

Comparison of Efficacy and Cost-Effectiveness of BIOMIC VIDEO and Vitek Antimicrobial Susceptibility Test Systems for Use in the Clinical Microbiology Laboratory

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Antimicrobial susceptibility testing expense may be a significant portion of a clinical microbiology laboratory's budget. This study compares the BIOMIC VIDEO system (Giles Scientific, Inc., New York, N.Y.) with the Vitek system (bioMérieux Vitek, Inc., Hazelwood, Mo.), an established automated method of antimicrobial susceptibility testing with the ability to generate MIC data. The BIOMIC system is relatively inexpensive and automates the reading of the classical disk agar diffusion test to provide both qualitative (susceptibility interpretation) and quantitative (MIC) data. The overall MIC correlation between the two systems for the 2,913 drug-organism combinations tested was 92.6%. The overall agreement for susceptibility interpretation was 97.4%. The BIOMIC system offers a 57.4% savings per test over the Vitek system. The BIOMIC system utilizes an older technology which is more efficient and yet yields results comparable to those of established automated MIC methods. The savings achievable in laboratories and hospitals nationwide may contribute significantly to the containment of national health care expenditures.

Antimicrobial testing is commonly automated today. It is a routine laboratory procedure whose expenditure may be a significant portion of the laboratory's supply budget. One of the most popular automated systems for determining antimicrobial susceptibilities is the Vitek Automated Microbiology System (bioMérieux Vitek, Inc., Hazelwood, Mo.). In actuality, the Vitek system is a modification of the classical tube dilution-MIC methodology.

In 1985, the BIOMIC VIDEO antimicrobial susceptibility test system was developed by Giles Scientific, Inc., New York, N.Y., to generate quantitative MIC data and qualitative susceptibility information from the relatively inexpensive disk agar diffusion tests. The BIOMIC test calculates discrete MICs, not classical doubling dilution MICs. Classical MICs are not absolute values, since the actual antimicrobial concentration required to inhibit growth is between the highest tested twofold dilution that inhibits growth and the next lowest dilution at which growth is observed. The MICs obtained by using the BIOMIC system are determined by the method established in 1971 by Ericsson and Sherris using linear regression analysis to compare the zone of inhibition on a disk diffusion test with doubling dilution MICs (6). Because it is semi-automated, the BIOMIC system also has the advantage of reading and interpreting zones of inhibition in as fast as five seconds, whereas previously this work-intensive task was done manually.

The BIOMIC system not only offers the qualitative category calls that are important in treatment but also provides descriptive quantitative information in discrete MICs, which many physicians desire. Since classical disk diffusion, although cost effective, does not provide quantitative MIC data and is not automated, clinical laboratories have mostly relied upon expensive automated dilution-based systems such as the Vitek system (4). The BIOMIC technology was previously virtually ignored by the clinical laboratory because of the availability of

other fully automated test systems, whose technology was seemingly more advanced. Now, because of economic concerns, the BIOMIC system is receiving more attention. The quantitative semi-automated disk diffusion testing which the BIOMIC system provides may help solve the budgetary problems of clinical laboratories.

The purpose of this investigation was to compare the quantitative and qualitative data obtained from the BIOMIC and Vitek antimicrobial susceptibility test systems, thereby testing their efficacy for routine clinical laboratory use. To reconcile any discordant test data, the E test was utilized. The E test is a highly accurate, manual, agar-based diffusion method which uses an antibiotic gradient on a test strip to determine MIC data (9).

MATERIALS AND METHODS

Bacterial isolates. A total of 223 fresh clinical isolates obtained from Tisch Hospital at New York University Medical Center were used in this study. The number of each type of organism used is shown in Table 1. Bacterial isolates were taken daily from the fresh stockpile at Tisch Hospital's microbiology laboratory.

Antimicrobial susceptibility tests. All inocula were prepared from the growth of pure cultures of bacteria cultivated for approximately 24 h on Trypticase soy agar with 5% defibrinated sheep blood (BBL, Cockeysville, Md.) at 35°C.

