

# Direct Comparison of Antimicrobial Susceptibility Testing by the BD Phoenix, bioMérieux VITEK 2, and Disk Diffusion Test Methods as Compared to Results Generated by the CLSI Broth Microdilution Test

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## ABSTRACT

**BACKGROUND.** Several options exist for performance of automated or manual antimicrobial susceptibility testing in clinical laboratories. We have assessed the use of the BD Phoenix, the bioMérieux VITEK 2, and the CLSI disk diffusion methods for testing common, aerobic bacteria.

**METHODS.** A collection of fresh clinical isolates and stock strains were tested in common by the three methods. They included staphylococci, enterococci, members of the *Enterobacteriaceae*, and selected species of non-fermenters. Results were compared to MICs determined using the CLSI broth microdilution method with specially prepared frozen panels.

**RESULTS.** A total of 410 commonly encountered aerobic pathogens (180 fresh clinical isolates, 230 stock strains) were tested. Overall susceptibility category agreements between the test methods and the reference procedure were 95.3% for Phoenix, 95.1% for VITEK 2, and 94.7% for disk diffusion. Percent very major (VM), major (M), and minor (m) error rates were 1.2, 1.8, and 3.2 for Phoenix, 2.7, 0.2, and 3.9 for VITEK 2, and 1.4, 0.2, and 4.5 for disk diffusion using the relevant organism-drug combinations successfully tested by each method. When on-scale MICs were obtained with the two instruments, the overall essential agreement (+/- one dilution) between the reference method and Phoenix was 91.7% and was 89.1% with VITEK 2. Differences were noted in the mean length of time to generate results: 9.1 h by VITEK 2, 13.4 h by Phoenix, and 16-18 h by disk testing. The overall labor requirements of each method were determined using batches of six tests performed separately by two technologists. An average of 1.3 min was required for VITEK 2, 3.2 min for Phoenix, and 3.0 min for disk tests.

**CONCLUSIONS.** Each method demonstrated specific strengths and shortcomings. The overall interpretive category error rates for the two instruments and the disk diffusion method were quite similar. The data analysis was complicated somewhat by results provided by one instrument or the disk method that were not available by all three methods for comparison. The VITEK 2 required the least technical time and provided the earliest results.

## INTRODUCTION

Clinical Microbiology Laboratories have a number of options for performance of their routine antimicrobial susceptibility testing. This study has compared directly the performance of two automated instrument systems for this purpose, the BD Phoenix and bioMérieux VITEK 2 as well as the CLSI disk diffusion method with a group of aerobic gram-positive and gram-negative bacteria. The study included parallel testing of fresh clinical isolates and selected stock cultures with both instruments, the disk test, and the CLSI and ISO reference broth microdilution method. In addition to the accuracy of the susceptibility results from the three methods, the efficiency of each system was assessed with regard to the amount of labor required per test and the time required to obtain results.

## MATERIALS AND METHODS

**Phoenix System.** The Phoenix used in the study included version 5.02H/V4.11B of clinical software, and used gram-positive combo panels (PMIC/ID-100) and gram-negative combo panels (NMIC-107). Panels were selected to coincide as much as possible with the current University Health System formulary.

**VITEK 2 System.** A VITEK 2XL with software version R04.01 was used for this study. AST-GP61 cards were used for the gram-positive isolates and AST-GN11 were used for the gram-negatives. Cards were selected to match the hospital formulary and the Phoenix panels as closely as possible.

**Disk diffusion tests.** The CLSI disk diffusion method (2) was performed on each isolate, and the category results compared to the category results generated by the broth microdilution reference method (3).

**Reference susceptibility testing method.** The reference CLSI (1) and ISO (5) broth microdilution method was used to test each isolate in the study. The reference MIC values and interpretive breakpoints (3) were used to calculate the essential and category agreements for the three test methods.

**Fresh clinical isolates.** A total of 180 consecutive isolates of members of the *Enterobacteriaceae*, *Pseudomonas aeruginosa*, *Acinetobacter baumannii*, staphylococci, and enterococci were tested in each system. The number of *E. coli* isolates was limited to 20.

**Stock strains.** A group of 230 retained clinical isolates from University Hospital and other sources were used to provide strains with greater antimicrobial resistance than those encountered among the fresh clinical isolates. These included *Enterobacteriaceae* that produced various ESBL, plasmid-mediated ampC, or hyperproduction of chromosomal ampC enzymes. Additional isolates of *P. aeruginosa* and *Acinetobacter* with multi-drug resistance were selected. A group of MRSA strains with previous *mecA* gene results and a group of VRE strains of various species were also tested.

