

# Evaluation of Radiometric System for Detecting Bacteremia

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An automated radiometric system (BACTEC, Johnston Laboratories) for detection of bacteremia was evaluated in parallel with a standard blood culture system in use in our laboratory. Of 1,445 blood cultures from 484 patients with possible bacteremia, 106 sets of cultures (excluding 39 presumed contaminated), representing 56 patients, were positive by both methods. The conventional system yielded 85 positive cultures from 48 patients, whereas the BACTEC system yielded 84 positive cultures from 43 patients. The BACTEC system failed to detect 22 cultures that were positive in the conventional system, and the conventional system failed to detect 21 cultures that were positive in the BACTEC system. The detection efficiency was generally equivalent in the two systems except for the lower detection rates of anaerobes and *Enterobacter aerogenes* by the BACTEC system and the lower detection rates of *Torulopsis glabrata* and, possibly, *Pseudomonas* sp. (group IVD) in the conventional system. The BACTEC system had a slight advantage over the conventional system in the time interval to detection of positivity. Approximately 20% of the positive cultures detected by the BACTEC system were detected on the first day of incubation compared with 7% by the conventional system. The recovery rates and detection times of anaerobes were less efficient by the BACTEC system than by the conventional system. It does not appear that the radiometric method has much advantage over available conventional methods.

Recent reports (1, 6) have suggested that a radiometric method is comparable in accuracy and is faster than some of the conventional techniques currently being used for the detection of bacteremia. A previous publication (5) from this laboratory reported a limited clinical comparison of a radiometric method of detecting bacteremia with the standard laboratory method. The present report compares an automated radiometric system (BACTEC, Johnston Laboratories, Cockeysville, Md.) with the standard blood culture system in use in our laboratory.

## MATERIALS AND METHODS

From October 1972 through January 1973, blood samples from two affiliated hospitals of the Mayo Clinic were inoculated (10%, vol/vol) into one bottle each of tryptic soy broth (Difco) and thiol broth (Difco); each bottle contained 100 ml of medium with sodium polyanetholesulfonate under vacuum with added CO<sub>2</sub>. These two bottles will be referred to as "conventional." Also inoculated on a 10% (vol/vol) basis were two bottles of media supplied by Johnston Laboratories, one containing 30 ml of enriched tryptic

soy broth (no. 6A) and the other containing 30 ml of prereduced tryptic soy broth (no. 7A) for the detection of anaerobes; both of these media contained 1.5  $\mu$ Ci of <sup>14</sup>C-labeled substrate.

**Conventional method.** The inoculated bottles were incubated unvented at 35 C and examined daily for 14 days. Subcultures were routinely made of all cultures, within the first 24 h after collection, to chocolate blood agar plates (BioQuest) which were incubated at 35 C in an atmosphere of 10% CO<sub>2</sub> for 48 h.

**BACTEC.** The aerobic culture vials were tested repeatedly on the day of receipt (a minimum of five times) and on days 2, 3, 4, 7, and 14 thereafter. The anaerobic vials were not tested on the day of receipt but were otherwise tested on the same schedule as the aerobic vials. All BACTEC vials with a "growth index" of 30 or greater were checked by Gram stain or immediate subculture. The negative aerobic vials were subcultured to chocolate blood agar plates (BioQuest) and incubated at 35 C in a 10% CO<sub>2</sub> atmosphere. The negative anaerobic vials were subcultured to blood agar plates (BioQuest) and incubated in anaerobic GasPak jars (BioQuest) at 35 C.

Identification of isolates was performed as described previously (3). Statistical comparisons between rates of detection and mean times of detection of positivity in both systems were also determined as

described previously (3). In this study, however, results of both bottles within one system were combined, and the first day of incubation was taken as the day on which the blood was inoculated into the medium.

### RESULTS

During this study, 1,445 sets of blood cultures from 484 patients were received (Table 1). There were 145 positive cultures (10%), defined by positivity in one or both methods. By using the arbitrary criteria for defining presumed contamination described previously (3), 39 of the cultures from 35 patients were considered to be contaminated. The remaining 106 positive cultures contained 111 organisms. A total of 85 cultures from 48 patients were positive in the conventional method, whereas 84 cultures from 43 patients were positive in the BACTEC system.

The 22 cultures (from 13 patients) that were positive by the conventional system but not by the BACTEC system contained 24 organisms, whereas the 21 cultures (from 8 patients) positive only in the BACTEC system yielded 22 organisms (Table 2). The conventional system failed to detect six cultures of *Pseudomonas* sp. (group IVD) from one patient and two cultures of *Pseudomonas maltophilia* from one patient. Conversely, there was only one culture of *Pseudomonas* sp. (group IVD) positive in the conventional system only. Five cultures containing *Torulopsis glabrata* from one patient were detected in the Bactec system only. Cultures containing *Enterobacter aerogenes*, *Bacteroides fragilis*, or *B. melaninogenicus* comprised about half of the cultures detected by the conventional system only.