(i) **Vitek susceptibility testing.** Vitek susceptibility testing was performed in the course of routine specimen workup at Tisch Hospital. Inocula were prepared in 5 ml of sterile saline solution to a turbidity equivalent to a 0.5 McFarland standard for gram-positive organisms or a 1.0 McFarland standard for gram-negative organisms. For gram-negative organisms, 50 μ l was transferred to 1.8 ml of sterile saline solution. For gram-positive organisms, 200 μ l was transferred to 1.8 ml of sterile saline solution. Vitek cards were then filled with the suspension by using a transfer tube and sealed with the Vitek Filling/Sealing module. Cards were then inserted into the Vitek reader. Vitek data were expressed as MICs. The MICs determined the category of microbial susceptibility as susceptible, intermediate, or resistant.

(ii) **Disk diffusion and BIOMIC susceptibility testing.** Bacterial isolates were suspended in 5 ml of brain heart infusion broth (BBL) so that the visual turbidity was equivalent to a 0.5 McFarland standard, and susceptibility tests were performed as outlined in the National Committee for Clinical Laboratory Standards performance standard (8). Two plates were prepared for gram-negative bacteria and one plate was prepared for gram-positive bacteria. Antibiotics were applied to the plates by using antibiotic dispensers. Table 2 shows the ranges of concentrations for the drugs tested. The agar plates were incubated for approximately 24 h at 35°C. The plates were read by the BIOMIC image analysis by using drug templates for the drugs listed in Table 2. As per protocol, zone sizes were

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TABLE 1. Type and number of isolates tested

Organism	No. of isolates
<i>Acinetobacter anitratus</i>	9
<i>Acinetobacter</i> spp.	1
<i>Citrobacter diversus</i>	2
<i>Citrobacter freundii</i>	12
<i>Enterobacter aerogenes</i>	14
<i>Enterobacter cloacae</i>	15
<i>Enterobacter</i> spp.	2
<i>Enterococcus faecalis</i>	10
<i>Enterococcus faecium</i>	2
<i>Enterococcus</i> spp.	2
<i>Escherichia coli</i>	18
<i>Klebsiella oxytoca</i>	5
<i>Klebsiella pneumoniae</i>	18
<i>Morganella morganii</i>	5
<i>Proteus mirabilis</i>	11
<i>Proteus</i> spp.	1
<i>Proteus vulgaris</i>	2
<i>Providencia rettgeri</i>	1
<i>Providencia stuartii</i>	1
<i>Pseudomonas aeruginosa</i>	10
<i>Serratia marcescens</i>	15
<i>Staphylococcus aureus</i>	45
<i>Staphylococcus epidermidis</i>	20
<i>Streptococcus agalactiae</i>	2
Total	223

adjusted when the image analysis showed incorrect zone sizes. Data were reported as MICs. The category of microbial susceptibility was determined from the zones of inhibition as susceptible, intermediate, or resistant.

Interpretation of results. Results were expressed as a ratio between the BIOMIC MIC and the Vitek MIC. When the reported MICs from each system were identical, the ratio was 1. When the BIOMIC MIC was greater than the Vitek MIC, the ratio was greater than 1. When the BIOMIC MIC was less than the Vitek MIC, the ratio was less than 1. When either MIC value was continuous and the other MIC fell within the range of the first, the ratio was adjusted to 1. The two systems were considered to be in agreement when the ratios ranged from 0.5 to 2.0 (\pm log doubling dilution) (11). Ratios were adjusted in a manner similar to that used by D'Amato et al. because BIOMIC MICs are expressed as discrete numbers whereas the Vitek MICs are doubling dilution MICs and are

TABLE 2. Ranges of antibiotic concentrations used in each testing system (μ g/ml)

