Original Article

Comparison of Hospitalwide and Custom Antibiograms for Clinical Isolates of *Pseudomonas aeruginosa*

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Abstract

Background: Hospital antibiograms, which are commonly used to determine empiric antibiotic therapy and as a tool in stewardship in a given institution, are open to bias when combining susceptibility results from various sources, hospital locations, and patient groups.

Methods: We assessed such differences, using *Pseudomonas aeruginosa* as a test case, with susceptibility data from 2008 through 2010 in our institution. Each year's data were analyzed separately. A variety of specific or subcategorical antibiograms were compared with each other as well as with versions including all tested isolates and those with results from inpatients and outpatients only. Statistical significance was determined at the .01 level using either chi-square or Fisher exact test, and clinical significance was defined as ≥ 10 percentage points.

Results: A variety of clinically significant differences were found that illustrated important differences within the intensive care unit environment and based on population, specifically adult versus pediatric. Concordance between statistically significant and clinically significant differences was poor.

Conclusion These results corroborate and extend previous similar observations and point to the potential importance of subanalyses in preparing the annual hospital antibiogram.

Key Words—antibiogram, antibiotic, bacterial susceptibility

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The use of antibiograms to help select empirical antibiotic therapy for suspected infection with likely or known pathogens is a well-established practice.^{1,2} However, it has been the subject of some debate whether assembled antibiograms based upon published standards are optimal in this regard. According to current standards, antibiograms are prepared by including all tested isolates (excluding duplicates from the same patient and surveillance cultures) for a specific time period.¹ However, this approach would include testing results from diverse populations and locations within the institution, and important differences for distinct patient groups or location could be masked within the overall summary numbers. Hospital antibiograms could be limited to inpatient isolates only, but even then they may include susceptibility results from both adult- and pediatric-derived isolates. The Clinical

and Laboratory Standards Institute (CLSI) guideline in this regard suggests that institutions may wish to consider and/or prepare subanalyses or custom antibiograms to address this issue. It has been shown that unit-specific antibiograms can vary substantially from hospitalwide (inclusive of all inpatient and/or outpatient isolates) summaries. Further, we have illustrated that inclusion of isolates from specific populations (ie, *Pseudomonas aeruginosa* isolates from cystic fibrosis patients) can skew the hospitalwide susceptibility numbers in a misleading way.³ As one considers the diversity of isolates, it becomes clear that they vary by patient group, hospital location, and source. All of these observations beg the question as to whether hospitalwide antibiograms suffer in their intent to inform the clinician due to the heterogeneity of sources. Further, if they have this limitation, what is the potential extent

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that any subanalysis might vary from the hospital's overall or hospitalwide antibiogram?

A number of studies have noted that inappropriate empiric therapy has been linked to increased morbidity and mortality,^{4,6} including some therapy specifically focusing on infections with *P. aeruginosa*,⁷⁻⁹ and it is therefore important that the most relevant susceptibility data be supplied to clinicians to guide their empirical treatment decisions. It was the purpose of the present study to investigate the degree of variance from a hospitalwide antibiogram to more targeted antibiograms for specific units, patient populations, or specific sources.

MATERIALS AND METHODS

The Medical University of South Carolina Medical Center is a 709-bed health care facility that is designated as a level 1 trauma center. It comprises 5 inpatient facilities including 2 adult hospital buildings and a children's hospital that includes an additional 50 neonatal special care beds. Some of these facilities are physically connected as contiguous space. Annual admissions exceed 34,000, and annual outpatient visits exceed 950,000. The study was approved by the Medical University's institutional review board.

