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MINIREVIEW

Reality of Developing a Community-Wide Antibiogram

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Antimicrobial surveillance may be defined as a systematic collection, analysis, and dissemination of data that may be used to identify resistance trends and assess the need for intervention (2). In 1988 the Centers for Disease Control and Prevention published guidelines for evaluation of surveillance systems for antimicrobial resistance (7), and an American Society for Microbiology task force (1) highlighted the importance of performing antimicrobial surveillance through local, national, and global networks. Unfortunately, the recommendations from this task force were not implemented, in part due to lack of funding (6). To this end, however, international as well as more than 21 national programs designed to capture susceptibility data for most clinically significant organisms (e.g., SENTRY and TSN) and 24 programs that focused on specific organisms (e.g., CARE and TRUST), were identified in 1999 through the World Health Organization Antimicrobial Resistance Information Bank (9). These programs may be government (e.g., ICARE and NNIS,), commercial (e.g., TSN), or industry (e.g., ARMp, MYSTIC, PROTEKT, SENTRY, and TRUST) supported. Additional data may be gleaned from postmarketing surveillance studies by pharmaceutical companies who monitor their new antimicrobial for resistance, e.g., MYSTIC (meropenem), SMART (quinupristin-dalfopristin), and ZAP (linezolid). Since testing methods may vary between laboratories and may potentially bias multilaboratory databases, some programs rely on a central laboratory to generate standardized susceptibility data. Quantitative (MIC) rather than qualitative (susceptible, intermediate, and resistant) data and the use of molecular methods, as employed in the MYSTIC and SENTRY programs, generally offer greater value in identifying resistance trends and providing a genetic basis for observed resistance, respectively.

ADVANTAGES OF SURVEILLANCE FOR ANTIMICROBIAL RESISTANCE

Appropriately and continuously collected data can be used to develop yearly antibiograms, detect shifts in susceptibility, and serve as a basis for empirical therapy, formulary decisions, and changes in prescribing and infection control practices. Solid data may be used to develop strategies for intervention by a multidisciplinary task force (5). Although regional, national, and global data may provide a sense of the magnitude of resistance to a given drug, local and/or (preferably) institutional data are generally of greater value to clinicians when managing their patients (8, 12).

Clinical microbiologists have an opportunity to play a key

TABLE 1. Comprehensive survey results from 10 hospitals

Question	No. (%) of respondents
No. of respondents completing questionnaire	10 (100)
Susceptibility testing methodology used	
Routine testing	
Microscan	3 (30)
Pasco	1 (10)
Vitek	6 (60)
S. pneumoniae	
Etest and/or disk diffusion	9 (90)
Pasco	1 (10)
Methodology used to generate antibiogram	
LIS	6 (60)
Automated testing system (Vitek or Microscan)	1 (10)
Both	3 (30)
Party responsible for preparing yearly hospital antibiogram	
Microbiologist	9 (90)
Pharmacist	1 (10)
Antibiogram preparation	
Only the first isolate taken from patient included	
Yes	5 (50)
No	5 (50)
Each organism tested against same antimicrobials	
Yes	10 (100)
No	0 (0)
At least 10 isolates of a given genus and/or species reported	
Yes	10 (100)
No	0 (0)
System in place to alert staff of atypical results	
Yes	9 (90)
No	1 (10)
Antibiogram includes results of manual and automated testing	
Yes	10 (100)
No	0 (0)

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TABLE 2. 2002 Community-wide antibiogram

Organism(s)	No. of isolates tested	% Susceptible to:								
		Aminoglycosides			Cephalosporins					
		Amikacin	Gentamicin	Tobramycin	Cefazolin	Cefepime	Cefotaxime	Ceftazidime	Ceftriaxone	Cefuroxime
Acinetobacter spp.	441	96	38	75	—[a]	46	—	29	13	—
Citrobacter spp.	398	99	90	89	37	97	78	82	79	50
Enterobacter spp.	1,186	99	91	93	—	94	72	77	78	41
E. coli	9,599	100	94	96	88	99	99	97	98	92
Klebsiella spp.	2,777	100	95	95	74	88	97	96	96	83
Proteus mirabilis	2,185	98	74	82	86	99	99	99	99	96
Pseudomonas aeruginosa	1863	90	74	88	—	74	—	82	—	—
Serratia spp.	272	99	95	89		96	73	81	91	
Stenotrophomonas maltophilia	217	—	—	—	—	—	—	56	—	—
Haemophilus influenzae	241	—	—	—	—	—	—	—	—	—
Enterococcus spp.	2,725	—	—	—	—	—	—	—	—	—
S. aureus	7,495	—	86	—	59	—	—	—	—	—
Coagulase-negative staphylococci	1880	—	70	—	26	—	—	—	—	—
S. pneumoniae	495	—	—	—	—	—	—	—	—	60