Drug	Range for BIOMIC	Range for Vitek
Amikacin	2.00–61.00	2–64
Ampicillin	0.25–46.00	0.25–32
Ampicillin-sulbactam	1.00–24.00	4–32
Aztreonam	3.00–32.00	8–32
Cefoxitin	0.90–48.00	2–32
Ceftazidime	1.10–64.00	8–32
Ceftriaxone	2.00–64.00	8–64
Cefuroxime	0.50–4.00	4–32
Cephalothin	0.70–64.00	2–32
Ciprofloxacin	0.25–8.00	0.5–4
Clindamycin	0.50–3.50	0.5–8
Erythromycin	0.25–40.00	0.5–8
Gentamicin	0.50–18.00	0.50–16
Imipenem	1.00–12.00	4–16
Ofloxacin	0.03–7.00	1–8
Oxacillin	0.20–16.00	2–8
Penicillin G	0.12–12.00	0.03–16
Piperacillin	1.80–330	8–256
Tetracycline	0.20–16.00	1–16
Ticarcillin	4.00–128.00	16–256
Ticarcillin-clavulanate	8.00–128.00	16–256
Tobramycin	0.80–18.00	0.5–16
Trimethoprim-sulfamethoxazole	8.00–152.00	10–320
Vancomycin	1.00–16.00	0.5–32

TABLE 3. Correlation of BIOMIC and Vitek MICs for gram-positive bacteria^a

Drug	% of tests with the following MIC ratio ^b :					% Agreement ^c
	<0.25	0.5	1	2	>4	
Ampicillin-sulbactam	9.2	9.2	69.2	10.8	1.5	89.2
Ampicillin	0.0	0.0	100.0	0.0	0.0	100.0
Cephalothin	17.9	0.0	77.6	4.5	0.0	82.1
Clindamycin	1.5	1.5	89.6	0.0	7.5	91.0
Ciprofloxacin	1.5	0.0	90.8	6.2	1.5	96.9
Erythromycin	4.5	1.5	85.1	7.5	1.5	94.0
Oxacillin	1.5	0.0	98.5	0.0	0.0	98.5
Penicillin G	16.4	11.9	70.1	1.5	0.0	83.6
Tetracycline	1.3	0.0	70.7	26.7	1.3	97.3
Trimethoprim-sulfamethoxazole	4.6	1.5	92.3	1.5	0.0	95.4
Vancomycin	0.0	1.5	40.3	40.3	17.9	82.1
Avg	5.3	2.5	80.4	9.0	2.8	91.8

^a A total of 81 gram-positive isolates (672 drug-organism combinations) were evaluated.

^b BIOMIC MIC/Vitek MIC (see text).

^c Ratios between 0.5 and 2.0 were considered to be in agreement.

based on a continuous scale (5). The category interpretations were also compared. To account for reproducibility error, if either the BIOMIC interpretation or the Vitek interpretation was intermediate, the two were considered to be in agreement.

Discordant results: E test referee. If the BIOMIC MIC/Vitek MIC ratio was out of the acceptable range, or if there was a conflict in the category call, an E test was performed, after confirmation by a repeat Vitek test, to determine which system was more reliable (9). Mueller-Hinton II plates (150-mm diameter) were prepared in the same manner as were the plates for BIOMIC testing. The E test strip was applied to the agar with a forceps. In addition, the appropriate antibiotic disk was also applied to ensure that the original zone size found by the BIOMIC test was correct. The E test MIC value was read after the plates were incubated for 24 h at 35°C.

Economic analysis. The cost per test for the BIOMIC and Vitek test systems was calculated with the prices charged to New York University Medical Center. The cost of testing was calculated for an entire year on the basis of 416 tests per week and quality control testing. Included in this calculation is the annual cost of service and support. The difference between the two systems indicated the savings for one year.

RESULTS

The MIC agreements between the BIOMIC and Vitek test systems, as determined by calculating the ratio of the BIOMIC MICs to the Vitek MICs, are shown in Tables 3 to 6. The MIC correlation was based upon 2,913 organism-drug combinations. The MIC agreements for gram-positive bacteria (Table 3) ranged from 82.1% for cephalothin and vancomycin to 100% for ampicillin. The overall MIC agreement between the two systems for gram-positive bacteria was 91.8%. For vancomycin, the trend was towards higher MICs in the BIOMIC system, with 17.9% of the ratios greater than 2. For cephalothin and penicillin G, the trend was towards lower MICs, with 17.9 and 16.4%, respectively, of the ratios being less than 0.25.

