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Cost-Effectiveness of 30- Compared to 20-Milliliter Blood Cultures: a Retrospective Study

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The importance of blood culture (BC) volume for detection of bloodstream infections (BSIs) is documented. Recently, improved diagnostic sensitivity was demonstrated for 30- versus 20-ml BCs in adults (Cockerill FR, Wilson JW, Vetter EA, Goodman KM, Torgerson CA, Harmsen WS, Schleck CD, IIstrup DM, Washington JA, Wilson WR. Clin Infect Dis 38:1724–1730, 2004, http://dx.doi.org/10.1128/JCM.01314-11). Hospitals receive higher reimbursement for patients with documented septicemia. We determined the cost-effectiveness of 30-ml versus 20-ml BCs using results from our institution and previously published data. Positive BC results from 292 bacteremic episodes were reviewed. The costs of the reagents, equipment, phlebotomist, and technologist time were determined. The medical records department provided Medicare reimbursement (MR) data for patients with selected ICD-9 codes. These data provided an estimate of the annualized increase in MR versus costs associated with conversion to 30-ml BCs. MR for 464 annual primary BSIs was $24,808/episode. An expected 7.2% increase in BSIs detected using 30-ml BCs would add 34 additional cases annually and increase MR by $843,472. Comparative MR data for cases where septicemia complicated another diagnosis were available for 4 International Classification of Diseases, Ninth Revision (ICD-9) codes: laparoscopic cholecystectomy, biliary tract disorders, pneumonia, and cellulitis. The mean incremental MR was $9,667 per episode, which projected to a $483,350 revenue increase annually. The annual cost associated with conversion to 30-ml BCs was estimated to be $157,798. Thus, the potential net increase in hospital revenue would be $1,169,031 for 30-ml versus 20-ml BCs. Our results suggest that conversion to 30-ml BCs may not only improve patient care by detecting more BSIs but also increase hospital revenue substantially.

According to the CDC, sepsis affects >800,000 Americans annually and is the ninth leading cause of disease-related deaths (1). The Agency for Healthcare Research and Quality lists sepsis as the most expensive condition treated in U.S. hospitals, costing more than $20 billion in 2011 (1). Blood culture (BC) remains the standard means of detecting sepsis secondary to bloodstream infections (BSIs) (2). Prior studies have shown that several variables influence the detection of bacteremia, including skin preparation prior to venipuncture, the method and site of collection, the types of media utilized, the number of cultures collected, and, most importantly, the volume of blood cultured (3).

All studies have indicated that as the volume of blood cultured increases, the likelihood of detecting bacteremia also increases (4–13). Patel et al. recently demonstrated that two 30-ml BC sets with 3 bottles per set (2 aerobic and 1 anaerobic) had improved pathogen detection for both nonconditional (not requiring detection in more than one set to be considered positive) and conditional (requiring detection in at least two positive blood cultures for classification as a pathogen and otherwise categorized as a contaminant) pathogens with an improved yield of 7.9% and 11.0%, respectively (3).

However, inoculation of only two 20-ml sets of BCs is standard practice in our institution and we suspect at many other similar institutions also (3). This practice is most likely secondary to the notion that increasing the number of blood culture bottles per episode of bacteremia will result in a significant increase in cost and inconvenience for both the health care facility and the patient (14).

The failure to obtain 30 ml of blood for each adult blood culture can result in lower microbial recovery. Given that the sensitivity of 30-ml BC sets is superior to that of 20-ml BC sets as reported by Patel et al. (3), we hypothesized that the institution of 30-ml BCs would result in increased third-party reimbursement for our hospital. Accordingly, we assessed the costs and potential financial benefits associated with conversion from 20-ml to 30-ml blood cultures in our institution. To our knowledge, this type of cost-benefit analysis has not previously been reported.

MATERIALS AND METHODS

Study design. This study reviewed blood culture results from a retrospective cohort of adult patients (age of ≥18 years) from 1 January 2012 to 1 March 2012 at Robert Wood Johnson University Hospital (RWJUH) in New Brunswick, NJ. A blood culture (BC) was defined as a set of two or three culture bottles which, when optimally filled with blood, would have a total volume of 20 ml (2-bottle set) or 30 ml (3-bottle set).

