Comparison of Vitek and Cobas Micro systems with a semiautomated conventional microsystem for identification and susceptibility testing of Gram negative bacilli

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Abstract

Aims—To compare the sensitivity and specificity of two semiautomated systems against a conventional (MIC 2000) test system for the identification and antibiotic susceptibility of Gram negative bacteria.

Methods—Clinical isolates of Gram negative bacilli (188 urinary and 229 non-urinary strains) were identified and tested for antibiotic susceptibility in the Cobas Micro and MIC 2000 systems. Of these, 359 strains were then tested in the Vitek and MIC 2000 systems. Two hundred and forty three strains were tested in all three systems immediately after isolation. Forty three were also tested only in the Vitek and MIC 2000 systems immediately after isolation. The remaining 174 strains were tested after storage at -20°C for several months.

Results—The Cobas Micro and MIC 2000 systems agreed on the identification of 310 of the 417 (74.3%) strains; the Vitek and MIC 2000 systems agreed on 338 of the 359 (94.2%) strains. The Cobas Micro system correctly identified 86.8% of strains tested after storage and 65.4% of those immediately after isolation. Organism-antibiotic combinations (non-urinary isolates) were tested in the Cobas Micro and MIC 2000 systems ($n = 2335$), in the Vitek and MIC 2000 systems ($n = 999$). Essential correlation (complete agreement plus minor errors) was observed in 98% (with 90% complete agreement) in the former and in 97% (with 86% complete agreement) in the latter. For the urinary isolates, 1949 organism-antibiotic combinations were analysed in the Cobas Micro and MIC 2000 systems where complete agreement was observed in 92% (with 3% very major discrepancies), for 1382 urinary organism-antibiotic combinations tested in the Vitek and MIC 2000 systems, the figures were 95% and 2%, respectively.

Conclusions—The Vitek system is highly accurate in the identification and antibiotic susceptibility testing of Gram negative bacteria. The Cobas Micro system has many shortcomings in its identification of Gram negative rods, especially freshly isolated strains, but it is comparable with the Vitek system in antibiotic susceptibility testing.

Reliable identification and susceptibility testing of bacteria are important for the diagnosis and treatment of infectious diseases. During the past decade, great progress has been made in the automation of microbiological techniques. Several systems with a varying degree of automation are now available for use in routine diagnostic laboratories. The choice of one system over another depends on several factors, including time required for determination and sensitivity testing, spectrum of organisms covered, mode of performance, personal preferences, and costs.

Several comparison studies of instruments for identification and susceptibility testing have been reported. Most systems have an efficiency of more than 90% and reproducibilities ranging from 85–96%.^{1–8} Stager and Davis⁹ have comprehensively reviewed the available systems.

Methods

A total of 417 routine clinical isolates of Gram negative bacteria (188 urinary strains, 180 non-urinary, and 49 non-urinary *Pseudomonas* strains) were tested in this study. Of these, 243 strains were collected and tested (on the day of the first isolation) in the two commercial test systems (Vitek and Cobas Micro) and the conventional test system (MIC 2000), and 43 strains were tested in only two systems (Vitek and MIC 2000). The remaining strains ($n = 174$) were kept frozen at -20°C until use. These strains had been tested before, but not simultaneously, in the two commercial systems and compared with the conventional system.

CONVENTIONAL TEST SYSTEM

Biochemical identification and microdilution minimum inhibitory concentration (MIC) testing were done in microtitre trays prepared inhouse using an MIC 2000 dispenser (Dynatech, The Netherlands), dispensing 0.1 ml volumes of each biochemical substrate and antimicrobial agent dilution per well. Identification was made on the basis of 22 biochemical reactions. If a definitive identification was not obtained, or if there was a disagreement in identification we used the API 20E (API bioMérieux Benelux BV, The Netherlands) for confirmation. *Pseudomonas* sp were identified by their pigment production and growth at 42°C or by the API NE (API bioMérieux).

Six appropriate twofold diluted concentrations of 12 different antimicrobial agents in

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Isosensitest broth (Unipath) were used to determine the MICs. Trays were inoculated with a bacterial suspension (5×10^5 cfu/ml) of fresh colonies in distilled water using an MIC 2000 inoculator (Dynatech). The trays were incubated at 37°C for 18 hours, after which the MIC endpoint was read visually as the lowest concentration of antimicrobial agent that completely inhibited bacterial growth. The reference strains of *Escherichia coli* (ATCC 25922) and *Pseudomonas aeruginosa* (ATCC 27853) served as controls. Susceptibility was determined as S(sensitive), I(intermediate) for non-urinary strains, or R(resistant), according to the breakpoints of

the WRG (Werkgroep Richtlijnen Gevoeligheids-bepalingen, The Netherlands). The MIC 2000 was supplemented with the disc diffusion test for those antibiotics which were present in one or both of the commercial systems, but not in the MIC 2000 system.