The current analysis utilized susceptibility results for all tested *P. aeruginosa* isolates evaluated by our Clinical Microbiology Laboratory for the years 2008 through 2010. This organism was selected for study in this exercise as it is a common nosocomial pathogen. Susceptibility was determined by disk diffusion in compliance CLSI standards for those years.^{10,11} Tested antibiotics of interest included piperacillin/tazobactam, cefepime, ceftazidime, imipenem, meropenem, ciprofloxacin, levofloxacin, amikacin, gentamicin, and tobramycin. Susceptibility data were available for each of these drugs for all 3 years, except for ceftazidime and imipenem which were not available for 2010. A variety of annual antibiograms were assembled and, in all cases, no duplicates or surveillance isolates were included. An antibiogram that included all tested isolates from both inpatient and outpatients was constructed as were versions that included inpatient or outpatient isolates only. The latter included both adult and pediatric isolates from all sources, which is consistent with current practice within many institutions for the production of annual antibiograms. Where the number of isolates in a category or subcategory permitted (ie, ≥ 15 per year), more exclusive antibiograms (subcategories) were prepared including adult inpatient, pediatric inpatient, all adult intensive care units (combined), all pediatric intensive care units

(combined), the adult medical intensive care unit (MICU), and the surgical trauma intensive care unit (STICU). Lastly, a number of additional subcategorical antibiograms were constructed based on isolate source. These were created separately for adult and pediatric classes and included blood, lower respiratory, urine, and "other"; these were further divided into inpatient and outpatient isolates. Results for these various versions were compared, but the main analysis contrasted the various subcategories with the inpatient antibiogram. In total, 496 comparisons were made. In 5 of these, the number of organisms in a given subcategory was less than 30; although none was associated with statistical or clinically significant differences, they were not considered further.

Comparisons of rates of susceptibility to the tested antibiotics were compared among the various antibiograms using chi-square or Fisher exact test, as appropriate. Significance was determined at $P = .01$ as a conservative estimate of significance due to the multiple comparisons being made. Each annual antibiogram was assessed separately in relation to that year's subcategory antibiograms. Antibiograms from 3 separate years were examined (within that year) to determine whether the types of differences found were consistent from year to year. In addition to the statistical analysis, a determination of clinical significance was also made, with a difference in susceptibility rate of $\geq 10\%$ being considered important/significant. This level was chosen as it was believed that it would be sufficient to alter a clinician's choice of empiric coverage when considering an institution's antibiogram.

RESULTS

The results of the statistical comparison of subcategories to the all inpatient antibiograms for each year of interest are presented in **Table 1**. Only results for those antibiotics for which all 3 years of data were available are included. Although few statistically significant differences were found, many clinically significant observations were apparent (**Table 2**). The most frequently detected differences were found in comparing the MICU results to those of the total inpatient (adult and pediatric isolates/all sources) antibiogram or the adult inpatient (adult only/all sources) antibiogram. There were also several instances in which results from this ICU varied from those for all adult ICUs combined. A sufficient number of isolates for analysis was only available in 2010 for the STICU. Results from comparisons of that unit to other subcategories yielded a variety of clinically significant differences, including with the MICU and the inpatient antibiograms. Susceptibility

Table 1. Comparison of differences in % susceptibility of inpatient subcategories to full inpatient antibiogram^a