Table 4 shows the results for aerobic gram-negative bacilli. MIC agreements ranged from 66.4% for tobramycin to 100% for ceftriaxone. The overall agreement for gram-negative bacilli was 91.7%. Tetracycline and tobramycin tended towards higher MICs, with 20.0 and 33.6%, respectively, of the ratios being greater than 2.

The MIC and interpretation correlations between the two systems for all organisms are shown in Table 5. The interpretation agreement was based upon 2,948 organism-drug combinations. The overall agreement between MICs was 92.6%. The overall agreement between category calls for the two systems was 97.4%. Interpretation agreements ranged from 91.0% for clindamycin to 100.0% for amikacin, cefotetan, ofloxacin, and vancomycin.

TABLE 4. Correlation of BIOMIC and Vitek MICs for gram-negative bacteria^a

Drug	% of tests with the following MIC ratio ^b :					% Agreement
	<0.25	0.5	1	2	>4	
Ampicillin-sulbactam	6.2	25.9	66.7	1.2	0.0	93.8
Amikacin	0.8	1.6	63.6	29.5	4.7	94.6
Ampicillin	7.9	9.5	77.0	3.2	2.4	89.7
Aztreonam	1.6	0.8	94.4	3.2	0.0	98.4
Cephalothin	6.7	0.5	82.6	9.2	1.0	92.3
Cefoxitin	0.0	6.2	66.7	24.7	2.5	97.5
Cefuroxime	8.6	1.2	90.1	0.0	0.0	91.4
Ciprofloxacin	0.7	1.4	93.5	3.6	0.7	98.6
Ceftriaxone	0.0	0.0	93.0	7.0	0.0	100.0
Ceftazidime	0.8	0.0	96.1	1.6	1.6	97.7
Gentamicin	0.0	2.9	47.1	42.1	7.9	92.1
Imipenem	1.6	0.0	98.4	0.0	0.0	98.4
Ofloxacin	2.4	2.4	95.2	0.0	0.0	97.6
Piperacillin	4.7	0.8	68.2	17.8	8.5	86.8
Tetracycline	0.0	0.0	48.9	31.1	20.0	80.0
Ticarcillin	3.9	4.7	89.8	1.6	0.0	96.1
Ticarcillin-clavulanic acid	4.7	2.4	92.9	0.0	0.0	95.3
Trimethoprim-sulfamethoxazole	0.0	0.0	92.3	5.4	2.3	97.7
Tobramycin	0.0	0.7	26.4	39.3	33.6	66.4
Avg	1.6	1.3	77.1	13.3	6.7	91.7

^a A total of 140 gram-negative isolates (2,268 organism-drug combinations) were evaluated.

^b BIOMIC MIC/Vitek MIC (see text).

^c Ratios between 0.5 and 2.0 were considered to be in agreement.

Table 6 shows the number of E tests which favored the BIOMIC MIC, the Vitek MIC, or neither, when there was a discordance between the MICs. The E test favored the BIOMIC MIC for 52.0% of the errors and the Vitek MIC for 43.4% of the errors. The E test did not favor either for 4.6% of the errors. Table 6 also shows the number of BIOMIC and Vitek category calls which agree with the E test category call. The BIOMIC test result agreed with the E test for 78.6% of the errors, whereas the Vitek test result agreed for only 8.5%. The E test did not indicate which test was most likely correct for 12.9% of the errors. The E test referee favored the MICs of the BIOMIC system for all drugs with the exception of amikacin, gentamicin, trimethoprim-sulfamethoxazole, tobramycin, and vancomycin. The E test also favored the BIOMIC susceptibility interpretation for most drugs with the exception of gentamicin.

The economic analysis is shown in Table 7. The cost per test for the BIOMIC system is \$1.61 and the cost per test for the Vitek system is \$3.78. A BIOMIC test represents 57.4% savings over one Vitek test. Table 7 also includes a comparison of the costs for one year of testing with either system. The number of tests per week and the costs for disposable materials are based on data from the Department of Clinical Microbiology at Tisch Hospital, New York University Medical Center. The total annual expenditure for the Vitek test system, at 416 tests per week with quality control testing and service and support costs, is \$97,948. The total expenditure for one year using the BIOMIC test system is \$35,669.20. The savings would be \$62,278.80 if BIOMIC testing were to replace Vitek testing.