For each adult blood culture at RWJUH, 20 ml of blood was obtained aseptically and distributed equally to one Bactec Plus Aerobic/F resin (here referred to as aerobic) bottle and one Bactec Lytic/10 Anaerobic/F (here referred to as anaerobic) bottle (Becton Dickinson, Sparks, MD) and incubated for 5 days in a Bactec FX instrument. This study was approved by the Rutgers Robert Wood Johnson Medical School Institutional Review Board.

Microorganisms isolated from cultures were identified by standard techniques. Single culture isolates of coagulase-negative staphylococci,

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TABLE 1 RWJUH mean Medicare reimbursement for four common disease conditions with and without bacteremia as a major clinical complication

Diagnosis	No.	Mean reimbursement ($)		Mean difference per episode ($)	Additional reimbursement ($)
		Without bacteremia	With bacteremia		
Cholecystectomy	2	$7,441	$27,390	$19,949	$39,898
Biliary tract disorder	3	$4,406	$57,346	$52,939	$158,817
Pneumonia	2	$3,351	$13,923	$10,571	$21,142
Cellulitis	2	$3,181	$6630	$3449	$6898

diphtheroids, and nonpneumococcal alpha-hemolytic streptococci were classified as contaminants (3). However, in instances where the same organism was isolated from 2 or more blood culture sets within a 48-h period, they were classified as true positives if they were the same species and had the same biotype and antibiogram (15, 16). Pathogens not requiring two or more positive sets to be classified as such (e.g., *Staphylococcus aureus*, *Escherichia coli*, and *Pseudomonas aeruginosa*) were also categorized as true positives (15, 16).

Most health care facilities, including ours, receive much of their reimbursement via Medicare billing. In addition to Medicare, many other third-party payers also reimburse using a diagnosis-related group (DRG)-based payment plan. Additionally, the International Classification of Diseases, Ninth Revision (ICD-9) codes (bacteremia/septicemia/severe sepsis) all fall under the same classification of major complications and comorbid conditions (MCC) for determination of their DRG weights.

Calculations. Medicare reimbursement data based on the RWJUH institutional rates were obtained from the medical records and accounts receivable departments during the study period for all patients with a primary DRG diagnosis of bacteremia/septicemia/severe sepsis and for several common ICD-9 codes: laparoscopic cholecystectomy with and without MCC, kidney and urinary tract infections with and without MCC, disorders of the biliary tract with and without MCC, simple pneumonia with and without MCC, other respiratory system diagnoses with and without MCC, cellulitis with and without MCC, major joint replacement or reattachment of the lower extremities with and without MCC, syncope and collapse with and without MCC, and fever of unknown origin. However, we include herein only four of these diagnoses (laparoscopic cholecystectomy, disorders of the biliary tract, simple pneumonia, and cellulitis) in our calculations since they were the only ones who had septicemia as a secondary MCC during the study period.

The cost of the additional BC bottles, equipment, phlebotomist, and technologist time and effort were obtained from the microbiology laboratory.

These data then were used to provide an estimate of the annualized increase in MR and costs associated with conversion to 30-ml BCs. For annualized calculations, data acquired during the study period were multiplied by 4.

Additionally, we assumed improved sensitivity for detection of bloodstream infections based on the recent report by Patel et al. (3) who determined that an additional 67 nonconditional and 10 conditional pathogen bacteremic episodes were detected with 30-ml BCs compared to 20-ml BCs out of a total of 1,063 total episodes (917 caused by nonconditional and 146 caused by conditional pathogens). We thus calculated the percent increase in sensitivity for 30-ml BCs to be 7.2% [77/(917 + 146) × 100%].

RESULTS

The results of 8,068 blood cultures submitted to the RWJUH microbiology laboratory during the study period were analyzed: 584 were true positives, 228 were categorized as contaminants, and 23 were of uncertain clinical significance.

Based on the assumption that each BSI episode would have 2 positive blood cultures, we estimated that there would have been 292 bacteremic episodes during the 3-month period or 1,168 episodes annually.

According to the data obtained from the medical records and accounts receivable departments, there were 116 episodes of primary septicemia during the 3-month study period for which Medicare reimbursed an average of $24,808 per episode. On an annualized basis and given an expected 7.2% increase associated with the use of 30-ml blood cultures, 34 additional septicemias [(116 × 4) × 0.072] would have been detected and associated with an increase in Medicare reimbursement of $843,472.