The mean detection times for *Escherichia coli* in each system were equivalent (Table 3). The differences of 3 days in the mean detection time of *B. fragilis* and 8 days for *T. glabrata* reflect the differences in detection efficiency between the two systems (Table 2).

Figure 1 compares the time required for the detection of positivity by the two methods in terms of the percentage positive by day and the cumulative percentage positive during the period of observation. Twenty percent of all cultures detected by BACTEC were positive on the first day of incubation, whereas 23% of the cultures found to be positive in both systems were detected by BACTEC on the first day of incubation. These rates compared with 6 and 8%, respectively, in the conventional method on the first day of incubation. Forty-seven percent of all positive cultures in the conventional system were detected on the second day, in contrast to 34% by BACTEC. Again, considering only those cultures detected in both methods, over 50% of the cultures positive in the

TABLE 2. Organisms detected by only one method

Organism	No. of cultures		Days of incubation	
	BAC-TEC	Conventional	BAC-TEC	Conventional
<i>Escherichia coli</i>	4	5	1.2	2.6
<i>Staphylococcus aureus</i>	1	3	6	10.5
<i>Streptococcus, viridans</i> group		2		2.5
<i>Streptococcus pneumoniae</i>	1	1	2	2
<i>Enterobacter aerogenes</i>		4		3
<i>Klebsiella</i> sp.		2		4
<i>Alcaligenes faecalis</i>	1		3	
<i>Pseudomonas</i> sp.	6	1	13	2
<i>Pseudomonas maltophilia</i>	2		2	
<i>Serratia marcescens</i>	1		4	
<i>Bacteroides fragilis</i>		4		4.0
<i>Bacteroides melaninogenicus</i>		2		5.5
<i>Fusobacterium nucleatum</i>	1		10	
<i>Torulopsis glabrata</i>	5		10.8	

TABLE 1. Summary of study: positive cultures, organisms isolated and patients with bacteremia

Method	Cultures (1,445)					Organisms					Patients (484)				
	Total positive	Contaminants	Adjusted total	Conventional only	BAC-TEC only	Total found	Contaminants	Adjusted total	Conventional only	BAC-TEC only	Total positive	Contaminants	Adjusted total	Conventional only	BAC-TEC only
One or both	145	39	106			152	41	111			83	35	56 <sup>a</sup>		
BACTEC	108	24	84		21	111	24	87		22	64	21	43		8
Conventional	105	20	85	22		110	21	89	24		67	19	48	13	

<sup>a</sup> The adjusted total is not 83 minus 35 because cultures positive in one system contained contaminants in the other or because later cultures from positive patients contained contaminants.

TABLE 3. Numbers of cultures and mean detection times, by organism

Organism	No. of cultures		Mean detection time (days)	
	BAC-TEC	Conventional	BAC-TEC	Conventional
<i>Escherichia coli</i>	23	24	2.2	2.5
<i>Klebsiella</i> sp.	2	4	1.5	3.0
<i>Enterobacter aerogenes</i>	2	6	2.5	2.5
<i>Proteus mirabilis</i>	1	1	3.0	3.0
<i>Streptococcus</i> , group D	8	8	1.9	1.9
<i>Streptococcus</i> , viridans group	8	10	5.1	3.6
<i>Streptococcus pneumoniae</i>	2	2	1	2
<i>Staphylococcus aureus</i>	14	16	3.4	4.5
<i>Pseudomonas</i> sp.	8	3	10.3	3.2
<i>Pseudomonas aeruginosa</i>	4	2	1.5	2
<i>Pseudomonas maltophilia</i>	1	1	1	2
<i>Alcaligenes faecalis</i>	1	0	3.0	
<i>Haemophilus aphrophilus</i>	1	1	4	4
<i>Bacteroides fragilis</i>	3	7	7	3.7
<i>Bacteroides melaninogenicus</i>	0	2		5.5
<i>Fusobacterium nucleatum</i>	1	0	10	
<i>Torulopsis glabrata</i>	7	2	5	13
<i>Serratia marcescens</i>	1	0	4	