Year and category	Antibiotic								
	TZP	ATM	FEP	MEM	CIP	LVX	AMK	GEN	TOB
2008									
All outpatient	6.1 / .0163	14.9 / .0008	9.9 / .0018	6.1 / .0313	7.7 / .0776	5.6 / .3298	7.7 / .0207	4.5 / .2321	1.7 / .5592
Adult inpatient	0.1 / .9626	0.3 / .9355	0.6 / .8446	0.5 / .8437	2.6 / .5065	3.1 / .5935	0.4 / .8764	1.0 / .7397	0.4 / .8764
Pediatric inpatient	0.9 / .7450	2.7 / .7606	5.0 / .5933	4.4 / .7553	21.4 / .0096	23.2 / .0706	3.3 / .7520	8.5 / .2795	3.3 / .7520
All adult ICU	4.0 / .3532	4.7 / .4993	3.5 / .5021	7.3 / .1252	6.7 / .3176	3.9 / .6991	1.2 / .7935	5.0 / .3499	6.6 / .1484
MICU	17.6 / .0283	26.2 / .0190	6.4 / .5032	15.5 / .0585	30.0 / .0056	26.1 / .1362	11.3 / .1236	27.1 / .0061	27.1 / .0026
Blood ^b	4.0 / 1.0000	12.7 / .2253	5.1 / .7495	6.1 / .7091	13.6 / .1755	8.0 / .7579	0.2 / 1.0000	5.5 / .7499	0.2 / .9724
Lower respiratory ^b	2.5 / .4248	2.6 / .5929	1.0 / .7810	4.1 / .2321	2.0 / .6757	3.9 / .5652	5.9 / .0779	7.4 / .0615	5.2 / .1201
Urine ^b	1.0 / .7751	1.6 / .7731	0.2 / .9645	4.1 / .2576	1.0 / .8519	3.7 / .6661	6.4 / .0530	7.2 / .0787	6.4 / .0530
Other source ^b	2.2 / .5519	9.4 / .4703	9.6 / .9524	4.8 / 1.0000	6.1 / .8197	3.9 / .8861	12.7 / .3977	9.9 / .3450	0.9 / .7801
2009									
All outpatient	5.7 / .0103	13.8 / .0002	4.9 / .0301	5.8 / .0263	6.3 / .0791	4.0 / .2861	2.0 / .4569	1.5 / .5990	4.1 / .0934
Adult inpatient	1.4 / .6124	1.9 / .6429	1.4 / .6124	1.4 / .6435	2.7 / .4871	3.1 / .4388	0.6 / .8119	1.1 / .7228	0.7 / .7979
Pediatric inpatient	9.9 / .0555	13.8 / .0970	9.9 / .0555	10.1 / .0978	19.6 / .0109	22.5 / .0014	4.7 / .5521	7.9 / .2804	5.1 / .5532
All adult ICU	3.9 / .2467	1.1 / .8312	0.1 / .9658	0.7 / .8386	1.4 / .7692	1.7 / .7266	5.7 / .0623	4.0 / .2608	1.1 / .7401
MICU	10.5 / .0328	11.4 / .1172	2.4 / .6163	9.4 / .0849	13.3 / .0534	10.4 / .1420	0.4 / .9335	4.6 / .3993	9.8 / .0574
Blood	7.8 / .3992	9.7 / .4037	1.9 / .8028	4.6 / .4827	9.9 / .3961	6.9 / .5837	4.7 / 1.0000	2.0 / 1.0000	0.7 / .9255
Lower respiratory	1.7 / .5934	1.1 / .8226	2.5 / .4444	3.2 / .3857	1.7 / .7167	0.5 / .9111	6.5 / .0674	7.1 / .0665	3.1 / .3661
Urine	0.3 / .9452	2.3 / .6945	0.9 / .8008	1.0 / .8059	4.7 / .3957	4.2 / .4641	3.4 / .3644	1.7 / .6835	1.0 / .7970
Other	0.5 / .1937	4.6 / .1750	3.1 / .0353	1.7 / .1175	8.0 / .0221	5.8 / .1343	10.8 / .0400	12.3 / .0037	5.0 / .0356
2010									
All outpatient	3.4 / .1661	12.9 / .0009	2.3 / .4032	3.9 / .1442	0.0 / .9931	1.9 / .6400	5.6 / .0631	3.6 / .3109	2.7 / .2083
Adult inpatient	0.9 / .7328	2.5 / .5384	1.1 / .7063	1.2 / .7011	2.1 / .5827	2.6 / .5214	1.0 / .7220	1.7 / .6302	0.8 / .7615
Pediatric inpatient	5.4 / .7072	22.8 / .0218	7.3 / .2882	7.6 / .4905	17.3 / .0565	22.9 / .0155	6.1 / .7132	13.2 / .1425	3.5 / 1.000
All adult ICU	0.2 / .9682	6.5 / .2950	3.1 / .4540	2.0 / .6251	3.3 / .5396	1.8 / .7497	6.2 / .1058	7.6 / .1160	0.8 / .8232
MICU	7.5 / .2044	9.9 / .2871	2.2 / .7605	1.9 / .7647	6.0 / .4645	3.8 / .6641	3.5 / .7510	3.7 / .7971	6.0 / .2852
Blood	13.4 / .1393	14.7 / .2680	11.5 / .1984	3.5 / .6619	13.9 / .3134	19.5 / .1181	10.4 / .3759	5.6 / .7081	0.1 / 1.0000
Lower respiratory	0.8 / .7952	2.2 / .6625	1.9 / .5713	1.6 / .6493	0.2 / .9703	1.4 / .7789	5.4 / .1241	5.1 / .2296	3.5 / .2562
Urine	4.4 / .2366	3.2 / .5994	4.9 / .2210	1.2 / .7613	3.7 / .4982	4.8 / .4183	3.7 / .3263	1.5 / .7552	3.8 / .2497
Other	4.3 / .7931	11.2 / .8194	1.3 / .8535	0.5 / .4955	2.5 / .7001	7.8 / .3921	11.7 / .2796	16.8 / .0205	0.8 / .5486