VITEK SYSTEM

The Vitek system (bioMérieux) is an integrated modular system consisting of a filling sealer unit, reading incubator, computer control module, data terminal, and multicopy printer. The Gram negative identification card was used for the identification of all strains. The Gram negative susceptibility-EU card and Gram negative susceptibility-HS cards (*Pseudomonas* strains) were used for the susceptibility testing of the 243 strains which were simultaneously tested in the Cobas Micro and the MIC 2000 systems, and the Gram negative susceptibility-GD, Gram negative susceptibility-OP, or Gram negative susceptibility-UA cards (urinary strains) for the susceptibility testing of the remaining strains. Cards were inoculated with a standardised inoculum and tests were done according to the manufacturer's instructions. Identification and MIC results were automatically printed at the end of the incubation period, which was six to 10 hours for most isolates. The WRG breakpoints were used for the interpretation of the MIC results.

Software, version R 6.4 (Vitek), was used.

COBAS MICRO SYSTEM

The Cobas Micro System (Becton Dickinson, The Netherlands) is a computer controlled instrument for automatic analysis and the interpretation of identification and susceptibility testing using specifically designed rotors. The system consists of a rotor centrifuge station, thermal printer, screen, keyboard, bar code reader and filter photometer. After centrifugation in the rotor centrifugation station, which permits the distribution of the inoculum into the rotor chambers, the rotor is incubated overnight at 37°C. After incubation the filter photometer measures absorbance values in the individual rotor chambers. Two types of rotor were used: a 33 chamber rotor for identification and a 16 chamber rotor for antimicrobial susceptibility testing. Rotors were inoculated with a standardised inoculum (Inocheck, Becton Dickinson, The Netherlands) and tests were done according to the manufacturer's instructions. The built-in computer provided an automated interpretation of the results.

CLASSIFICATION OF RESULTS OF SUSCEPTIBILITY TESTING

The comparative results were classified as follows:

(1) *Complete agreement*: the results were within the same category (sensitive, intermediate (for non-urinary strains), or resistant).

(2) *Minor error (for non-urinary strains only)*: the results were within a category which was sensitive or resistant for one system and intermediate for the other system.

Table 1 Comparison of identification of Gram negative micro-organisms by MIC 2000, Cobas Micro, and Vitek

Organism MIC 2000	Cobas Micro		Vitek	
	No of isolates	Correct species (genus)	No of isolates	Correct species (genus)
<i>Escherichia coli</i>	140	90	131	131
<i>Klebsiella pneumoniae</i>	33	31 (32)	27	27
<i>K. oxytoca</i>	25	20 (23)	22	22
<i>K. ozaenae</i>	1	1	1	1
<i>Enterobacter aerogenes</i>	10	6	8	7
<i>E. cloacae</i>	20	18	19	18
<i>E. agglomerans</i>	2	2	1	1
<i>E. amnigenes</i>			1	
<i>Proteus mirabilis</i>	27	26	21	21
<i>Proteus</i> spp (other)	5	4	4	4
<i>Morganella morganii</i>	10	10	7	7
<i>Providencia stuartii</i>	6	4 (5)	2	2
<i>Proteus rettgeri</i>	1		1	1
<i>Citrobacter freundii</i>	7	4	7	5 (7)
<i>C. diversus</i>	5	3 (5)	3	3
<i>C. amalonaticus</i>	1	1		
<i>Serratia marcescens</i>	10	9	10	10
<i>Serratia liquefaciens</i>	2	(1)	1	(1)
<i>Acinetobacter</i> spp	23	16	19	14
<i>Shigella sonnei</i>	1	1	1	1
<i>Shigella</i> spp	3	3	1	1
<i>Salmonella</i> spp	8	7	8	7
<i>Yersinia enterocolitica</i>	2	2	2	2
<i>Pseudomonas aeruginosa</i>	59	39 (59)	50	47
<i>Pseudomonas</i> spp (other)	4	2 (3)	2	
<i>Xanthomonas maltophilia</i>	12	11	10	6
Total (genus and species)	417	310 (74.3%)	359	338 (94.2%)
Total (genus)	417	339 (81.3%)	359	341 (95%)

