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Assessing a Standardized Decision-Making Algorithm for Blood Culture Collection in the Intensive Care Unit

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Abstract

Purpose: Blood cultures are commonly ordered for patients with low risk of bacteremia. Indications for obtaining blood cultures are often broad and ill defined, and decision algorithms for appropriate blood cultures have not been comprehensively evaluated in critically-ill populations.

Methods: We conducted a retrospective analysis to assess the frequency of inappropriate blood cultures in the ICUs at Montefiore Medical Center based on an evidence-based guidance algorithm. Blood cultures were reviewed against this algorithm to determine their appropriateness. We calculated the prevalence of inappropriate blood culture and explored the reasons for these collected cultures.

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Author Statement

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Ari Moskowitz: conceptualization, methodology, validation, formal analysis, writing - review & editing, supervision, project administration.
Jen-Ting Chen: conceptualization, methodology, resources, data curation.
Inessa Gendline: methodology, resources, writing - review and editing.
Austin Saline: writing - original draft, writing - review and editing.
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Results: 300 patients were randomly selected from an initial cohort of 3,370 patients. 294 patients were included and of these, 167 patients had at least 1 blood culture drawn. 125 patients had one or more inappropriate blood culture. 61.4% of blood cultures drawn were assessed to be inappropriate. The most common reason for inappropriate cultures was a culture drawn as a result of isolated fever or leukocytosis.

Conclusion: In a cohort of critically-ill patients, inappropriate blood cultures were common. The indications for blood cultures are often not evidence-based, and evidence-based algorithms to guide the collection of blood cultures may offer a way to decrease inappropriate culture orders.

Keywords

Blood Cultures; Fever workup; Inappropriate Cultures; Intensive Care; ICU

Background

Blood cultures are commonly ordered for patients with a low risk of bacteremia[1,2] and just 5–10% of blood cultures yield clinically significant pathogens[3,4]. Inappropriate ordering of blood cultures increases the risk of false positive results due to contamination, which is associated with longer hospital stays, excess antibiotic usage, and unnecessary removal of central venous catheters[1,2]. Inappropriate blood sampling also causes patient discomfort and is associated with anemia.

Historically, there has been a lack of clear, concise guidance on how to decide when to order blood cultures. Indications for obtaining blood cultures in hospitalized, non-neutropenic patients are broad and ill defined[5,6]. In one study of inpatient clinicians, the major factors identified influencing the decision to order blood cultures included concern for missing an infection and the dogma that blood cultures are a standard component of a fever workup[5]. Minimizing inappropriate blood cultures in critically ill patients is especially important as false positive or contaminated blood cultures can have additional ramifications and the risks and benefits of blood cultures are magnified.

In one recent study, Fabre et. al developed and assessed an evidence-based algorithm to guide the collection of blood cultures in hospitalized patients[1]. Using this algorithm in the Distribute Study, the investigators found that 30% of blood cultures collected on the medical intensive care unit were not indicated and greater than 40% of blood cultures collected on general medicine units were not indicated[1]. After implementation of their evidence-based algorithm, rates of inappropriate blood cultures substantially decreased[1]. In this retrospective analysis of a critically ill patient cohort, we externally assessed the prevalence and drivers of inappropriate blood culture collection using the blood culture guidance algorithm developed by Fabre et. al.

Methods

Population

This was a retrospective, single-center but multi-hospital study of non-neutropenic, mechanically ventilated patients hospitalized in the intensive care units of Montefiore

Medical Center (MMC) between 2017 and 2018. Given the large number of mechanically ventilated patients during this time period, a randomly selected subset of 300 patients were selected for review. Patients were excluded only for neutropenia. This study was approved by the Albert Einstein College of Medicine Institutional Review Board (IRB #2018–9244).