**Discrepancy resolution.** Discrepancies between the susceptibility results generated by the two instruments or the disk method and the reference MICs and categories were retested one time. The overall essential agreement of MICs and category agreements

were calculated for each method using the CLSI broth microdilution results as the reference values.

**Determination of system efficiency.** The average times required for identifications and susceptibility test results by each

instrument was determined. In addition, the technologist time required for each method was measured, and included all aspects of test inoculation, test performance, and results recovery for each system.

## RESULTS

Table 1. Characteristics of some stock strains used in the study

<i>Enterobacteriaceae</i>			
39	ESBL producers		
1	plasmid mediated Amp-C		
2	carbapenamase producers		
<i>S. aureus</i>		<i>Enterococcus</i> spp.	
30	<i>mecA</i> positive	22	<i>VRE: E. avium</i>
20	<i>mecA</i> negative	1	<i>E. durans</i>
CNS	15 <i>mecA</i> positive	6	<i>E. faecalis</i>
	6 <i>mecA</i> negative	13	<i>E. faecium</i>

Table 2. Overall error rates and category agreement for all antimicrobial agents by organism group

Organism Group	Phoenix				VITEK 2				Disk Diffusion			
	VM	M	m	CA	VM	M	m	CA	VM	M	m	CA
<i>Enterobacteriaceae</i>	6	5	55	1490	12	2	60	1482	10	4	93	1449
<i>Pseudomonas</i> spp.	3	1	17	459	6	0	28	460	1	2	24	358
Non- <i>Enterobacteriaceae</i>	1	0	15	172	7	1	23	160	0	0	1	111
<i>S. aureus</i>	1	0	10	395	1	0	8	397	0	0	9	397
CNS	1	28	4	285	1	2	3	312	1	0	4	314
<i>Enterococcus</i> spp.	1	2	3	276	2	0	4	276	0	0	2	124
<b>Total</b>	<b>13</b>	<b>36</b>	<b>104</b>	<b>3077</b>	<b>29</b>	<b>5</b>	<b>126</b>	<b>3087</b>	<b>12</b>	<b>6</b>	<b>133</b>	<b>2753</b>
<b>Frequency %</b>	<b>1.2%</b>	<b>1.8%</b>	<b>3.2%</b>	<b>95.3%</b>	<b>2.7%</b>	<b>0.2%</b>	<b>3.9%</b>	<b>95.1%</b>	<b>1.4%</b>	<b>0.2%</b>	<b>4.5%</b>	<b>94.7%</b>

VM = Very Major Error, M = Major Error, m = Minor Error, CA = Category Agreement

Table 3. Error rates for gram-negative organisms by antimicrobial agent

### *Enterobacteriaceae*

	Reference Method				Phoenix					VITEK 2					Disk Diffusion				
	S	I	R	Total	VM	M	m	O	N	VM	M	m	O	N	VM	M	m	O	N
Ampicillin	20			111	0	1	2	108	111	0	0	1	110	111	0	0	1	110	111
Cefotaxime	98	4	50	152	0	1	5	146	152	2	1	8	141	150	0	0	12	140	152
Cefepime	122	4	9	135	0	1	0	134	135	1	1	1	132	134	2	0	6	127	135
Pip/Tazo	109	6	17	132	0	1	8	123	132	4	0	6	122	128	0	0	11	121	132
Meropenem	140	1	1	142	0	0	0	142	142	0	0	1	141	142	1	0	1	140	142
Amikacin	141	7	5	153	2	0	5	146	151	2	0	4	147	151	0	0	10	143	153
Gentamicin	109	8	34	151	1	0	7	143	150	1	0	3	147	150	1	0	7	143	151
Tobramycin	107	15	29	151	1	0	5	145	150	0	0	8	143	151	1	0	9	141	151
Ciprofloxacin	106	7	22	135	1	0	5	129	134	0	0	5	130	135	0	0	7	128	135
Trimeth/Sulfa	104		44	148	1	1	0	146	147	0	0	0	148	148	0	3	1	144	148
Nitrofurantoin	67	24	55	146	0	0	18	128	146	2	0	23	121	144	5	1	28	112	146
<b>TOTAL</b>	<b>1123</b>	<b>76</b>	<b>357</b>	<b>1556</b>	<b>6</b>	<b>5</b>	<b>55</b>	<b>1490</b>	<b>1556</b>	<b>12</b>	<b>2</b>	<b>60</b>	<b>1483</b>	<b>1556</b>	<b>10</b>	<b>4</b>	<b>93</b>	<b>1449</b>	<b>1556</b>
<b>FREQUENCY %</b>	<b>72.2%</b>	<b>4.9%</b>	<b>22.9%</b>		<b>1.7%</b>	<b>0.4%</b>	<b>3.5%</b>	<b>95.8%</b>		<b>3.4%</b>	<b>0.2%</b>	<b>3.9%</b>	<b>95.3%</b>		<b>2.8%</b>	<b>0.4%</b>	<b>5.9%</b>	<b>93.1%</b>	