Table 2 Comparison of identification of Gram negative micro-organisms by Cobas Micro immediately after isolation or after storage at -20°C

Organism MIC 2000	Cobas Micro at isolation		Cobas Micro after storage -20°C	
	No of isolates	Correct species (genus)	No of isolates	Correct species (genus)
<i>Escherichia coli</i>	108	63	32	27
<i>Klebsiella pneumoniae</i>	16	14 (15)	17	17
<i>K. oxytoca</i>	14	9 (12)	11	11
<i>K. ozaenae</i>			1	1
<i>Enterobacter aerogenes</i>	7	4	3	2
<i>E. cloacae</i>	16	14	4	4
<i>E. agglomerans</i>	1		2	2
<i>Proteus mirabilis</i>	16	15	11	11
<i>Proteus</i> spp (other)	1	1	4	3
<i>Morganella morganii</i>	3	3	7	7
<i>Providencia stuartii</i>			6	4 (5)
<i>Proteus rettgeri</i>			1	
<i>Citrobacter freundii</i>	4	3	3	1
<i>C. diversus</i>	3	1 (3)	2	2
<i>C. amalonaticus</i>			1	1
<i>Serratia marcescens</i>	4	4	6	5
<i>S. liquefaciens</i>	1	(1)	1	
<i>Acinetobacter</i> spp	13	7	10	9
<i>Shigella sonnei</i>	1	1		
<i>Shigella</i> spp			3	3
<i>Salmonella</i> spp	1	1	7	6
<i>Yersinia enterocolitica</i>			2	2
<i>Pseudomonas aeruginosa</i>	30	15 (30)	29	24 (29)
<i>Pseudomonas</i> spp (other)	1		3	2 (3)
<i>Xanthomonas maltophilia</i>	4	4	8	7
Total (genus and species)	243	159 (65.4%)	174	151 (86.8%)
Total (genus)	243	181 (74.5%)	174	158 (91%)

(3) *Major error*: the results in the test system were in the resistant category whereas they were sensitive in the standard system.

(4) *Very major error*: the results in the test system were in the sensitive category, whereas they were resistant in the standard system.

(5) *Essential correlation*: this comprised the sum of the percentages of complete agreement and minor error.

Results

IDENTIFICATION

Table 1 compares the identification of the Gram negative isolates using the MIC 2000, Cobas Micro, and Vitek systems, respectively. No additional "external" reactions were used in the identification of the strains in the different systems. Of the 359 strains tested in complete agreement with the MIC 2000

Table 3 Discrepancies in identification using MIC 2000, Cobas Micro, and Vitek

MIC 2000	Total No of strains	Cobas Micro misidentification	No of strains	Total No of strains	Vitek misidentification	No of strains
<i>Escherichia coli</i>	140	<i>Shigella sonnei</i>	32			
		<i>Shigella</i> spp	10			
		<i>Vibrio</i> spp	7			
		<i>Plesiomonas</i>	1			
<i>Klebsiella pneumoniae</i>	33	<i>Serratia plymuthica</i>	1			
		<i>K ozaenae</i>	1			
<i>K oxytoca</i>	25	<i>Vibrio parahaemolyticus</i>	1			
		<i>K pneumoniae</i>	3			
		<i>E cloacae</i>	1			
<i>Enterobacter aerogenes</i>	10	<i>Kluyvera ascorbata</i>	2	8	<i>K pneumoniae</i>	1
		<i>Klebsiella</i> spp	1			
		<i>Shigella fonticola</i>	1			
<i>E cloacae</i>	20	<i>C freundii</i>	2	19	<i>Serratia fonticola</i>	1
<i>E amnigenes</i>				1	<i>C freundii/amalonicus</i>	1
<i>P mirabilis</i>	27	<i>Flavobacterium</i>	1			
<i>P vulgaris</i>	3	<i>Proteus rettgeri</i>	1			
<i>Providencia stuartii</i>	6	<i>Morganella morganii</i>	1			
		<i>P rettgeri</i>	1			
<i>Proteus rettgeri</i>	1	<i>F odoratum</i>	1			
<i>C freundii</i>	7	<i>Yersinia enterocolitica</i>	1	7	<i>C amalonicus</i>	2
		<i>Chryseomonas luteola</i>	1			
		<i>Y pseudotuberculosis</i>	1			
<i>C diversus</i>	5	<i>C amalonicus</i>	2			
<i>Serratia marcescens</i>	10	<i>K pneumoniae</i>	1			
<i>S liquefaciens</i>	2	<i>S marcescens</i>	1	1	<i>S marcescens</i>	1
		<i>E cloacae</i>	1			
<i>Acinetobacter</i>	23	<i>Moraxella</i> spp	3	19	Non-viable organism	3
		<i>P rettgeri</i>	1		No growth	1
		<i>Pasteurella aerogenes</i>	1		Unidentified organism	1
		<i>Alcaligenes</i>	2			
<i>Salmonella</i> spp	8	<i>Hafnia alvei</i>	1	8	Unidentified organism	1
<i>Ps aeruginosa</i>	59	<i>P putida</i>	7	50	Unidentified organism	3
		<i>P fluorescens</i>	7			
		<i>P mendocina</i>	5			
		<i>P stutzeri</i>	1			
<i>Ps aeruginosa</i>				7*	Unidentified organism	1
<i>Ps fluorescens</i>	1	<i>Alcaligenes</i>	1	1	<i>Flavimonas</i>	1
<i>Ps stutzeri</i>	1	<i>P alcaligenes</i>	1			
<i>Ps acidovorans</i>				1	Unidentified organism	1
<i>Xanthomonas maltophilia</i>	12	<i>K ozaenae</i>	1	10	Unidentified organism	4

