therapy was defined as treatment ordered during PICU admission and either receipt of the first dose or 48 hours or more from any other broad-spectrum antibiotic administration.

[c] Suspected septic shock was defined as new initiation of broad-spectrum antibiotic therapy in the PICU and a temperature of 38.5C° or higher or lower than 36.0C° and new vasopressor requirement within 24 hours of the initial antibiotic dose. New initiation of antibiotic therapy was defined as therapy ordered during PICU admission and either receipt of the first dose or 48 hours or more from any other broad-spectrum antibiotic administration.

during which blood cultures were drawn within 24 hours were not significantly different in the preintervention and postintervention periods (56.7% and 55.0%; $P = .75$). Comparing the preintervention and postintervention periods, there were no significant differences in in-hospital mortality (2.0% vs 1.6%; $P = .23$) or mortality in the subgroup of patients with suspected septic shock occurrences (12.2% vs 10.0%; $P = .51$). During the preintervention and postintervention periods, both hospital 7-day readmission rates (4.9% and 4.4%; $P = .42$) and PICU 7-day readmission rates (3.1% and 3.1%; $P = .98$) were not significantly different. Hospital length of stay was similar between the 2 periods, but median (interquartile range) PICU length of stay was significantly shorter in the preintervention compared with the postintervention period (1.81 [0.9-4.2] vs 1.91 [1.0-4.0] days; $P = .04$).

Discussion

A novel, 2-tiered clinical practice guideline improved blood culture use in a tertiary care PICU. A transdisciplinary collaboration successfully implemented a multifaceted approach to engage frontline clinicians in practice change, solicited and provided bidirectional feedback, and refined implementation tools. Subsequently, fewer blood cultures were collected, clinicians continued to order blood cultures in patients meeting criteria for "suspected infection" or "suspected septic shock" with similar frequencies before vs after intervention, peripheral venipuncture became the preferred site for blood culture collection, and mortality and readmission rates remained stable.

Although the 2016 task force recommendations on sepsis are clear that recognition of sepsis "mandates urgent attention," clinicians struggle with imperfect diagnostic tools.[13(p18)] Blood cultures are considered an important screening tool in patients with fever and possible bacteremia, but the yield is low and up to half are falsely positive.[1,2] One aim of this project was to address the absence of clinical consensus about why and how to obtain a blood culture in a critically ill pediatric patient to decrease the number of unnecessary blood cultures being drawn. By engaging physicians, nurses, and the vascular access team in the discussion, we developed 2 novel documents that provided a framework for all members of the PICU team to reference when considering ordering a blood culture. These documents are now well established in our PICU, and we have documented a sustained decrease in the overall number of blood cultures being drawn after intervention. This shift in practice required a multifaceted approach: providing physicians with feedback about the numbers of cultures performed on their patients enhanced early buy-in about the scope of the problem, presenting the new guideline at various venues and in a serial fashion increased our ability to engage frontline caregivers in the PICU, and seeking feedback repeatedly about the 2 documents ensured that we could adapt the tools to the reality of our unit's workflow and environment. Both documents underwent many revisions in response to questions and comments brought forth by PICU and non-PICU providers, highlighting that quality improvement is an iterative process whose champions must be flexible.

Because sepsis is common and deadly in PICU patients, we considered whether a reduction in the rate of blood cultures collected reflects a potentially detrimental decreased level of surveillance for a serious disease. During our study period, mortality and PICU and hospital readmission rates were not significantly different before and after the guidelines were introduced. Furthermore, rates of suspected septic shock occurrences were decreased after the intervention, and rates of mortality in those with suspected septic shock were not significantly different in the preintervention and postintervention periods. We did not see an increase in the number of episodes of suspected septic shock after intervention to suggest delayed diagnosis by decreased use of blood cultures, nor did we observe a decreased proportion of suspected septic shock occurrences during which a blood culture was obtained that would suggest inappropriate undertesting. These findings suggest that important balancing metrics remained stable after the intervention and that clinicians still ordered appropriate blood cultures when faced with patients who exhibited clinical signs of septic shock despite the overall reduction in blood culture use. Our data observed a reduced number of suspected infections and suspected septic shock occurrences. Because these 2 outcomes, by definition, required initiation of new antibiotics, it is possible that education around appropriate blood culture use had an unintended consequence of improving antibiotic stewardship, a finding that needs to be further explored.

Together, these results suggest that improved use of blood cultures and a reduction in unnecessary testing is possible while maintaining diligent screening for bacteremia when clinical suspicion arises. Fever is one sign of sepsis, but sepsis ultimately is a clinical diagnosis that is supported by, but not dependent on, a blood culture. Asking clinicians to systematically work through a sound and thoughtful algorithm when faced with a change in patient status keeps sepsis on the differential and does not allow anyone to ignore the warning sign that fever and hypothermia can represent. Blood cultures remain a critical tool to diagnose sepsis and guide management and should not be abandoned, but their use can be safely improved.

Limitations

This was a single-center, quality improvement project. Work to implement similar practice changes at 2 additional PICUs is currently under way to test our findings' generalizability. There are limited published data on blood culture utilization rates from other hospitals to compare whether the baseline blood culture utilization rate in this PICU was high before starting the intervention, although the existing data suggest that our preintervention use was lower (160 per 1000 patient-days vs a published 228 per 1000 patient-days).[14] When comparing patient demographics across the 2 time periods, data were not available to adjust for any potential differences in case mix or patient acuity; however, similar populations of patients were admitted over the 2 years of study. Our definitions of suspected infection and suspected septic shock and our method of extracting electronic medical record data may have misclassified some outcomes. For example, a postoperative patient with a temperature lower than 36°C receiving perioperative aztreonam owing to medication allergies would have

met our criteria for suspected infection or a patient receiving ceftriaxone sodium for tracheitis who then requires phenylephrine for transient hypotension during procedural sedation would have met the criteria for suspected septic shock. These misclassifications should have been similar across the study periods and would not be expected to bias the results.

Conclusions

A systematic approach to blood cultures may help to optimize laboratory use in critically ill children. This clinical decision support initiative decreased the total number of cultures and the proportion drawn from CVCs. The concern that fewer cultures would equate to a detrimental decreased level of surveillance for sepsis was not borne out in our results, with stable postintervention mortality rates and readmission rates and, most importantly, no increase in episodes of suspected septic shock after intervention or mortality associated with episodes of suspected septic shock. Further studies are needed to define how differences in unit practices and culture would affect the effectiveness and implementation of safe strategies to improve blood culture use.

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