Data Collection

Blood culture data was included from each patient's first mechanically ventilated ICU stay during their admission. Only blood cultures collected during the first 14 days of the patient's ICU course were included, which was decided on prior to the start of data collection. Two independent investigators (AS and EL) each reviewed 20 blood cultures using the algorithm described below to determine the appropriateness of each blood culture ordered. *A priori* a kappa level of >0.8 was set as a minimal level of agreement to proceed with further independent chart review. Agreement after 20 charts reviewed demonstrated a kappa of 0.85. The investigators then divided the remaining charts for independent review.

Blood Culture appropriateness algorithm

The algorithm used to determine if a blood culture was appropriate was created by a research team at John's Hopkins and validated in that hospital[1]. This algorithm was reviewed by a multidisciplinary team at MMC including physicians from the Departments of Infectious Disease and Critical Care Medicine and was adapted for use in this study (see Figure 1)

Statistical Analysis

Patient characteristics were described using means with standard deviations or medians with interquartile ranges as appropriate. Categorical variables were described using frequencies and percentages. All characteristics were assessed overall and broken down by whether no blood culture was drawn, only appropriate blood cultures were drawn, or if at least one inappropriate blood culture was drawn. The prevalence and number of inappropriate blood cultures were calculated. Reasons for inappropriate blood cultures were tabulated and presented graphically.

Results

Patient Population

A total of 300 patients were randomly selected out of an initial cohort of 3,370 patients, and 294 were included in the final analysis (see Figure 2). Of the 6 patients who were not included in the final analysis, 3 were duplicate medical record numbers (MRNs) and 3 of the MRNs had no corresponding patient data in the electronic medical record (EMR). Of these 294 patients, 167 (55.7%) had at least 1 blood culture drawn during the first 14 days of their index ICU stay. Characteristics of patients overall, and broken down by blood culture status can be found in Table 1.

Blood Culture Appropriateness

Overall, a total of 376 blood cultures were collected from 167 patients. The median number of blood cultures per patient was 2.0 (IQR 1.0, 3.0). 42 (25.1%) patients had only appropriate blood cultures collected and 125 (74.4%) had one or more inappropriate blood culture drawn. Fifteen (9.0%) patients had 5 or more cultures drawn over the first 14 days. In most cases, when blood cultures were drawn only a single set (1 aerobic and 1 anaerobic) was obtained (n=299, 79.5%).

Of the 376 blood cultures analyzed, 231 (61.4%) were assessed to be inappropriate. Reasons for inappropriate cultures can be found in the Pareto diagram in Figure 3. In short, the most common reason for inappropriate cultures drawn was low risk bacteremia with a blood culture drawn as a result of isolated fever or leukocytosis (n=92, 24.5% of all cultures drawn). Additional common indications were inappropriate repeat cultures after a recent one had been drawn (n=61, 16.2%) and cases with an intermediate risk of bacteremia but a primary site (e.g. lung) that could be cultured instead (n=45, 12.0%).

Results of Blood Cultures

A total of 33 (8.8%) blood cultures had growth. Of these, 29 (87.9%) grew organisms that were adjudicated as pathogenic and 4 (12.1%) grew organisms that were adjudicated as contaminant. The determination of pathogenicity was made by the clinical team and was assessed by reviewers on the basis of treatment approach and clinical documentation. Of the 29 pathogenic blood cultures, 22 were deemed appropriate (75.86%) and 7 were deemed inappropriate (24.14%). Of the 4 cultures classified as contaminant, 1 was deemed appropriate (25%) and 3 were deemed inappropriate (75%).

Discussion

Using a previously described decision algorithm, we found that 64.1% of blood cultures drawn in critically-ill patients may be inappropriate. Inappropriate blood cultures were commonly collected in patients with an isolated fever or leukocytosis despite having a low-risk of bacteremia. Unwarranted repeat cultures were also common. Blood cultures were often collected in patients with an intermediate-risk of bacteremia in spite of a primary site (e.g. lung) that could be cultured. Notably, during most of these instances, only a single set (1 anaerobic bottle + 1 aerobic bottle) of blood cultures were collected instead of two sets.