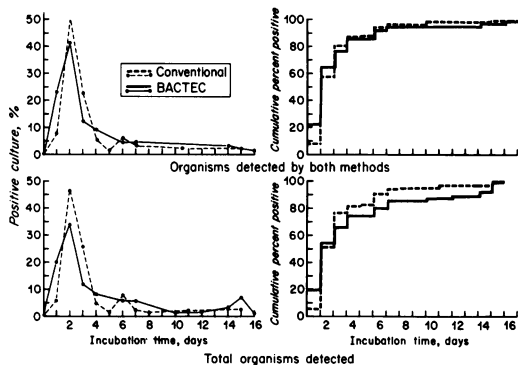


FIG. 1. Percentage of cultures positive and cumulative percentage of cultures positive by day in terms of organisms detected by both methods and of total organisms detected.

conventional system were detected on the second day of incubation, in contrast to 41% of those detected by BACTEC. Thus, the BACTEC system detected approximately 15% more of the positives on the first day of incubation than did the conventional system. By the

second day of incubation, cumulative percentages of positivity in both systems were equivalent. After the second day of incubation, the conventional system had a slight advantage.

In Fig. 2 are compared the cumulative rates of positivity for four groups of organisms detected by both methods. BACTEC was slightly faster in detecting positivity in groups 1, 2, and 3. By the second day of incubation, the two methods were equivalent in terms of cumulative percentages of positivity for these three groups. The conventional method detected 68% of the anaerobes on the third day of incubation compared with 25% detected by BACTEC at this time.

Of the 65 organisms in 63 cultures positive by both methods, 20 organisms (30%) were detected on the same day of incubation by both methods; 16 of these organisms were found in both systems on the second day of incubation (Fig. 3). Seventeen organisms (26%) were detected first in the conventional system and 28 (43%) were detected first by BACTEC. The slight advantage of the BACTEC system over the conventional system was primarily due to the detection of positive cultures on the first day of incubation. Fifteen cultures positive on the first day of incubation in the BACTEC system were positive on the second day in the conventional system. Conversely, four cultures positive on the first day in the conventional systems were positive on the second day in the BACTEC system.

From Fig. 4 it is apparent that the greater number of cultures positive first in the BACTEC system (11 cultures; 17%) was almost entirely attributable to the gram-positive cocci (group 2) and the pseudomonads (group 3). Of

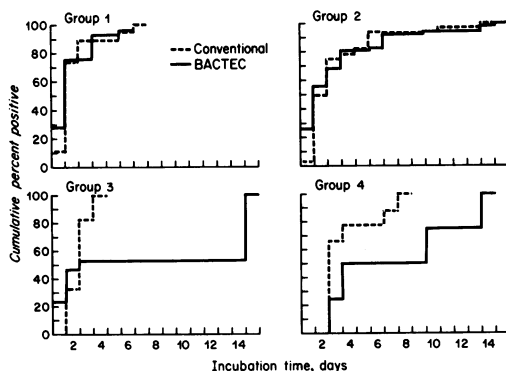


FIG. 2. Cumulative percentages of positive cultures of four groups of organisms detected by both methods. Group 1, Enterobacteriaceae; group 2, gram-positive cocci; group 3, pseudomonads; and group 4, anaerobes.

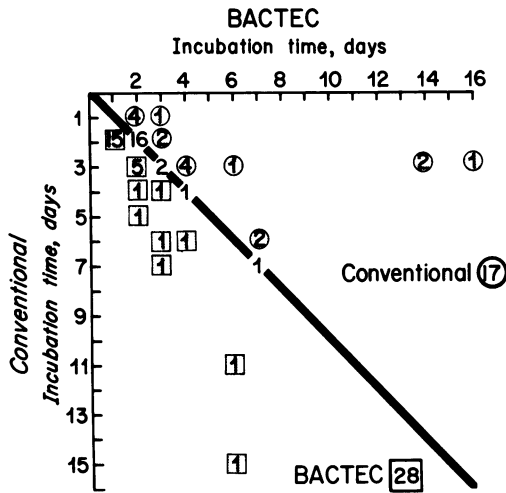


FIG. 3. Cross classification comparing incubation times of organisms from cultures positive by both methods.

eight cultures with gram-positive cocci (group 2) detected on the first day of incubation by BACTEC and on the second day by the conventional system, six were *Staphylococcus aureus*. The BACTEC system was first in the detection of all five of the cultures containing pseudomonads, whereas neither method had an overall advantage in detecting the Enterobacteriaceae (group 1). The three cultures with anaerobes (group 4) detected by both methods were detected first by the conventional system.

DISCUSSION

The results of this study suggest that the BACTEC system has a slight advantage over the conventional system in regard to detection of positivity during the first day of incubation. Overall, the BACTEC system was first in the detection of 9 positive cultures containing 11 organisms (17% of the 65 organisms that were detected in 63 cultures positive in both methods). This advantage was almost entirely attributable to *S. aureus* and the pseudomonads. The detection efficiency in the two systems was generally equivalent except for the lower detection rates of anaerobes and *E. aerogenes* by the BACTEC system and the lower detection rates of *T. glabrata* and, possibly, *Pseudomonas* sp. (group IVD) by the conventional system.