DISCUSSION

The BIOMIC antimicrobial susceptibility test system has been shown in previous studies to be comparable to the classical as well as the commercial dilution methods for obtaining

MICs (5, 10). In this study, the BIOMIC system was found to be comparable to the commonly used Vitek automated antimicrobial susceptibility system, with an overall agreement of 92.6% for MIC data and 97.4% agreement for category calls for the drugs and organisms tested in this investigation. Hence, the BIOMIC system has been shown to be effective for susceptibility testing of both gram-negative and gram-positive bacteria when compared with the Vitek automated system.

In some instances, the data indicated minor discordances between the two systems when testing members of family *Enterobacteriaceae* with tetracycline (80.0% agreement). This lower correlation can be explained by the use of an "all-organism" regression line derived for tetracycline disk diffusion which is used by the BIOMIC system to calculate MICs. It has been shown previously that some members of the family *Enterobacteriaceae* do not fit this regression line (2). Other studies have shown, however, that in comparison with broth microdilution methods, the Vitek system has also shown some discrepancies for tetracycline MICs when testing some members of *Enterobacteriaceae* (1, 7). In separate studies, the BIOMIC system compared favorably (88.7% agreement) with broth microdilution methods for tetracycline MICs. Since the E test referee favored the BIOMIC MICs for tetracycline (8 favored BIOMIC, 3 favored Vitek), the error is more likely the fault of the Vitek antimicrobial susceptibility system (10).

There was a major discordance (33.6%) between the two systems for the MICs of the aminoglycoside antibiotic tobramycin when testing members of the *Enterobacteriaceae*, especially the organisms *Escherichia coli*, *Enterobacter* spp., and *Klebsiella pneumoniae*. The trend was towards higher MICs in the BIOMIC system than in the Vitek system, which was supported by the E test MICs (28 favored Vitek, 9 favored BIOMIC, and 7 favored neither). This discordance can be attributed, in part, to the problems associated with the different methods used for testing tobramycin. Drug permeability and diffusion are major factors when considering the three testing methods. In a bacterial liquid suspension, there is a higher degree of permeability for tobramycin than with the concentration gradient created on agar by a single high-content disk. Therefore, a bacterial suspension such as the one used for the Vitek system could result in lower and more accurate MICs which are more comparable to an in vivo situation. Another explanation for the discordance is the drug itself. When tested by disk diffusion, tobramycin has a very narrow interpretive range for microbial susceptibility (zone size [in millimeters]: ≤ 12 , sensitive; ≥ 15 , resistant). These limits may lead to significant differences in MICs from errors as small as ± 1 mm in the zone size. The E test does not experience this problem because a concentration gradient is already in place on the strip at the start of testing, allowing for a more precise measurement. Technique differences may also account for some differences in the data.

It has been shown that a parabolic regression line may correlate zones of inhibition and doubling dilution MICs better than a linear regression line for some β -lactam drugs. Therefore, some minor correlation problems with β -lactam drugs, such as piperacillin (13.2% discordance), may result from the use of the BIOMIC system, which uses only the linear portion of the regression line (3).

Between 1980 and 1990, national health care expenditures more than doubled from \$250 billion to \$666 billion per year. Hospital care, the largest component of national health care expenditures, exceeded \$250 billion in 1990 (11). During the period 1983 to 1989, outpatient expenses in hospitals rose 142 percent. Among outpatient expenses, laboratory procedures

TABLE 5. Correlation of BIOMIC and Vitek MICs and susceptibility interpretations for all organisms