As with many common studies ordered by clinicians, the true indications for blood cultures are vauge and often not evidence-based. The decision to draw blood cultures is generally based more on tradition (e.g. part of the “fever workup”) than on clinical data and defined practice[7]. However, drawing blood cultures is not a harmless intervention. They may result in patient discomfort, phlebotomy-associated anemia, and errors of interpretation and uncertain management implications [1,2], which may be harmful to patient care.

There is limited literature that focuses on optimizing decision making around blood culture collection—especially for critically ill patients[8]. In one multicenter pediatric study (BrighT STAR), the implementation of an evidence-based algorithm resulted in

a substantial reduction in both the collection of blood cultures and in broad-spectrum antibiotic use[9]. In the adult population, small single center studies have found high rates of potentially inappropriate blood cultures but have not leveraged specific algorithms in making appropriateness determinations[7,8,10]. In the DISTRIBUTE study, the evidence-based algorithm developed by Farbe et. al. found that 30% of blood cultures in the medical intensive care unit were not indicated and greater than 40% in the medicine units were not indicated[1]. After implementation of their evidence-based algorithm, appropriateness of blood culture utilization significantly improved [1].

To our knowledge, the present study is the first to externally assess the algorithm proposed by Fabre et. al. Our results suggesting a very high rate of potentially inappropriate blood cultures highlight an important area for future quality improvement initiatives. Further, there is a clear need for evidence-based guidelines on blood culture collection, especially because the most common reason for potentially inappropriate culture was isolated fever or leukocytosis, which carry a very low specificity for bacteremia. In addition, many inappropriate cultures were those drawn soon after an initial culture had already been drawn – often immediately after the patient had been transferred to the unit. These repeat cultures offer little benefit and increase patient discomfort, worsen anemia, and may result in false-positives due to skin contamination.

Limitations of our study include our study population and the diversity of specialization of our attending physicians. Our hospital cares for an underserved and underrepresented population with a high rate of comorbidities, bacterial colonization, and antibiotic resistance. As such, clinicians may have engaged in a broader infectious workup than they otherwise would have due to a real or perceived danger of missing bacteremia. Additionally, our study took place in multiple units managed by attendings with diverse training backgrounds, including pulmonology/critical care, cardiology, anesthesia, and surgery. Notably, we did not stratify our results based on this diversity. Therefore, it is impossible to determine if there is a difference in non-indicated blood cultures between the medical, surgical, and cardiac intensive care units or based on the training practices of one or more disciplines. These factors may limit the generalizability of our findings to other institutions.

Conclusions

In a cohort of mechanically ventilated, critically-ill patients, inappropriate blood cultures were common. The most common reason for inappropriate collection was having an isolated fever or leukocytosis. Using an evidence-based algorithm to guide decision making may improve appropriateness and utility of blood cultures in critically-ill patients.

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References

1. Fabre V, Klein E, Salinas AB, Jones G, Carroll KC, Milstone AM, ... & Cosgrove SE (2020). A diagnostic stewardship intervention to improve blood culture use among adult nonneutropenic

inpatients: the distribute study. Journal of clinical microbiology, 58(10), e01053–20. [PubMed: 32759354]

