ORIGINAL RESEARCH

Analysis of Strategies to Improve Cost Effectiveness of Blood Cultures

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BACKGROUND: Approximately 90% of all blood cultures grow no organisms (ie, are true negatives), and 5% are thought to represent contaminants (ie, are false positives). The cost effectiveness of blood cultures could therefore be improved by developing rules that safely decreased the number of cultures drawn from patients with a low likelihood of having bacteremia and/or by improving the process of obtaining cultures, thereby decreasing the number of contaminants. We analyzed the potential effects of these two approaches.

METHODS: We annualized the hospital costs and lengths of stay for patients with true-negative and false-positive blood cultures from a retrospective analysis of 939 sets of cultures drawn in January 2002.

RESULTS: Of the 939 blood culture sets, 816 (87%) were true negatives and generated annualized costs of approximately $750,000. Although only 56 (6%) of the blood culture sets were false positives, they resulted in annualized costs of $1.4-$1.8 million and added an estimated 1450-2200 extra hospital days/year.

CONCLUSIONS: Despite there being nearly 15 times as many true-negative blood cultures as false positive ones, far greater improvements in resource utilization would result from reducing the number of contaminated blood cultures than by reducing the number of true negatives. The potential savings from this approach are of sufficient magnitude to justify investing considerable resources to attaining this goal. ***Journal of Hospital Medicine* 2006;1:272–276.**

KEYWORDS: cost effectiveness, blood cultures.

Because as many as 90% of all blood cultures grow no organisms[1] developing rules that predict which patients are at the lowest risk of having bacteremia could improve the utilization of this test and markedly reduce its cost. Of the approximate 10% of cultures that do grow organisms, only about half represent true bacteremia (ie, true positives), whereas the other half are considered contaminants (ie, false positives)[2]; the latter are known to increase both the cost and duration of care.[3] Accordingly, reducing the number of contaminants could also reduce the cost of care. We assessed which of these two strategies would be the most cost effective. Although only 6% of the blood cultures obtained at our hospital represented contaminants, their associated cost was more than twice that associated with the 87% of cultures that were true negatives.

METHODS

We conducted a retrospective review of microbiological results and hospital records of patients for whom blood cultures were obtained in January 2002 at Denver Health Medical Center, a 400-bed university-affiliated public safety net hospital. The study

DOI 10.1002/jhm.115
Published online in Wiley InterScience (www.interscience.wiley.com).

was given exempt status by the Colorado Multiple Institutional Review Board. Patients were identified using a preexisting laboratory database.

We adopted the definitions used by Bates et al.[3] for the inclusion and exclusion criteria and the definition of a blood culture episode so that we could apply the financial data presented by these authors to our results. Briefly, a blood culture set was defined as a single venipuncture, regardless of the number of bottles sent for culturing, and a blood culture episode was defined as the 48-hour period beginning when a blood culture was drawn. All sets within the same 48-hour period were considered part of the same episode. Cultures that grew bacteria were classified as either true positive, representing bacteremia, or false positive, representing contaminants. Determination of whether a patient had a true-positive culture versus a contaminant was made in a weekly conference attended by the chief of the Infectious Disease Division, an Infectious Disease fellow, and at least one microbiologist, during which the species of organism cultured and the associated clinical data for each patient were considered. Organisms considered to indicate false positives included diphtheroids, Bacillus sp, Propionibacterium sp, coagulase-negative staphylococci, and micrococci. All other organisms were considered true positives in the setting of appropriate clinical criteria as specified by the CDC guidelines.[4] Hospital charges and lengths of stay were obtained from our institutional database.

The cost associated with a true-negative blood culture was determined by summing the charges for phlebotomy and microbiological testing obtained from the January 2005 Denver Health hospital charge master and applying the cost-to-charge ratio reported on the Medicare Cost Report for inpatient services (not including the costs of physician salaries and benefits).

The cost of a false positive was determined two ways: (a) adjusting the data reported by Bates et al.[3] for changes in the Consumer Price Index[5] and (b) comparing the actual hospital charges of the patients in our sample who had false-positive cultures with those who did not (adjusting both by the hospital's inpatient cost-to-charge ratio, again not including the cost of physician salaries and benefits).