Note: Values shown are difference / P. Bold indicates statistical significance; $P \leq .01$. AMK = amikacin; ATM = aztreonam; CIP = ciprofloxacin; FEP = cefepime; GEN = gentamicin; ICU = intensive care unit; LVX = levofloxacin; MEM = meropenem; MICU = medical intensive care unit; TOB = tobramycin; TZP = piperacillin/tazobactam.

^aAll inpatient results including adult and pediatrics, ICU and non-ICU, and all sources.

^bInpatient isolates only.

rates from the adult inpatient antibiogram often differed, in a clinically significant manner, from the pediatric inpatient version.

The antibiotics associated with the greatest number of clinically significant differences were the fluoroquinolones, whereas those with the least number were the

Table 2. Clinically significant differences in percent susceptible^{a,b}

Year and comparison	Antibiotic										
	TZP	ATM	FEP	CAZ	IPM	MER	CIP	LVX	AMK	GEN	TOB
2008											
Pediatric inpatient to all inpatient								-21.4			
Adult inpatient to pediatric inpatient							-24.3	-23.2			
MICU to all adult ICU	-13.6	-21.5								-22.1	-20.4
MICU to adult inpatient	-17.7	-22.9			-17.5	-14.9	-27.4		-10.9	-26.1	-26.6
MICU to all inpatient	-17.6	-26.2		-10.3	-18.4	-15.5	-30.0	-26.2	-11.3	-27.1	-27.0
Inpatient blood to all inpatient		12.7					13.6				
Outpatient lower respiratory to all outpatient							-16.1				
Outpatient other to all outpatient							14.3	14.4	13.6		
2009											
Pediatric inpatient to all inpatient		13.6						-22.5			
Adult inpatient to pediatric inpatient	-11.2	-15.7	-11.2	-16.0	-13.2	-11.6	-22.2	-25.6			
MICU to all adult ICU					-15.7		-12.0				
MICU to adult inpatient		-10.4			-16.9	-14.9	-10.7				
MICU to all inpatient	-10.5	-11.5			-18.5	-15.5	-13.4	-10.4			
Inpatient blood to all inpatient					-20.3						
Inpatient other to all inpatient					14.0					13.8	
Outpatient urine to all outpatient							-10.5				
Outpatient other to all outpatient							11.8	15.2			
2010											
Inpatient to outpatient		-12.9									
Pediatric inpatient to all inpatient							17.3				
Adult inpatient to pediatric inpatient		-25.3					-19.4	-25.5		-14.9	
MICU to STICU	-17.2		-13.8				-16.5	-19.9		-13.8	-13.8
STICU to all adult ICU		10.2									
STICU to all inpatient			12.7								
Outpatient lower respiratory to all outpatient								-14.7	-16.3		

Note: Bold indicates statistical significance; $P \leq .01$. AMK = amikacin; ATM = aztreonam; CAZ = ceftazidime; CIP = ciprofloxacin; FEP = cefepime; GEN = gentamicin; IPM = imipenem; LVX = levofloxacin; MEM = meropenem; MICU = medical intensive care unit; STICU = surgical trauma intensive care unit; TOB = tobramycin; TZP = piperacillin/tazobactam.

^aAbsolute or numerical difference.