*Additional strains tested by Vitek and MIC 2000 only.

Table 4 Correlation and classification of results of susceptibility testing for non-urinary Gram negative isolates comparing MIC 2000 with Vitek and Cobas Micro

Antimicrobial agent	Number of drug/micro-organism combinations	Complete agreement* (%)	Minor error** (%)	Major error† (%)	Very major error†† (%)	Essential correlation (%)‡
Vitek/MIC 2000						
Ampicillin	195	71.3	26.2	1.5	1.0	97.5
Piperacillin	184	84.2	10.9	4.3	0.6	95.1
Cefotaxime	184	89.1	8.2	1.1	1.6	97.3
Cefuroxime	126	86.5	9.5	3.2	0.8	96.0
Gentamicin	184	93.5	4.9	1.6	0	98.4
Amikacin	126	96.0	4.0	0	0	100
Totals	999	86.1	11.2	2.0	0.7	
Essential correlation* (%)						97.3
Cobas/MIC 2000						
Ampicillin	213	76.1	21.1	1.9	0.9	97.2
Amoxicillin/clavulanic acid	213	70.0	28.6	0	1.4	98.6
Piperacillin	205	82.9	11.2	5.9	0	94.1
Imipenem	213	96.2	1.9	1.9	0	98.1
Cefotaxime	213	92.0	5.6	1.4	1.0	97.6
Gentamicin	213	97.2	2.8	0	0	100
Netilmicin	213	95.8	4.2	0	0	100
Amikacin	213	94.8	4.7	0.5	0	99.5
Ciprofloxacin	213	98.1	1.4	0.5	0	99.5
Pefloxacin	213	95.3	1.4	2.8	0.5	96.7
Trimethoprim	213	87.3	7.5	3.3	1.9	94.8
Totals	2335	89.6	8.2	1.6	0.6	
Essential correlation* (%)						97.8

*Category results identical.

**Minor error: intermediate susceptible results for one system with susceptible or resistant results for the other.

†Major error: resistant results in the test system (Vitek or Cobas) and susceptible results in the MIC 2000.

††Very major error: susceptible results in the test system (Vitek or Cobas) and resistant results in the MIC 2000.

‡ec (essential correlation) = complete agreement plus minor error

Table 5 Correlation and classification of results of susceptibility testing for urinary Gram negative isolates comparing MIC 2000 with Vitek and Cobas Micro