Drug	% of tests with the following MIC ratio ^a :					% Agreement ^b	
	<0.25	0.5	1	2	>4	MIC	Susceptibility interpretation
Amikacin	0.8	1.6	63.6	29.5	4.7	94.6	100.0
Ampicillin	7.8	9.4	77.3	3.1	2.3	89.8	97.1
Ampicillin-sulbactam	7.5	18.5	67.8	5.5	0.7	91.8	96.6
Aztreonam	1.6	0.8	94.4	3.2	0.0	98.4	96.8
Cefotetan							100.0
Cefoxitin	0.0	6.2	66.7	24.7	2.5	97.5	96.3
Ceftazidime	0.8	0.0	96.1	1.6	1.6	97.7	97.7
Ceftriaxone	0.0	0.0	93.0	7.0	0.0	100.0	96.9
Cefuroxime	8.6	1.2	90.1	0.0	0.0	91.4	92.6
Cephalothin	6.7	0.5	82.6	9.2	1.0	92.3	97.4
Ciprofloxacin	1.0	1.0	92.6	4.4	1.0	98.0	99.0
Clindamycin	1.5	1.5	89.6	0.0	7.5	91.0	91.0
Erythromycin	4.5	1.5	85.1	7.5	1.5	94.0	98.5
Gentamicin	0.0	2.9	47.1	42.1	7.9	92.1	99.3
Imipenem	1.6	0.0	98.4	0.0	0.0	98.4	99.2
Ofloxacin	2.4	2.4	95.2	0.0	0.0	97.6	100.0
Oxacillin	1.5	0.0	98.5	0.0	0.0	98.5	98.5
Penicillin G	16.4	11.9	70.1	1.5	0.0	83.6	97.5
Piperacillin	4.7	0.8	68.2	17.8	8.5	86.8	91.5
Tetracycline	0.8	0.0	62.5	28.3	8.3	90.8	98.3
Ticarcillin	3.9	4.7	89.8	1.6	0.0	96.1	98.4
Ticarcillin-clavulanic acid	4.7	2.4	92.9	0.0	0.0	95.3	97.6
Tobramycin	0.0	0.7	26.4	39.3	33.6	66.4	97.9
Trimethoprim-sulfamethoxazole	1.5	0.5	92.3	4.1	1.5	96.9	97.4
Vancomycin	0.0	1.5	40.3	40.3	17.9	82.1	100.0
Avg	3.3	2.9	78.4	11.3	4.2	92.6	97.4

^a BIOMIC MIC/Vitek MIC (see text).^b MIC ratios between 0.5 and 2.0 were considered to be in agreement; see text for explanation of susceptibility interpretation agreement.

TABLE 6. E test resolution of discordant results

Drug	No. of E tests favoring BIOMIC, Vitek, or neither test system					
	MIC determination			Susceptibility interpretation		
	BIOMIC	Vitek	Neither	BIOMIC	Vitek	Neither
Ampicillin-sulbactam	7	1	0	5	0	0
Amikacin	1	6	0			
Ampicillin	9	2	1	3	0	1
Aztreonam	2	1	0	1	1	1
Cephalothin	6	1	0	5	0	0
Cefoxitin	3	1	0	1	0	1
Cefuroxime	5	1	1	3	0	2
Clindamycin	6	1	0	6	0	0
Ciprofloxacin	3	1	0	2	0	0
Ceftriaxone	3	1	0	2	0	2
Ceftazidime	3	0	0	3	0	0
Erythromycin	3	1	0	1	0	0
Gentamicin	0	11	0	0	1	0
Imipenem	1	1	0	1	0	0
Ofloxacin	2	0	0			
Oxacillin	1	0	0	1	0	0
Penicillin G	8	3	0	1	1	0
Piperacillin	10	6	0	7	2	2
Tetracycline	8	3	0	2	0	0
Ticarcillin	4	1	0	2	0	0
Ticarcillin-clavulanic acid	2	2	0	2	0	0
Trimethoprim-sulfamethoxazole	2	5	0	4	1	0
Tobramycin	9	28	7	3	0	0
Vancomycin	4	8	0			
Total	102 (52%)	85 (43.4%)	9 (4.6%)	55 (78.6%)	6 (8.5%)	9 (12.9%)

TABLE 7. Economic analysis of the Vitek and BIOMIC test systems

Cost factor(s)	BIOMIC (\$)	Vitek (\$)
Disposables/test		
Mueller-Hinton plate	0.75	
Pipette tip		0.02
Swab	0.002	
Saline tube	0.03	0.03
Antibiotic disks (12 × \$0.07/disk)	0.83	
Susceptibility panel (avg)		3.73
Cost/test	1.61	3.78
Cost/wk (416 tests/wk)	669.76	1,572.48
Quality control (cost/wk; 3 plates or 6 cards, respectively)	4.84	22.68
Total cost/wk	674.60	1,595.16
Cost/yr	35,079.20	82,948.32
Service and support/yr	590.00	15,000.00
Total cost/yr	35,669.20	97,948.00
Annual savings (%) BIOMIC vs Vitek	62,278.80 (63.5)	

were among the highest increasing costs (159 percent). These rising costs are of major concern to everyone today.