### *Pseudomonas*

	Reference Method				Phoenix					VITEK 2					Disk Diffusion				
	S	I	R	Total	VM	M	m	CA	N	VM	M	m	CA	N	VM	M	m	CA	N
Ampicillin	0	0	55	55	0	0	0	52	52	0	0	0	55	55			N/A		
Pip/Tazo	41		14	55	1	0	0	53	53	5	0	0	50	50	1	2	0	52	54
Cefepime	30	10	15	55	0	1	8	45	54	0	0	13	42	55	0	0	13	42	55
Meropenem	38	3	14	55	1	0	3	50	53	1	0	3	51	54	0	0	3	52	55
Amikacin	49	0	6	55	1	0	0	53	53	0	0	0	55	55	0	0	1	54	55
Gentamicin	39	6	10	55	0	0	3	49	52	0	0	5	50	55	0	0	3	52	55
Tobramycin	44	2	9	55	0	0	1	53	54	0	0	1	54	55	0	0	1	54	55
Ciprofloxacin	35	4	16	55	0	0	2	52	54	0	0	5	49	54	0	0	3	52	55
Nitrofurantoin			55	55	0	0	0	52	52	0	0	1	54	55			N/A		
<b>TOTAL</b>	<b>276</b>	<b>25</b>	<b>194</b>	<b>495</b>	<b>3</b>	<b>1</b>	<b>17</b>	<b>459</b>	<b>480</b>	<b>6</b>	<b>0</b>	<b>28</b>	<b>460</b>	<b>494</b>	<b>1</b>	<b>2</b>	<b>24</b>	<b>358</b>	<b>385</b>
<b>FREQUENCY %</b>	<b>55.8%</b>	<b>5.1%</b>	<b>39.2%</b>		<b>1.6%</b>	<b>0.4%</b>	<b>3.5%</b>	<b>95.6%</b>		<b>3.1%</b>	<b>0.0%</b>	<b>5.7%</b>	<b>92.9%</b>		<b>1.2%</b>	<b>0.7%</b>	<b>6.2%</b>	<b>93.0%</b>	

### Non-fermenters other than *Pseudomonas*

	Reference Method				Phoenix					VITEK 2					Disk Diffusion				
	S	I	R	Total	VM	M	m	CA	N	VM	M	m	CA	N	VM	M	m	CA	N
Ampicillin	0	7	21	28	0	0	7	21	28	1	0	4	23	28					
Cefotaxime	3	11	12	26	1	0	5	20	26	1	1	11	13	26					
Gentamicin	16	1	11	28	0	0	0	28	28	0	0	1	27	28	0	0	0	28	28
Tobramycin	17	1	10	28	0	0	0	28	28	1	0	3	24	28	0	0	0	28	28
Amikacin	20	2	6	28	0	0	2	25	27	4	0	3	21	28	0	0	1	27	28
Ciprofloxacin	17	1	10	28	0	0	0	26	26	0	0	0	28	28	0	0	1	28	28
Nitrofurantoin	0	1	24	25	0	0	1	24	25	0	0	1	24	25					
<b>TOTAL</b>	<b>73</b>	<b>24</b>	<b>94</b>	<b>191</b>	<b>1</b>	<b>0</b>	<b>15</b>	<b>172</b>	<b>188</b>	<b>7</b>	<b>1</b>	<b>23</b>	<b>160</b>	<b>191</b>	<b>0</b>	<b>0</b>	<b>1</b>	<b>111</b>	<b>112</b>
<b>FREQUENCY %</b>	<b>38.2%</b>	<b>12.6%</b>	<b>49.2%</b>		<b>1.1%</b>	<b>0.0%</b>	<b>7.9%</b>	<b>90.1%</b>		<b>7.4%</b>	<b>1.4%</b>	<b>12.0%</b>	<b>83.8%</b>		<b>0.0%</b>	<b>0.0%</b>	<b>0.9%</b>	<b>99.1%</b>	