2. Fabre V, Sharara SL, Salinas AB, Carroll KC, Desai S, & Cosgrove SE (2020). Does this patient need blood cultures? A scoping review of indications for blood cultures in adult nonneutropenic inpatients. Clinical Infectious Diseases, 71(5), 1339–1347. [PubMed: 31942949]
3. Linsenmeyer K, Gupta K, Strymish JM, Dhanani M, Brecher SM, & Breu AC (2016). Culture if spikes? Indications and yield of blood cultures in hospitalized medical patients. Journal of hospital medicine, 11(5), 336–340. [PubMed: 26762577]
4. Vitrat-Hincky V, François P, Labarère J, Recule C, Stahl JP, & Pavese P. (2011). Appropriateness of blood culture testing parameters in routine practice. Results from a cross-sectional study. European journal of clinical microbiology & infectious diseases, 30(4), 533–539. [PubMed: 21086006]
5. Fabre V, Milstone AM, Keller SC, Carroll KC, & Cosgrove SE (2018). Prescribers' knowledge, attitudes and perceptions about blood culturing practices for adult hospitalized patients: a call for action. Infection Control & Hospital Epidemiology, 39(11), 1394–1396. [PubMed: 30226121]
6. Grace CJ, Lieberman J, Pierce K, & Littenberg B. (2001). Usefulness of blood culture for hospitalized patients who are receiving antibiotic therapy. Clinical infectious diseases, 32(11), 1651–1655. [PubMed: 11340541]
7. Hoops KE, Fackler JC, King A, Colantuoni E, Milstone AM, & Woods-Hill C. (2020). How good is our diagnostic intuition? Clinician prediction of bacteremia in critically ill children. BMC medical informatics and decision making, 20(1), 1–8. [PubMed: 31906929]
8. Vaughn VM, Szymczak JE, Newton DW, & Fakih MG (2019). Addressing the overuse of cultures to optimize patient care. Annals of Internal Medicine, 171(7_Supplement), S73–S74. [PubMed: 31569221]
9. Woods-Hill CZ, Colantuoni EA, Koontz DW, Voskertchian A, Xie A, Thurm C, ... & Zerr DM (2022). Association of Diagnostic Stewardship for Blood Cultures in Critically Ill Children With Culture Rates, Antibiotic Use, and Patient Outcomes: Results of the Bright STAR Collaborative. JAMA pediatrics
10. Boerman AW, Schinkel M, Meijerink L, van den Ende ES, Pladet LC, Scholtemeijer MG, ... & Nanayakkara PW (2022). Using machine learning to predict blood culture outcomes in the emergency department: a single-centre, retrospective, observational study. BMJ open, 12(1), e053332.

Highlights

- There is a lack of clear and concise guidance on when to order blood cultures
- Blood cultures from our ICUs were reviewed using an evidence-based algorithm
- A high percentage of blood cultures drawn may not be clinically indicated
- Non-indicated cultures were commonly drawn due to isolated fever or leukocytosis
- Our paper shows the need for evidence based guidelines on blood culture collection