^bOnly those comparisons with one or more clinically significant differences for a given year are displayed; no result/data indicates a difference $<10\%$.

cephalosporins. Statistically or clinically significant differences were not consistent from one antibiotic to the next nor were they consistent from year to year. Further, there was poor concordance between statistical and clinical significance (Table 2).

DISCUSSION

The CLSI provides guidance for the construction (what data to include) and dissemination (to whom and how often) of antibigrams. Regardless, antibigrams present data that may be useful in making for-

mulary decisions and setting antimicrobial use policies or in the analysis of antimicrobial use-resistance relationships. Information provided by antibigrams can be key to many antimicrobial stewardship initiatives and have been listed as a minimum requirement for such programs in a recently published policy statement.¹² However, the main use is undoubtedly as a guide to empiric antibiotic selection. As the selection of appropriate initial therapy is of paramount importance in a variety of serious infections, it is vital that that information presented in the antibigram be reliable for

that purpose. In following CLSI guidance, an institution could prepare an antibiogram reflecting all tested isolates for the period of interest (excepting duplicates and surveillance specimens). However, by combining susceptibility results from all locations, patient populations, and sources, important distinctions or differences that exist for subcategories may be masked. Such differences have been well described, and a number of reports have been published that point out potential pitfalls of combining all tested isolates into one hospitalwide antibiogram.¹³⁻¹⁵

Several studies have illustrated differences between antibiograms reflecting isolates from patients in ICUs to hospitalwide versions.¹⁶⁻¹⁹ Our results are consistent with this observation. This is actually quite predictable as numerous studies have documented higher levels of antibiotic use with resultant higher rates of resistance in the ICU environment.²⁰⁻²⁵ In a report from Project ICARE, Fridkin and colleagues illustrated higher resistance rates in ICU compared to non-ICU settings, which, in turn, exhibited higher rates than in isolates from outpatients.²⁶ Moreover, important differences may exist in different ICUs in the same hospital as noted here and by others.¹⁸ We have previously reported the consequences of including cystic fibrosis-derived isolates of *P. aeruginosa* with all others on the hospitalwide rates of susceptibility.³ This practice produces a lower susceptibility rate than one would find if such isolates were excluded or analyzed separately. Another valid question would be whether an antibiogram constructed solely with documented infection-associated isolates would vary from the typical hospitalwide antibiogram, which is typically based upon all tested isolates. It stands to reason that such antibiograms could be quite different. However, a study of this issue with infection-based data from ICU patients found no important differences from the hospitalwide antibiogram except in the case of methicillin-resistant *Staphylococci*.²⁷ At the same time, a different report comparing the hospitalwide antibiogram to one including only isolates associated with hospital-acquired infections described a variety of important differences in resistance rates with a number of organisms.²⁸

We have taken these observations another step, albeit with only one organism, and have shown that not only do differences exist when comparing inpatient versus outpatient and ICU versus hospitalwide, but that distinctions in pediatric versus adult (or hospitalwide) and specific source versus hospitalwide may also be considerable and clinically relevant. Our results corroborate those of previous investigations described previously. A number of specific findings merit further

discussion. Pediatric and adult inpatient results were often clinically significantly different such that combining results from these 2 population groups would be unwise. Clinically significant differences were seen with all drugs over all years, but the comparisons that differed varied from drug to drug and year to year. For example, the MICU versus all inpatient antibiogram differences seen in 2008 and 2009 were not seen in 2010. This would indicate that such comparative analyses need to be performed on a yearly basis.