VM = Very Major Error, M = Major Error, m = Minor Error, CA = Category Agreement

Table 4. Error rates for gram-positive organisms by antimicrobial agents

**S. aureus**

	Reference Method				Phoenix					VITEK 2					Disk Diffusion				
	S	I	R	Total	VM	M	m	CA	N	VM	M	m	CA	N	VM	M	m	CA	N
Penicillin			59	59	0	0	0	59	59	0	0	0	59	59	0	0	0	59	59
Oxacillin	24		38	62	0	0	0	62	62	0	0	0	662	62	0	0	0	62	62
Erythromycin	22		40	62	0	0	0	62	62	0	0	1	61	62	0	0	0	62	62
Clindamycin	25		12	37	0	0	0	37	37	1	0	0	36	37	0	0	0	37	37
Gatifloxacin	40	11	11	62	1	0	10	51	62	0	0	7	55	62	0	0	9	53	62
Tetracycline	59		3	62	0	0	0	62	62	0	0	0	62	62	0	0	0	62	62
Nitrofurantoin	62			62	0	0	0	62	62	0	0	0	62	62	0	0	0	62	62
<b>TOTAL</b>	<b>232</b>	<b>11</b>	<b>163</b>	<b>406</b>	<b>1</b>	<b>0</b>	<b>10</b>	<b>395</b>	<b>406</b>	<b>1</b>	<b>0</b>	<b>8</b>	<b>396</b>	<b>406</b>	<b>0</b>	<b>0</b>	<b>9</b>	<b>397</b>	<b>406</b>
<b>FREQUENCY %</b>	<b>57.1%</b>	<b>2.7%</b>	<b>40.0%</b>		<b>0.6%</b>	<b>0.0%</b>	<b>2.5%</b>	<b>97.3%</b>		<b>0.6%</b>	<b>0.0%</b>	<b>2.0%</b>	<b>97.8%</b>		<b>0.0%</b>	<b>0.0%</b>	<b>2.2%</b>	<b>97.8%</b>	

**CNS**

	Reference Method				Phoenix					VITEK 2					Disk Diffusion				
	S	I	R	Total	VM	M	m	CA	N	VM	M	m	CA	N	VM	M	m	CA	N
Penicillin	3		41	44	0	2	0	42	44	0	1	0	42	43	0	0	0	44	44
Oxacillin	22		27	49	0	0	0	49	49	0	1	0	48	49	1	0	0	48	49
Clindamycin	32		17	49	1	0	0	47	48	1	0	0	48	49	0	0	1	48	49
Gatifloxacin	33	4	12	49	0	0	4	45	49	0	0	3	46	49	0	0	3	46	49
Tetracycline	28		3	31	0	26	0	5	31	0	0	0	31	31	0	0	0	31	31
Vancomycin	48			48	0	0	0	48	48	0	0	0	48	48	0	0	0	48	48
Nitrofurantoin	49			49	0	0	0	49	49	0	0	0	49	49	0	0	0	49	49
<b>TOTAL</b>	<b>215</b>	<b>4</b>	<b>100</b>	<b>319</b>	<b>1</b>	<b>28</b>	<b>4</b>	<b>285</b>	<b>318</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>312</b>	<b>318</b>	<b>1</b>	<b>0</b>	<b>4</b>	<b>314</b>	<b>319</b>
<b>FREQUENCY %</b>	<b>67.4%</b>	<b>1.3%</b>	<b>31.3%</b>		<b>1.0%</b>	<b>13.0%</b>	<b>1.3%</b>	<b>89.3%</b>		<b>1.0%</b>	<b>0.9%</b>	<b>0.9%</b>	<b>97.9%</b>		<b>1.0%</b>	<b>0.0%</b>	<b>1.3%</b>	<b>98.4%</b>	