Antimicrobial agent	Number of drug/micro-organism combinations	Complete agreement* (%)	Major error* (%)	Very major error* (%)
Vitek/MIC 2000				
Ampicillin	157	94.3	4.5	1.2
Amoxicillin/clavulanic acid	119	89.9	8.4	1.7
Piperacillin	119	93.3	5.9	0.8
Norfloxacin	156	98.7	1.3	0
Nitrofurantoin	158	88.6	5.1	6.3
Cotrimoxazole	158	93.0	5.1	1.9
Nalidixic acid	119	96.7	0.8	2.5
Cefotaxime	119	97.5	0.8	1.7
Cefuroxime	119	98.3	0	1.7
Gentamicin	158	98.1	1.9	0
Totals	1382	94.8	3.4	1.8
Cobas/MIC 2000				
Ampicillin	182	88.5	6.0	5.5
Amoxicillin/clavulanic acid	182	90.1	7.1	2.8
Piperacillin	208†	85.1	14.4	0.5
Gentamicin	207†	97.1	2.9	0
Pipemidic acid	208†	95.7	2.4	1.9
Norfloxacin	208†	98.1	1.4	0.5
Ciprofloxacin	208†	98.6	1.4	0
Sulfamethoxazole	182	91.8	0.5	7.7
Trimethoprim	182	84.6	13.7	1.7
Nitrofurantoin	182	85.1	2.7	12.2
Totals	1949	91.7	5.2	3.1

*See legend to table 4.

†Including *Pseudomonas* isolates.

system, Vitek identified 95% at genus level and 94.2% at species level. The 43 additional isolates, which were tested only in the Vitek and MIC 2000 systems, showed complete agreement for 42 strains. One strain, *Ps. aeruginosa*, was recorded as an unidentified organism in the Vitek system. These results raised the total agreement at species level between the Vitek and MIC 2000 systems to 94.5%.

The Cobas Micro system identified 310 of the 417 (74.3%) strains at species level in full agreement with the MIC 2000 system and 339 (81.3%) at genus level. A remarkable difference was observed in the Cobas Micro system for the 243 strains identified immediately after isolation (65.4% at species level; 74.5% at genus level) and the 174 strains tested after storage for several months at -20°C (86.8% at species level; 90.8% at genus level) (table 2). No such differences in identification rates were observed with the Vitek system.

Most of the misidentifications with Vitek were with *Acinetobacter* sp, *Pseudomonas* sp, or *X. maltophilia* strains (15 strains), which were recorded as unidentified or non-viable micro-organisms. Only seven strains in the entire study were misidentified by the Vitek system (table 3). The Cobas Micro system misidentified 107 strains at genus or species level in almost all genera tested (table 3).

ANTIMICROBIAL SUSCEPTIBILITY

Tables 4, 5, and 6 compare the Vitek and Cobas Micro systems with the MIC 2000 system for the antimicrobial susceptibility testing of non-urinary Gram negative isolates (without *Pseudomonas*), urinary Gram negative isolates, and non-urinary *Pseudomonas* isolates, respectively. Complete agreement between the Vitek and MIC 2000 systems for non-urinary strains was obtained in 86.1% of cases (table 4). Very major errors were obtained in only 0.7%. Between the Cobas Micro and MIC 2000 systems, complete agreement for non-urinary strains was obtained in 89.6%; very major errors occurred in 0.6%. Many minor errors were seen in the Cobas Micro and Vitek systems: 26% and 21%, respectively, for ampicillin and 28% for amoxicillin/clavulanic acid in the Cobas system. For the urinary strains (table 5), the figures for complete agreement and for very major errors between the Vitek and MIC 2000 systems were 94.8% and 1.8%, respectively, and for Cobas Micro and MIC 2000 91.7% and 3.1%, respectively. Nitrofurantoin yielded the highest number of major errors in both systems, and sulfamethoxazole and ampicillin in the Cobas Micro. For non-urinary *Pseudomonas* sp, the Vitek system completely agreed with the MIC 2000 system in 75.8% of results (0.4% very major errors). The percentage agreement between Cobas Micro and MIC 2000 was 79.3% (0.5% very major errors) (table 6).

Essential correlation was obtained in more than 95% of all comparative results except for piperacillin and trimethoprim in the Cobas Micro system.

Table 6 Correlation and classification of results of susceptibility testing for non-urinary *Pseudomonas* isolates comparing MIC 2000 with Vitek and Cobas Micro