The length of stay and cost of care for patients with true- and false-positive blood cultures were compared by chi-square analysis. $P < .05$ was considered statistically significant. The data were not normally distributed and, as such, are presented as medians and interquartile ranges.

TABLE 1
Results of Blood Cultures from January 2002

	Bacteremia		
Blood cultures	Number positive (%)	Number negative (%)	Total
Number positive (%)	62 (7)	56 (6)	118 (13)
Number negative (%)	0 (0)	815 (87)	815 (87)
Total	62 (7)	871 (93)	933 (100)

TABLE 2
Laboratory Charges for Blood Cultures in July 2005

	Charge ($)	Tests (N)	Total ($)
True-negative cultures			
Phlebotomy	$13.25		
Microbiology	$147.50		
Subtotal	$160.75	815	$131,011
False-positive cultures			
Phlebotomy	$13.25		
Microbiology	$147.50		
Identification	$60.75		
Sensitivity	$89.75		
Subtotal	$311.25	56	$17,430
			$148,441

RESULTS

Table 1 summarizes the interpretation of the 939 blood cultures drawn in January 2002. Only 6 culture sets (0.6%) could not be classified. The positive predictive value of a positive blood culture was only 53%.

Laboratory charges for patients with true-negative and false-positive blood cultures in January 2002 are shown in Table 2. Annualized, the associated charges were $1,781,292, and the costs were $748,143.

Bates et al.[3] found that false-positive blood cultures increased the length of hospital stay by 4.5 days and increased total charges by $4385 over those for patients with no contaminants. This adjusted to $6878 in 2005 according to the Consumer Price Index.[5] After grouping our blood cultures into episodes as defined by Bates et al. (Table 3), we had 41 episodes of contaminated blood cultures that would annualize to charges of $3,383,976 and costs of $1,421,270 after applying the cost-to-charge ratio.

TABLE 3
Blood Culture Episodes, January 2002[a]

	Bacteremia		
Blood cultures	Number positive (%)	Number negative (%)	Total
Number positive (%)	39 (9)	41 (10)	80 (19)
Number negative (%)	0 (0)	335 (81)	335 (81)
Total	39 (9)	376 (91)	415 (100)

[a] Per Bates et al.[3]

The median length of hospital stay and total charges for the patients with true-negative and false-positive blood cultures at Denver Health in January 2002 are summarized in Table 4. Using this approach, patients with false-positive blood cultures at our institution added 1450-2200 extra hospital days and accrued additional charges of $4,305,000 and costs of $1,808,100.

DISCUSSION

The important finding of this study is that, despite there being nearly 15 times as many true-negative blood cultures as false-positive ones, the savings generated by reducing contaminants would be approximately twice that saved by reducing the true negatives (eg, a 50% reduction in the rate of contamination would reduce the total number of false-positive episodes by 246 annually, saving $710,635-$904,050, whereas reducing the true negatives by 50% would only save approximately $375,000.

There is no independent gold standard for evaluating the operating characteristics of a blood culture.[6] Data from a series of repeated blood cultures represent the closest surrogate. Weinstein et al.[7] drew at least 3 sets of cultures from 282 bacteremic patients and noted that bacteremia was documented in 91.5% of the first cultures, in 99.3% in 1 of the first 2 cultures, and in 99.6% in 1 of the first 3 cultures. Because 2 blood culture sets are drawn routinely, the difference between those 2 (if negative) and a third (if it represents a true positive) is 0.3% and would represent a "false-negative" culture rate. Given that the true-negative rate of blood cultures is 87%-90%,[1] the potential 0.3% "false-negative" rate would not affect our analysis, and as such, we chose to ignore it. Accordingly, all sets of blood cultures with no growth were classified as true negatives.

Although we cannot show a cause-and-effect relationship between false-positive cultures and the charges associated resulting from them, a recent study suggested that much of the excess length of stay of such patients is attributable to the false-positive culture itself.[8]

Because health care costs have exceeded increases in general goods and services, adjusting the results of Bates et al.[3] using the Consumer Price Index likely underestimated the projected cost of the false-positive cultures. This limitation likely accounts for the observation that the difference in actual charges for our patients between those who did and those who did not have false-positive blood cultures was greater than the cost of these false-positive cultures as estimated by extrapolating from the data of Bates et al.[3] Given the magnitude of the financial difference we observed, however, we suggest that this difference is not of sufficient size to alter our conclusion.