**Enterococcus spp.**

	Reference Method				Phoenix					VITEK 2					Disk Diffusion				
	S	I	R	Total	VM	M	m	CA	N	VM	M	m	CA	N	VM	M	m	CA	N
Penicillin	29		30	59	0	1	0	58	59	1	0	0	58	59					
Ampicillin	31	0	28	59	0	1	0	58	59	0	0	0	59	59	0	0	0	59	59
Erythromycin	1	8	36	45	0	0	1	44	45	0	0	2	43	45					
Tetracycline	24		28	52	1	0	1	50	52	0	0	0	52	52					
Vancomycin	14	1	36	51	0	0	1	50	51	1	0	2	48	51	0	0	2	49	51
Nitrofurantoin	16	0	0	16	0	0	0	16	16	0	0	0	16	16	0	0	0	16	16
<b>TOTAL</b>	<b>115</b>	<b>9</b>	<b>158</b>	<b>282</b>	<b>1</b>	<b>2</b>	<b>3</b>	<b>276</b>	<b>282</b>	<b>2</b>	<b>0</b>	<b>4</b>	<b>276</b>	<b>282</b>	<b>0</b>	<b>0</b>	<b>2</b>	<b>124</b>	<b>126</b>
<b>FREQUENCY %</b>	<b>40.8%</b>	<b>3.2%</b>	<b>56.0%</b>		<b>0.6%</b>	<b>1.7%</b>	<b>1.1%</b>	<b>97.9%</b>		<b>1.3%</b>	<b>0.0%</b>	<b>1.4%</b>	<b>97.9%</b>		<b>0.0%</b>	<b>0.0%</b>	<b>1.6%</b>	<b>98.4%</b>	

VM = Very Major Error, M = Major Error, m = Minor Error, CA = Category Agreement

Table 5. Time required for generation of susceptibility results

Gram-negatives	Phoenix	VITEK 2
<i>Enterobacteriaceae</i>	11:58:11 <sup>a</sup>	7:35:31 <sup>a</sup>
<i>Pseudomonas</i> spp.	15:39:04 <sup>a</sup>	11:45:53 <sup>a</sup>
Non- <i>Enterobacteriaceae</i>	12:32:24 <sup>a</sup>	9:06:06 <sup>a</sup>
Gram-positives	Phoenix	VITEK 2
<i>S. aureus</i>	13:02:21 <sup>b</sup>	7:05:29 <sup>b</sup>
CNS	14:43:36 <sup>b</sup>	9:32:11 <sup>b</sup>
<i>Enterococcus</i> spp.	12:22:21 <sup>b</sup>	9:38:00 <sup>b</sup>

<sup>a</sup> p<0.05 ; <sup>b</sup> p<0.05

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Table 6. Comparison of MICs generated by instrument and reference methods

Organism Group	Total # MICs	% On scale MICs	% Strains with on scale MICs within +/- 1 dilution of Reference		
			# strains on scale	# strains +/-1	%EA <sup>a</sup>
<i>Enterobacteriaceae</i>					
Phoenix	1683	13.5%	228	186	81.6
Vitek 2	1989	13.4%	266	206	77.4
<i>Pseudomonas</i> spp.					
Phoenix	385	30.9%	119	116	97.5
Vitek 2	550	24.9%	137	131	95.6
Non <i>Enterobacteriaceae</i>					
Phoenix	192	13.0%	25	23	92.0
Vitek 2	384	19.3%	74	61	82.4
<i>S. aureus</i>					
Phoenix	558	17.6%	98	96	98.0
Vitek 2	496	8.3%	41	39	95.1
CNS					
Phoenix	294	23.8%	70	60	85.7
Vitek 2	392	18.9%	74	70	94.6
<i>Enterococcus</i> spp.					
Phoenix	354	20.9%	74	71	95.0
Vitek 2	472	19.9%	94	84	89.3
<b>Overall Average</b>					
<b>Phoenix</b>					<b>91.5</b>
<b>Vitek 2</b>					<b>89.1</b>

<sup>a</sup> Percent of MICs that agree within 1 twofold dilution

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Table 7. Technical time required for test setup and recovery of results

TECH 1				
	Phoenix	Vitek 2	Disk Diffusion	
1. Initial Prep Time	3:52	0:30	Set up	10:12:55
2. Prepare McFarlands	6:15	3:36	Read & record	8:54:50
3. Inoculate panels, check plates	4:28	3:22		
4. Load Instrument	2:03	0:05		
<b>total</b>	<b>16:38</b>	<b>7:33</b>		<b>19:07:45</b>
<b>total/test</b>	<b>2:46</b>	<b>1:15</b>		<b>3:11</b>
TECH 2 (2 Phoenix runs)				
	Phoenix (run1)	Vitek 2	Disk Diffusion	
1. Initial Prep Time	5:35	0:30	Set up	8:50:23
2. Prepare McFarlands	11:29		Read & record	8:24:00
3. Inoculate panels, check plates	4:47	7:11 (2&3)		
4. Load Instrument	3:19	0:08		
<b>total</b>	<b>25:10</b>	<b>7:49</b>		<b>17:14:23</b>
<b>total/test</b>	<b>4:11</b>	<b>1:18</b>		<b>2:52:24</b>
	Phoenix (run2)			
	4:20			
	10:50			
	4:23			
	2:14			
<b>total</b>	<b>21:47</b>			
<b>total/test</b>	<b>3:37</b>			
OVERALL AVERAGE				
	Phoenix	Vitek 2	Disk Diffusion	
	16:38			
	25:10	7:33		19:07:45
	21:47	7:49		17:14:23
<b>average</b>	<b>19:12:30</b>	<b>7:41</b>		<b>18:11:04</b>
<b>average/test</b>	<b>3:12</b>	<b>1:16</b>		<b>3:01</b>