Hospitals are consolidating services and laboratory testing is becoming increasingly centralized. Thus, the clinical laboratory is facing many changes. Newer, cheaper, and more efficient laboratory testing methods need to be considered. The economic implications of the BIOMIC test system are significant. The hypothetical savings for acute care hospitals by size is shown in Table 8. Small hospitals (6 to 199 beds) were considered to order 150 to 249 susceptibility tests per week. Medium-size hospitals (200 to 499 beds) were considered to order 250 to 349 susceptibility tests per week. Large hospitals (500 beds or more) were considered to order 350 or more susceptibility tests per week. When projected nationally, if all laboratories were to use the BIOMIC system over the Vitek or another comparable system, there would be a total savings of \$123,959,808 or more.

The BIOMIC system most likely will not replace the multiple-use Vitek or other automated systems in the clinical laboratory. Instead, the BIOMIC system should be used to supplement these more expensive automated systems, allowing laboratories to use such systems more for identifications rather than for susceptibility testing. The BIOMIC system also offers an opportunity to small laboratories in the United States and other nations (especially developing nations) to generate quantitative data, inexpensively and efficiently, which are equivalent to those of a more expensive automated system. Although the BIOMIC system cannot provide finalized data within the same period as the Vitek system (4 to 8 h), it can offer preliminary MICs with reasonable correlation to the final MICs, as reported by D'Amato et al. (5).

Certainly the Vitek system allows rapid, automated testing of antibiotic substances. Unfortunately the system as well as

TABLE 8. Economic projection for hospital savings in the United States

Size of hospital (no. of beds)	No. in 1992 ^a	Savings/yr/hospital (\$)
6-199	3,861	17,857-29,025
200-499	1,421	29,138-40,309
≥500	337	40,422+
Total	5,619	122,959,808+ ^b

^a National Center for Health Statistics Public Health Service, Hyattsville, Md.

^b Total projected annual savings for all hospitals.

the associated service fees can prove to be expensive and limited in some ways. For example, the flexibility for testing drugs is limited. The cards used to test an organism are fixed drug panels. They may or may not include drugs a clinician would want to test, forcing the laboratory to use several combinations of cards to get all the drugs they need tested. The cards themselves are not cheap. Use of multiple cards increases costs considerably. The machine is also expensive. Costs such as these are part of the national crisis in health care today, especially since laboratory testing is a major component of national health care expenditures.

The disk diffusion method has several advantages over the classical dilution methods. The disk diffusion method is highly reproducible, flexible, and cost effective. Numerous tests can be performed on a single agar medium with any number of drug combinations. Dilution methods, on the other hand, are work intensive and are not nearly as flexible. Disk diffusion is limited, however, to rapidly growing bacteria, and the measuring of the zones is work intensive. The disk diffusion test also provides only qualitative information when read manually. While qualitative information is useful, it does not indicate the degree to which the organism is susceptible to the antibiotic.

There are many methods available to clinical microbiology laboratories for routine antimicrobial susceptibility testing, among which are the very popular but very expensive automated MIC-generating systems. Although the most economical susceptibility technique currently available is the Bauer-Kirby disk agar diffusion test, this method does not provide quantitative MIC data and is a manual test. As an assay alternative, the BIOMIC system can help remedy these deficiencies by providing highly reproducible, quantitative, and semi-automated testing at a profound savings. Additionally, it offers the advantage of flexibility for antimicrobial agent selection and it is interfaceable with any laboratory computer system (reducing transcription errors). Use of the BIOMIC system can consequently reduce a significant portion of laboratory expense, thereby shifting the current laboratory trend from one of ever increasing costs towards a cost reducing policy; this would be a welcome change in view of our national health care crisis.

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