Antimicrobial agent	Number of drug/micro-organism combinations	Complete agreement* (%)	Minor error* (%)	Major error* (%)	Very major error* (%)	Essential correlation (%)*
Vitek/MIC 2000						
Piperacillin	41	92.7	7.3	0	0	100
Ticarcillin/clavulanic acid	34	50.0	44.2	2.9	2.9	94.2
Cefotaxime	41	68.3	26.8	4.9	0	95.1
Amikacin	34	44.1	55.9	0	0	100
Tobramycin	41	85.4	14.6	0	0	100
Ciprofloxacin	57	96.5	3.3	0	0	100
Totals	248	75.8	22.6	1.2	0.4	
Essential correlation* (%)						98.4
Cobas/MIC 2000						
Piperacillin	55	74.5	0	25.5	0	74.5
Imipenem	57	86.0	8.8	5.2	0	94.8
Gentamicin	57	89.4	8.8	1.8	0	98.2
Netilmicin	57	87.7	5.3	3.5	3.5	93.0
Amikacin	57	77.2	19.3	3.5	0	96.5
Ciprofloxacin	57	78.9	3.5	17.5	0	82.4
Pefloxacin	57	61.4	28.0	10.6	0	89.4
Totals	397	79.3	10.6	9.6	0.5	
Essential correlation* (%)						89.9

*See legend to table 4.

Discussion

Automated bacterial identification and susceptibility testing systems offer several advantages over conventional methods, one of which is the rapid provision of accurate information to the clinician. The Vitek system offers a rapid system (six to 10 hours) compared with the Cobas Micro and our MIC 2000 system (both 21 hours). The Cobas Micro system does offer the choice of a short incubation period (five hours), but should this short incubation period inadvertently be prolonged (>6 hours) the rotor will be rejected, and it will not be accepted for further incubation in the event of a misidentification at five hours. The Vitek system is fully automated, whereas the Cobas Micro system has no incubation chamber, which makes a manual incubation step necessary. The rate of correct identification of Gram negative bacteria by the Vitek system in our study (94%) is within the range of that obtained with comparable systems^{1,2,7,8} and with the Vitek system^{9,10} in other studies. The Cobas Micro system offers an unacceptably low rate of correct identifications (74%) at genus and species level. Remarkable misidentifications were 42 strains of *E coli* (MIC 2000 and Vitek) which were identified as *Shigella sonnei* or *Shigella* sp by the Cobas Micro system.

To our knowledge, there are only two detailed studies^{3,6} and one abstract (O'Hara CM, Miller JM, Rhoden DL. Abstract presented at 91st Annual Meeting of the American Society for Microbiology, 1991) evaluating the Cobas Micro system in the identification of Gram negative bacteria. The identification rates obtained in these studies vary from 69–97%, depending on the types of micro-organisms, the use of additional "external" reactions, and the incubation period used. In this study we found a large difference in the correct identification rate in the Cobas Micro system when strains were tested after several months of storage at –20°C (86.8% at species level) or immediately after isolation (65.4% at species level). Adaptation to the culture media in the laboratory might explain this. No such differences were found in antibiotic susceptibility testing after storage.

The results for susceptibility testing of Gram negative isolates using the Vitek and the Cobas Micro systems compared favourably with our conventional system (97% essential correlation for non-urinary strains and 95% and 91%, respectively, for urinary strains), and with those from other studies.^{4–6,10} Non-urinary *Pseudomonas* strains scored somewhat lower in the Cobas Micro system (89.9% essential correlation). Both commercial systems showed many minor errors for the non-urinary strains with the penicillin group of antibiotics (Vitek: ampicillin 26.2% and piperacillin 10.9%; Cobas Micro: ampicillin 21.1%, amoxicillin/clavulanic acid 28.6% and piperacillin 11.2%) (table 5). Although the essential correlation for the system comparisons was high (97%), complete agreement was only

obtained in about 86%–89% due to these minor error discrepancies. Backes *et al* also found a high percentage of minor errors with ampicillin (26%) when comparing the Vitek system with the MicroMedia systems.¹¹ We found many very major errors for urinary strains with nitrofurantoin in both systems, and with sulfamethoxazole and ampicillin in the Cobas system. Some of these errors were the result of unsuitable drug-organism combinations, which can give variable results in the laboratory (for example, *Proteus*-nitrofurantoin, *Klebsiella/Enterobacter*-ampicillin).^{11,12} Fortunately these combinations are clinically unimportant.

The findings of this study suggest that the Vitek system is highly accurate in the identification and antibiotic susceptibility testing of clinically important Gram negative bacteria. The Cobas Micro system had many shortcomings in the identification of Gram negative bacteria, although the system was comparable with the Vitek system in determining antibiotic susceptibility. Both systems showed some weaknesses in the antibiotic sensitivity testing of *Pseudomonas* isolates. For the routine diagnostic microbiology laboratory, the Vitek system could offer a reliable replacement for conventional test systems.

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