We were also able to evaluate the MR data where septicemia was a complication of another diagnosis for four common ICD-9 codes: laparoscopic cholecystectomy, disorders of the biliary tract, simple pneumonia, and cellulitis. The mean reimbursements for the four ICD-9 codes without and with bacteremias are shown in Table 1. The average MR for these episodes was $9,667. A 7.2% increase in each of these secondary BSIs based on 30-ml blood cultures would result in detection of 50 additional cases [(1168 − 464) × 0.072] and an increased MR of $483,350 (50 × $9,667) annually. Additionally, this reimbursement likely would be larger in a study that was designed to capture differences in reimbursement over a longer period of time and which included other ICD-9 diagnostic codes.

We determined the capital and operational costs associated with conversion to 30-ml blood cultures. The RWJUH Microbiology Laboratory processes an average of 2,514 adult blood cultures each month. Each BC bottle costs $2.58, so an increase from 2- to 3-bottle BC sets would result in an additional expense of $77,833 annually (1 additional BC bottle for each blood culture). The annualized cost of additional phlebotomist time and effort was estimated to be $13,827, and the annualized cost of additional microbiology technologist time and effort was estimated to be $47,138 (Table 2.). The cost of an additional Bactec FX incubator stack is estimated to be $95,000; amortizing this expense over 5 years resulted in a calculated cost of $19,000/year. Taken together, the total annualized cost of labor, supplies, and equipment associated with conversion to 30-ml blood cultures during a 5-year period was estimated to be $157,798.

TABLE 2 Labor costs associated with conversion from a 20-ml to 30-ml blood culture system

Staff position	Hourly salary ($)	Time for inoculating/processing 1 extra blood culture bottle (min)	Cost annualized ($)
Phlebotomist	27.50	1	13,827
Microtechnology technician	37.50	2.5	47,138

Therefore, based upon all of our in-house and calculated data, we estimated that conversion to 30-ml blood cultures would result in a net increase in our institution's revenue by $1,169,031 ($843,479 + $483,350 − $157,789). The actual increase would likely be higher since only 4 ICD-9 codes with MCC were captured during the 3-month study period.

DISCUSSION

Bloodstream infections can be life threatening and cause serious complications, including multisystem organ failure, which result in significant morbidity and mortality (14). Accordingly, it is critical to detect the etiologic pathogen and institute directed antimicrobial therapy (14). Patel et al. recently showed that 30-ml compared with 20-ml blood cultures lead to a 7.2% improvement in BSI detection (3). In that study, the cost-effectiveness of 30-ml blood cultures was not assessed.

The results of this study have shown that at our hospital a 7.2% increase in detection of primary BSIs would result in the annual detection of 34 additional BSI episodes and an increased MR of $843,479. Revenue increases associated with enhanced detection of secondary BSIs are more difficult to calculate, given the small number of ICD-9 codes for which we had comparative data. Only 9 out of 709 episodes were from secondary bloodstream infections. That said, for just four ICD-9 codes, the calculated annual increase in hospital revenue was $483,350. Accounting for the costs associated with conversion from 20-ml to 30-ml blood cultures, we determined that the net increase in MR to the hospital would be $1,169,031.

It is important to consider that drawing higher volumes of blood increases the risk of nosocomial anemia; therefore, the potential benefits with higher volume blood cultures must be balanced against this risk, especially in patients with comorbid conditions associated with anemia. Additionally, difficult venous access, poor collection techniques, and a lack of appreciation for the importance of obtaining adequately filled blood culture bottles on the part of those collecting specimens often lead to inadequate blood volume collection. These issues may be exacerbated by a requirement to obtain greater volumes of blood.

There are several limitations to this study. We have not taken into account the additional cost of processing false positives, i.e., contaminants with the addition of a 3rd bottle in each culture set (17–20). Patel et al. have reported that the number of contaminants associated with 43,158 blood cultures increased from 61 to 75 for 30-ml blood cultures (3).

Additionally, the number of observations for secondary BSIs was relatively small as mentioned, and the reimbursement rate in each of these categories was highly variable; i.e., the mean additional reimbursement maybe less accurate as a result.

Further studies comparing and assessing the Medicare reimbursement for 20-ml versus 30-ml blood culture volumes over a longer period of time, in different health care settings (community hospital versus tertiary care center), and with inclusion of special populations such as neutropenic patients and MCC for additional diagnoses will shed further light on our observations.

Although conversion to 30-ml blood cultures results in increased institutional costs, our data suggest that these costs will be more than offset by the increased reimbursement that will occur as a consequence of documenting additional bloodstream infections. We conclude that the institution of 30-ml blood cultures is a cost-effective approach for improving patient care.

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