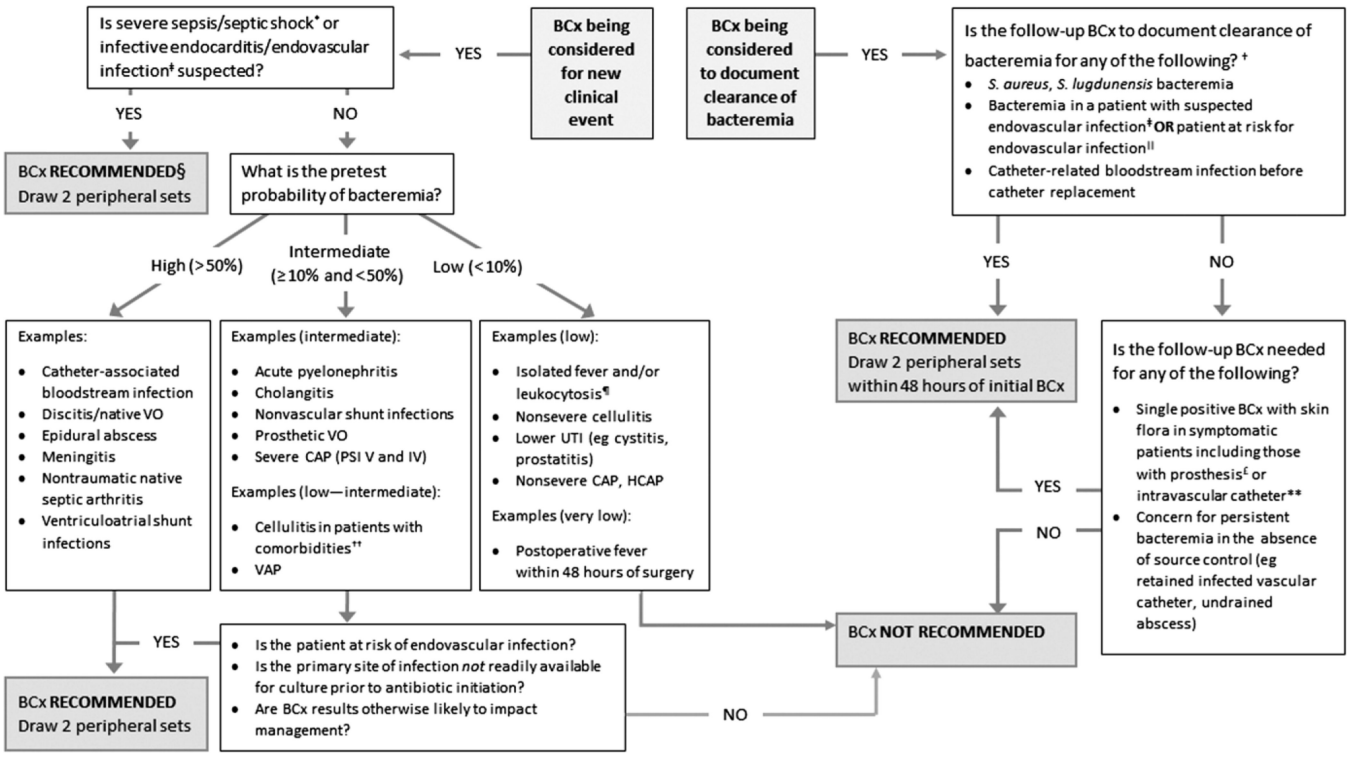

Figure 1: Algorithm for bacterial blood cultures recommendations in nonneutropenic patients

The algorithm is not a substitute for clinical judgment. *Blood culture (BCx) required by US Centers for Medicare and Medicaid Services severe sepsis criteria of the Severe Sepsis and Septic Shock Early Management Bundle. †BCx positive for Candida species require routine follow-up blood culture (FUBCx). ‡Septic thrombophlebitis, infected endovascular thrombi, implantable cardioverter defibrillator (ICD)/pacemaker lead infections, intravascular catheter infections, and vascular graft infections. §Consider > 2 sets for suspected endocarditis. ||Patients at risk of endovascular infection: ICD/pacemaker, vascular graft, prosthetic valves and prosthetic material used for cardiac valve repair, history of infective endocarditis, valvulopathy in heart transplant recipient, unrepaired congenital heart disease, repaired congenital heart disease with residual shunt or valvular regurgitation, or within the first 6 months postrepair. ¶Before ordering BCx, assess the patient's clinical history and perform a physical examination to identify infectious and noninfectious sources for the isolated fever episode and review the potential benefit added by BCx. £Prosthesis: joint or intravascular prosthesis. **Routine additional FUBCx for a single BCx with skin flora (eg, coagulasenegative staphylococci) in an immunocompetent patient are not necessary unless bacteremia is suspected or a prosthesis is present. ††Cellulitis in patients with comorbidities: immunocompromised hosts or those at risk of poor outcomes from sequelae from missed Staphylococcus aureus bacteremia. Abbreviations: BCx, blood culture; CAP, community-acquired pneumonia; HCAP, healthcare-associated pneumonia; PSI, Pneumonia Severity Index; S. aureus, Staphylococcus aureus; S. lugdunensis, Staphylococcus lugdunensis; UTI, urinary tract infection; VAP, ventilator-associated pneumonia; VO, vertebral osteomyelitis. [2]