Several issues should be appreciated in weighing our results and their potential implications. This was a single-center analysis, and our results may not be consistent or relevant to those of other institutions. Also, we limited our assessment to one pathogen, *P. aeruginosa*, and a select group of antibiotics, so our findings might not apply to other organisms and/or drugs. As an example, no clinically significant differences were seen in comparing urine isolates to those of other antibiogram categories. This would be a less likely finding if a more common urinary pathogen were assessed. We chose to study *P. aeruginosa* because it is a common cause of nosocomial infections and is well known to have multiple resistance mechanisms affecting susceptibility to several classes of antibiotics. For these reasons, it appeared to be an appropriate representative pathogen with which to test our hypothesis. However, it may represent a worst case scenario, and other common pathogens should be considered and analyzed as well. Our definition of clinical significance could certainly be questioned. Choosing one value is, at best, an oversimplification; the magnitude of difference that would influence empiric antibiotic choices varies from clinician to clinician and would likely be influenced by type of infection and other factors. Other issues should also be kept in mind in interpreting our findings. One could certainly pose the question of whether our results would apply similarly to hospital- and community-acquired infections/pathogens. As dates of admission and organism isolation were not considered, we are unable to answer this logical question. Other investigators have illustrated that pathogens involved in hospital-acquired infections may have higher resistance rates.^{27,28} Lastly, a small number (5) of comparisons involved subcategories with between 15 and 29 isolates, whereas the current CLSI guidance requires a minimum of 30. As already noted, none of these 5 instances were associated with statistically or clinically significant differences and therefore had no bearing on our conclusions.

Our results would suggest that more specific antibiograms, based upon location, patient type, or

source, may provide better guidance for empiric therapy decisions based on those subgroups, assuming considerable diversity in these variables and adequate numbers of tested organisms. Institutions would be well advised to perform and assess subanalyses, as suggested in CLSI guidance, to determine what antibiogram information or format best informs its clinicians in making empiric antibiotic prescribing decisions.