Physicians working at Denver Health are directly employed by the hospital, and the cost of physician salaries and benefits is included in the cost-to-charge ratio reported in our Medicare Cost Report. For purposes of this study, however, we elected to utilize a cost-to-charge ratio that was *exclusive* of physician salaries and benefits (ie, 0.42 rather than 0.66) because most hospitals in the United States do not employ their physicians. Accordingly, the costs we present underestimate the true cost to our institution by approximately 32% but are more representative of the costs of services provided by most hospitals in the United States.

Recent studies have shown that the rate of false-positive cultures is higher when blood is drawn from indwelling catheters than when it is obtained by peripheral venipuncture.[9,10] The rates we cite from the literature[2] and from our own institution (Table 1) are aggregate data that include samples drawn from both sites. Separating these would not alter our conclusion that a 50% reduction in false positives would save approximately twice as much as a 50% reduction in false negatives. These studies do, however, identify an important method for reducing false positives: sampling by venipuncture whenever possible, and only drawing through a catheter under very limited circumstances.

There are additional factors that favor a strategy of reducing contaminants over one that attempts to reduce the number of true-negative cultures. First, reducing the total number of true-

TABLE 4
Length of Stay and Hospital Charges for Patients with True-Negative and False-Positive Blood Cultures in January 2002 (Median)

	Length of stay (days)	Interquartile range (days)	Total Charges ($)	Interquartile Range ($)
True negative	5	2-12	$15,158	$7,007-$40,270
False positive	8[a]	4-13.5	$23,908[a]	$14,083-$52,031
Difference	3		$8,750	

[a] $P < .001$

negative blood cultures by 50% would require a very ambitious prediction rule that did not reduce the number of true positives to any meaningful extent. Prediction rules to reduce blood culture testing have been developed for patients with community-acquired pneumonia, but the rules only reduced the number of cultures by 37% and, more importantly, left 11% of true bacteremias undetected.[8] Reducing contaminants would have *no* effect on the detection of true positives, whereas any prediction rule would inevitably increase the risk of missing true bacteremia in at least a fraction of patients. Second, methods aimed at reducing contaminants can be implemented immediately, whereas deriving a prediction rule would take years to develop and test before it could be utilized. Third, implementing prediction rules may be difficult because many physicians prefer to rely on their clinical impressions.[11]

Reducing contaminants would require improving the technique by which blood cultures are obtained, with the objective of shifting a portion of false positives to true negatives. This might be accomplished in many ways: increasing the time spent on antiseptic scrubbing, improving the ways in which antiseptic devices are used, waiting for the antiseptic to air-dry completely, choosing the antiseptic that is most effective in trials, drawing blood by venipuncture instead of through an indwelling catheter, limiting the number of venipuncture attempts before requiring a second site to be prepared, requiring all cultures be drawn by trained phlebotomists, and reducing phlebotomist turnover, among others. Denver Health has a 4-page set of directions for phlebotomists to follow when obtaining blood cultures. Accordingly, there are numerous places the process could break down. Although having 2 phlebotomists involved (ie, one to perform the procedure and the other to observe and guide the first, assuring that all the appropriate steps are followed) might be considered an extraordinary step, our findings suggest the potential saving to the institution could far outweigh the additional personnel expense resulting from such an approach. Other potential solutions we have considered but not tested include providing a monthly salary bonus to the phlebotomist with the lowest contamination rate or giving bonuses to every phlebotomist who achieves a zero contamination rate.

In summary, we have concluded that the resource utilization associated with obtaining blood cultures can best be improved by reducing the small percentage of cultures that represent contaminants rather than by developing rules to reduce the much larger number of true negatives. The magnitude of the potential savings resulting from reducing contaminants is sufficiently large to warrant expending additional resources to accomplish this task.

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Received 5 December 2005; revision received 4 April 2006; accepted 31 May 2006.

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