The results presented in this report are in disagreement with those reported by DeBlanc et al. (1). In their study, 70% of the positives were detected first by the BACTEC method and 65% of the positives were detected on the first day of

incubation; 24% of the positive cultures required the same time for detection in both methods, and 6% were detected first by the routine method (4% on the day of inoculation). This apparent discrepancy between results may be due to differences in the types of organisms isolated in the two studies. Thirty-four isolates (or 30% of the total number of organisms) detected by the BACTEC method in their study were *Streptococcus pneumoniae*, compared with only two such isolates (2.5% of the total number of organisms) detected by the BACTEC system in our study. The mean detection time of this species in our study was 1 day. A comparably short incubation time of *S. pneumoniae* in their study might account for some of the disparity in results.

Also, DeBlanc (unpublished data) reports that, of 23 anaerobic cultures that were positive by one or both methods, BACTEC recovered 23 (100%) and their routine system recovered only 2 (9%). Their routine method consisted of inoculating 2 ml of blood into 20 ml of thioglycolate medium (BBL 20889), 1 ml of blood into 18 ml of supplemented peptone broth (BD 4955), and 2 ml of blood into 50 ml of prereduced brain heart infusion broth with sodium polyanetholesulfonate (Robbins Labs, Inc.). It is not clear, however, if the thioglycolate medium had been boiled to drive off dissolved oxygen prior to use and if it was incubated anaerobically after the inoculation with blood. It is likely that the supplemented

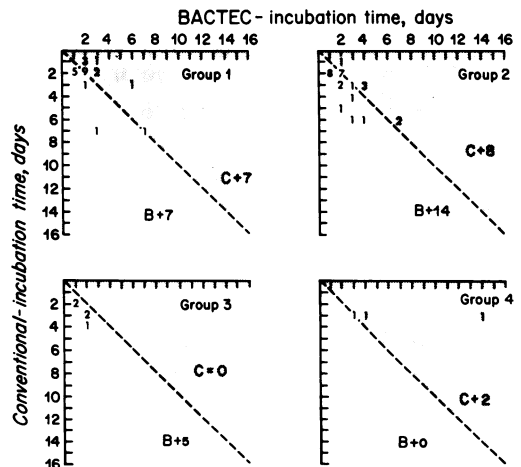


FIG. 4. Cross classification comparing incubation times of cultures detected by both methods, by groups of organisms. Group 1, Enterobacteriaceae; group 2, gram-positive cocci (label covers a "1" at day 14 and a "1" at day 16); group 3, pseudomonads; and group 4, anaerobes.

peptone broth tube was vented because anaerobic tubes have only recently become available from this commercial source. Finally, it is likely that the differences between the volumes of blood inoculated into our conventional system and those used by DeBlanc et al. may have been responsible for some differences in isolation rates of anaerobes between the two studies. Evidence (unpublished) supporting this thesis has been collected recently in this laboratory in a comparison between our conventional system and the aerobic and anaerobic supplemented peptone broth tubes.

Although the BACTEC system may offer certain advantages for some laboratories in terms of automation and speed of detection of positivity, it has certain limitations. First, there is a problem with "false positive" cultures—vials (primarily aerobic) with growth indices of 30 or more but which give repeatedly negative smears and subcultures. In our experience, there were 175 such cultures, representing 12% of those received. The amount of work associated with these types of cultures was substantial and time consuming. Second, in a large laboratory, the time required to process 50 sets of blood cultures in the BACTEC system was roughly twice that required to process the same number of cultures in the conventional system. In our estimation, the degree of automation of the BACTEC system is not commensurate with its price (\$35,000). Third, in our experience, the BACTEC system was not totally reliable for recovery of anaerobes, and these represent a substantial number of isolates and patients with bacteremia (4). It has also been demonstrated (2) that the BACTEC system does not reliably detect *Haemophilus influenzae*. Since the pediatric popula-

tion was deliberately excluded from this study, because of the volumes of blood involved, we were unable to evaluate this point specifically.

Conflicts among reports regarding the efficacy of new techniques or media for the detection of bacteremia are not surprising because there are no uniformly accepted standards against which to judge the new procedures. Standard or conventional procedures differ considerably in terms of the volumes and types of media used, volumes of blood inoculated, atmosphere and duration of incubation, frequency of examination of cultures, timing and frequency of routine subcultures, and media selection and atmosphere of incubation for subculture. It therefore is a safe assumption that the BACTEC system would be superior to some conventional methods and equivalent, or even inferior, to other conventional methods, depending on what constitutes the conventional methods.

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