REFERENCES

1. Clinical and Laboratory Standards Institute (CLSI). *Analysis and Presentation of Cumulative Antimicrobial Susceptibility Test Data*. 3rd ed. Approved guideline M30-A3. Wayne, PA: CLSI; 2009.
2. Goldmann DA, Weinstein RA, Wenzel RP, et al. Strategies to prevent and control the emergence and spread of antimicrobial-resistant microorganisms in hospitals. *JAMA*. 1996;275:234-240.
3. Bosso JA, Mauldin PD, Steed LL. Consequences of combining cystic fibrosis- and non-cystic fibrosis-derived *Pseudomonas aeruginosa* antibiotic susceptibility results in hospital antibiograms. *Ann Pharmacother*. 2006;40:1946-1949.
4. Fraser A, Paul M, Almanasreh N, et al. TREAT Study Group. Benefit of appropriate empirical antibiotic treatment: thirty-day mortality and duration of hospital stay. *Am J Med*. 2006;119:970-976.
5. Ibrahim EH, Sherman G, Ward S, et al. The influence of inadequate antimicrobial treatment of bloodstream infections on patient outcomes in the ICU setting. *Chest*. 2000;118:146-155.
6. Kollef MH, Sherman G, Ward S, et al. Inadequate antimicrobial treatment of infections: a risk factor for hospital mortality among critically ill patients. *Chest*. 1999;115:462-474.
7. Kang C, Kim A, Kim H, et al. *Pseudomonas aeruginosa* bacteremia: risk factors for mortality and influence of delayed receipt of effective antimicrobial therapy on clinical outcome. *Clin Infect Dis*. 2003;37:745-751.
8. Lodise TP Jr, Patel N, Kwa A, et al. Predictors of 30-day mortality among patients with *Pseudomonas aeruginosa* bloodstream infections: impact of delayed appropriate antibiotic selection. *Antimicrob Agents Chemother*. 2007;51:3510-3515.
9. Micek ST, Lloyd AE, Ritchie DJ, et al. *Pseudomonas aeruginosa* bloodstream infection: importance of appropriate initial antimicrobial treatment. *Antimicrob Agents Chemother*. 2005;49:1306-1311.
10. Clinical and Laboratory Standards Institute (CLSI). *Performance Standards for Antimicrobial Disk Susceptibility Tests*. 9th ed. Approved standard M02-A9. Wayne, PA: CLSI; 2008.
11. Clinical and Laboratory Standards Institute (CLSI). *Performance Standards for Antimicrobial Disk Susceptibility Tests*. 10th ed. Approved standard M02-A10. Wayne, PA: CLSI; 2009.
12. Society for Healthcare Epidemiology of America, Infectious Diseases Society of America, Pediatric Infectious Diseases Society. Policy statement on antimicrobial stewardship by the Society for Healthcare Epidemiology of America (SHEA), the Infectious Diseases Society of America (IDSA), and the Pediatric Infectious Diseases Society (PIDS). *Infect Control Hosp Epidemiol*. 2012;33:322-327.
13. Flaherty JP, Weinstein RA. Nosocomial infection caused by antibiotic-resistant organisms in the intensive-care unit. *Infect Control Hosp Epidemiol*. 1996;17:236-248.
14. Itokazu GS, Quinn JP, Bell-Dixon C, et al. Antimicrobial resistance rates among aerobic gram-negative bacilli recovered from patients in intensive care units: evaluation of a national postmarketing surveillance program. *Clin Infect Dis*. 1996;23:779-784.
15. Monnet DL, Archibald LK, Phillips L, et al. Antimicrobial use and resistance in US hospitals: complexities of analysis and modeling. *Infect Control Hosp Epidemiol*. 1998;19:388-394.
16. Binkely S, Fishman NO, LaRosa LA, et al. Comparison of unit-specific and hospital-wide antibiograms: potential implications for selection of empirical antimicrobial therapy. *Infect Control Hosp Epidemiol*. 2006;27:682-687.
17. Kaufman D, Haas CE, Edinger R, et al. Antibiotic susceptibility in the surgical intensive care unit compared with the hospital-wide antibiogram. *Arch Surg*. 1998;133:1041-1045.
18. Namias N, Samiian L, Nino D, et al. Incidence and susceptibility of pathogenic bacteria vary between intensive care units within a single hospital: implications for empiric antibiotic strategies. *J Trauma*. 2000;49:638-646.
19. White RL, Friedrich LV, Mihn LB, et al. Assessment of the relationship between antimicrobial usage and susceptibility: differences between the hospital and specific patient-care areas. *Clin Infect Dis*. 2000;31:16-23.
20. Archibald L, Phillips L, Monnet D, et al. Antimicrobial resistance in isolates from inpatients and outpatients in the United States: increasing importance of the intensive care unit. *Clin Infect Dis*. 1997;24:211-215.
21. Bryce EA, Smith JA. Focused microbiological surveillance and gram-negative β -lactamase-mediated resistance in an intensive care unit. *Infect Control Hosp Epidemiol*. 1995;16:331-334.
22. Gaynes R, Monnet D. The contribution of antibiotic use on the frequency of antibiotic resistance in hospitals: antibiotic resistance: origins, evolution, selection, and spread. *Ciba Found Symp*. 1997;207:47-60.
23. Pierson CL, Friedman BA. Comparison of susceptibility to β -lactam antimicrobial agents among bacteria isolated from intensive care units. *Diagn Microbiol Infect Dis*. 1992;15:19S-30S.
24. Stratton CW, Ratner H, Johnston PE, et al. Focused microbiologic surveillance by specific hospital unit as a sensitive means of defining antimicrobial resistance problems. *Diagn Microbiol Infect Dis*. 1992;15:11S-18S.

25. Stratton CW, Ratner H, Johnston PE, et al. Focused microbiologic surveillance by specific hospital unit: practical application and clinical utility. *Clin Ther.* 1993;15(suppl A):12-20.
 26. Fridkin SK, Steward CD, Edwards JR, et al. Surveillance of antimicrobial use and antimicrobial resistance in US hospitals: project ICARE phase 2. *Clin Infect Dis.* 1999;29:245-252.
 27. Fridkin SK, Edwards JR, Tenover FC, et al. Antimicrobial resistance prevalence rates in hospital antibiograms reflect prevalence rates among pathogens associated with hospital-acquired infections. *Clin Infect Dis.* 2001;33:324-330.
 28. Bantar C, Alcazar G, Franco D, et al. Are laboratory-based antibiograms reliable to guide the selection of empirical antimicrobial treatment in patients with hospital-acquired infections? *J Antimicrob Chemother.* 2007;59:140-143. ■
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