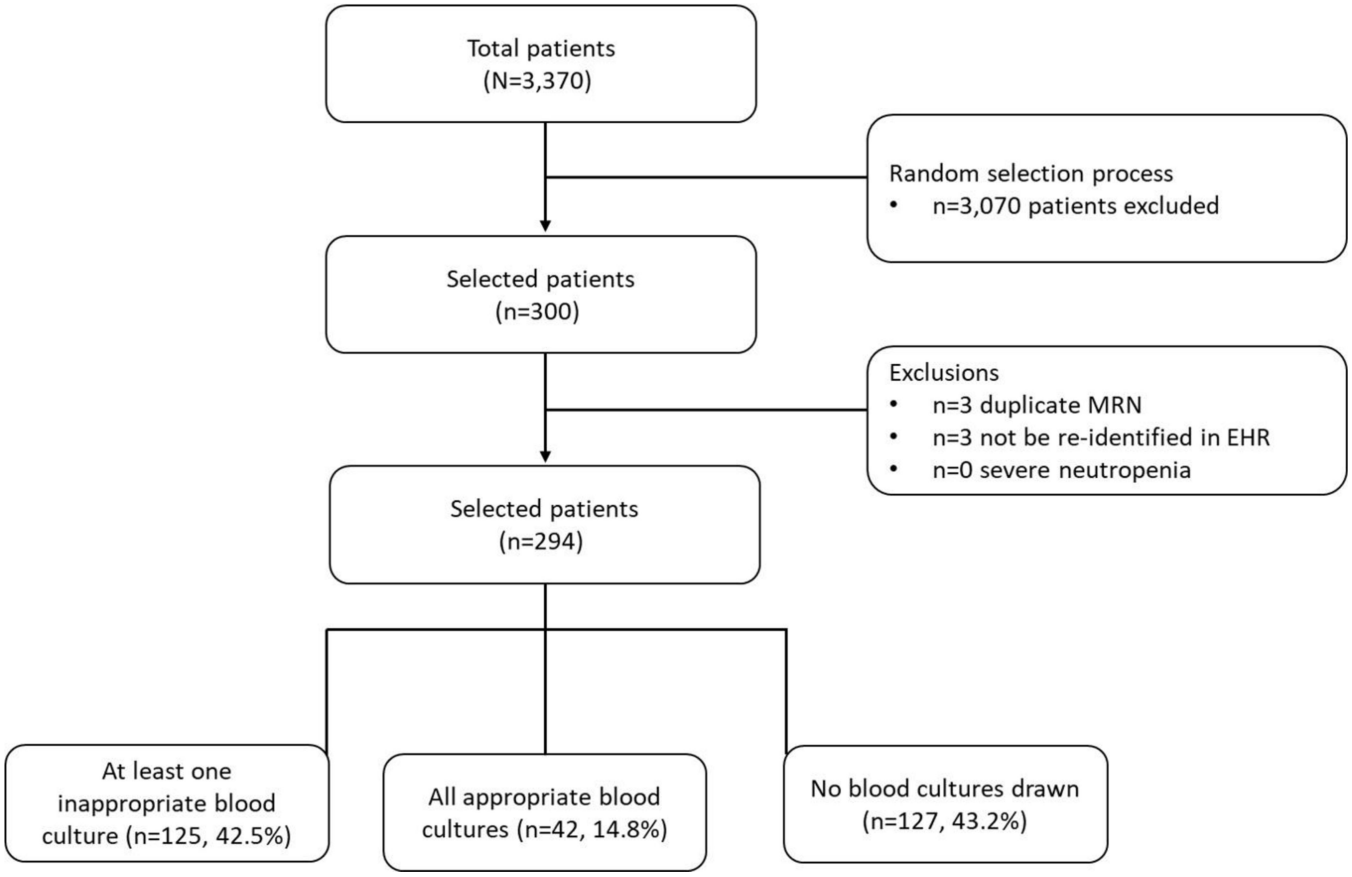

Figure 2: Cohort selection

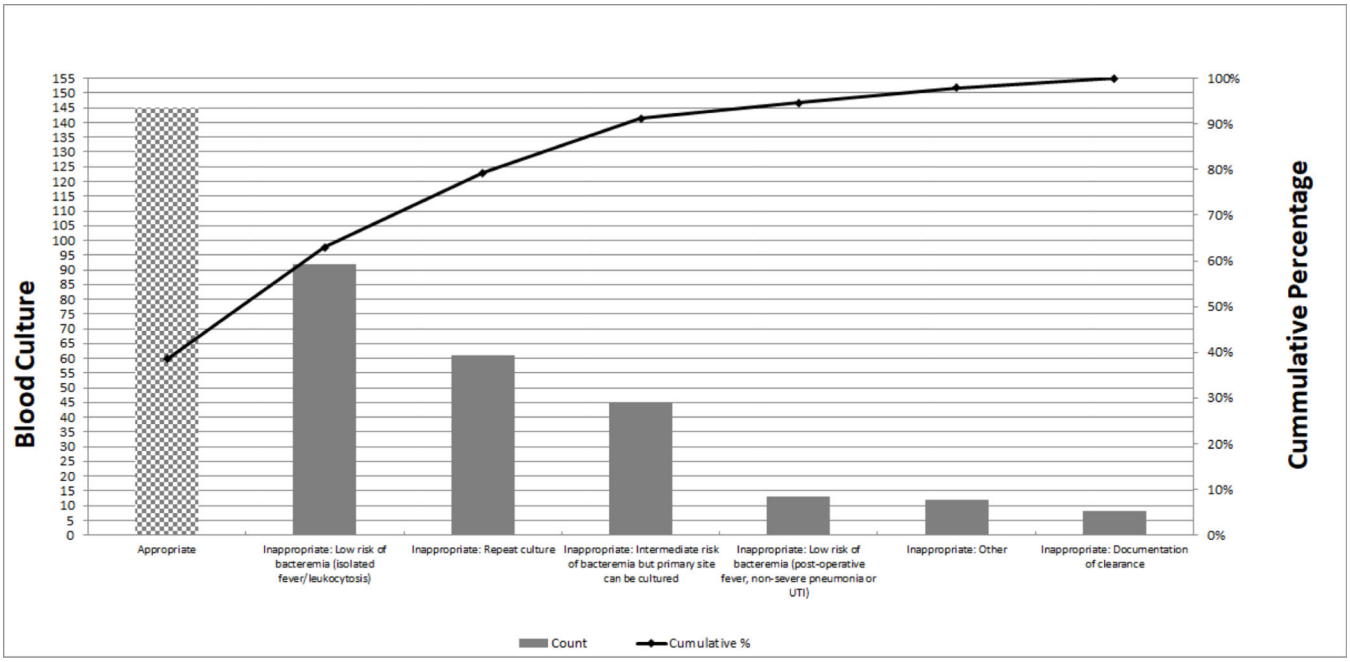

Figure 3: Pareto chart detailing reasons for inappropriate blood culture collection

Table 1:

Cohort Characteristics

	All Patients (n=294)	Patients with no Blood Cultures (n=127)	Only appropriate Blood Cultures (n=42)	1 or more inappropriate Blood Cultures (n=125)
Demographics				
Age, years, mean (SD)	63.8 (14.3)	63.6 (13.5)	64.6 (13.5)	63.7 (15.6)
Sex, male (n,%)	153 (52.0)	72 (56.7)	21(50.0)	60 (48.0)
Race (n, %)				
Black	90 (30.6)	30 (23.6)	16 (38.1)	44 (35.2)
White	58 (19.7)	23 (18.1)	10 (23.8)	25 (20.0)
Other/Unknown	146 (49.7)	74 (58.3)	16 (38.1)	56 (44.8)
Hispanic Ethnicity (n, %)	88 (29.9)	47 (37.0)	8 (19.0)	33 (26.4)
Characteristics				
APACHE Score, mean [SD]	67.6 (25.7)	60.2 (23.8)	79.7 (28.8)	71.1 (24.2)
Acute Respiratory Distress Syndrome (n, % yes)	86 (29.3)	21 (16.5)	15 (35.7)	50 (40.0)
Charlson comorbidity, mean (SD)	4.0 (2.7)	3.5 (2.6)	3.9 (2.3)	4.7 (2.7)
Outcomes				
Length of ICU Stay, median days	7.4 (7.2)	4.6 (4.6)	6.3 (5.0)	10.5 (8.6)
Discharge status, died (n, %)	69 (23.5)	11 (8.7)	17 (40.5)	41 (32.8)