Table 9. Subjective assessment of the advantages and disadvantages of the VITEK 2

**PROS**

- Foil pouch containing the card is easy to open.
- Supplies are more compact and do not require as much storage space.
- Card setup is quick and smart carrier is user friendly.
- Volume of inoculum does not need to be kept constant during adjustment to a 0.5 McFarland standard.
- VITEK 2 photometer reads the inoculum density more quickly.
- Card straw can be used to streak purity check plate.
- Disposable supplies, e.g. saline and plastic tubes, can be purchased from any vendor and are not specific to the VITEK 2.
- The VITEK 2 setup procedure produces less bio-hazardous and paper waste.
- Identification reports will print automatically if there is an acceptable identification.
- Susceptibility reports print automatically when review is not required.
- Removing completed cards is less time consuming.
- Daily maintenance is easy to perform.
- Modem is available on the VITEK 2 for assistance from instrument services.

**CONS**

- Cards must be stored in the refrigerator.
- Beta-lactamase result must be entered on gram-positive susceptibility cards.
- Some susceptibility results must be "expertized" in the computer before the results can be finalized and printed.
- VITEK 2 reports are more difficult to interpret.
- Monthly maintenance is labor intensive.
- Saline and tips must be changed monthly or when low.
- Saline pump dispenser can become contaminated.
- Printer uses perforated paper that requires more time to tear apart.

Table 8. Subjective assessment of the advantages and disadvantages of the Phoenix

**PROS**

- Off-line testing does not need to be performed.
- Panels can be stored at room temperature.
- No monthly cleaning of instrument required.
- No saline bag or tips to change.
- Printer uses computer paper without perforations to tear.
- Report printouts are easier to interpret.

**CONS**

- Panel packages can be difficult to open. Rarely, the foil can cause cuts.
- Supplies are bulky and require a large amount of storage space.
- The bulk of the supplies creates a large volume of bio-hazardous and paper waste.
- Each panel must be marked as critical when entering data into the computer in order to get an automatic printout of the identification. Final results do not print automatically and must be printed using icons on the computer screen.
- ID broth needs a constant volume when adjusting inoculum to a 0.5 McFarland standard. ID broth must be added and then removed to keep the volume constant during the adjustment.
- Panel snap caps can get caught when the reader rotates.
- Panels are entered into the system using both the keys on the keyboard and buttons on the instrument panel. This can make the process confusing.
- Inoculating loop must be used to inoculate the purity check plate.
- Pipette must be used to inoculate AST broth.
- AST Indicator solution must be added to the AST broth. AST indicator solution must be refrigerated.
- Screwing and unscrewing the ID broth and AST broth is repetitive and time consuming.
- Snapping the plastic cap onto the panel can create a safety hazard due to the splash from inoculum.
- AST broth tubes do not fit properly in the setup tray and can fall out.
- Phoenix inoculum adjustment photometer takes longer to take a reading.
- Daily quality control takes longer than VITEK 2.
- Removing the completed panels is more time consuming than VITEK 2.

**CONCLUSION**

- Both instrument systems and the disk method produced very similar overall susceptibility category agreements, i.e., 95.3% for Phoenix, 95.1% for VITEK 2, and 94.7% for disk diffusion. These overall error rates are within the allowed rates proposed in the draft ISO global document on acceptable performance of susceptibility test devices (6).
- With regard to interpretive errors, the Phoenix had 1.8% Major errors, primarily with gram-positive organisms (30/36) of which 26 were the result of a tetracycline expert rule rather than provision of an MIC result. VITEK 2 had 9% Very Major errors with *P. aeruginosa* and piperacillin/tazobactam.
- The VITEK 2 required the least technical time per test (1.3 min), and provided the earliest results (mean of 9.1 hours). These results are consistent with the earlier findings of Eigner, et al (4).