[a]—, not tested or inappropriate for treatment.

role in their hospitals' surveillance programs and in their communities. Microbiologists must ensure that a standardized method of susceptibility testing is being used with a panel of antimicrobials appropriate for each body site and based on their hospital formulary. They must provide accurate, clear, concise, and timely reports for use in guiding therapy and infection control decisions within the hospital. Although the responsibility for preparation and distribution of annual antibiograms may rest with clinical pharmacists, infectious disease specialists, or perhaps infection control practitioners, microbiologists should, by virtue of the fact that the results are generated from the laboratory, be involved, if not directly responsible, for this task. The microbiologist is also encouraged to take a leadership role in the multidisciplinary approach of compiling local surveillance data and annual antibiogram development. This includes developing and maintaining a monitoring program, enhancing cooperation and communication among health care providers within the community, providing a means of benchmarking and reconciling techniques used among the community laboratories, assessing local patterns of susceptibility, identifying emerging resistance, and conveying these data to the appropriate individuals in order to affect policies in treatment and develop strategies for preventing resistance in their hospitals and communities.

Until recently, hospitals followed their own set of guidelines for abstracting and presenting data in the form of an antibiogram. Formal standardized guidelines to gather data and prepare antibiograms did not exist. In 2001, an NCCLS subcommittee published proposed guidelines for the medical community to use in analyzing and presenting cumulative antimicrobial susceptibility test data. This document (M39-A) (10) provides a standardized means of data extraction for all drugs tested, including primary, specialized (e.g., β-lactamase) results and data verified by using an expert system but excluding surveillance data and separate reflex testing results for more resistant organisms. The guidelines also outline how the data should be presented, i.e., reporting the percent susceptibility for the first isolate from a patient within an analysis period (generally 1 year), inclusive dates that the results were generated, population tested (e.g., inpatient, intensive care unit, or nursing home), specimen source, maximum number of isolates tested (with a minimum of 10 for each organism listed), and separate data for gram-negative, gram-positive, aerobic, and anaerobic organisms and listing drugs alphabetically or by class. Furthermore, the M39A document recommends avoiding selective reporting (cascading), where secondary agents are reported only if the isolate is resistant to the primary agent(s) of a specific drug class. Thus, all isolates stored should be analyzed for the cumulative antimicrobial susceptibility report. If only the isolates resistant to the primary agents were analyzed and reported, this would bias the secondary agents to higher levels of resistance.

DEVELOPMENT OF A CWA

The increasing prevalence of antimicrobial resistance is a concern shared by health care workers around the globe. Although numerous national and international surveillance programs have been introduced to determine trends and assess the magnitude of resistance, we are unaware of published surveillance initiatives to standardize microbiological practices within a community and develop a community-wide antibiogram (CWA).

One of the first steps in developing a CWA is to develop a microbiology network. Over the years we have developed a cooperative spirit within our microbiology community. In fact, the supervisors and directors of the hospital and public health microbiology laboratories meet as a group (Jacksonville Microbiology Users Group) on a regular basis to exchange information, establish a standard of care in the community, and highlight new findings. Likewise, microbiologists meet as a group (Jacksonville Area Microbiology Society) each month for approved continuing education programs and have developed an annual First Coast Infectious Disease/Clinical Microbiology Symposium (www.firstcoastidcm.com) where participants from Florida, Georgia, and other areas of the country gather to hear distinguished speakers discuss timely topics of interest and recommended standards. Previously, one of the

TABLE 2—*Continued*

% Susceptible to:																	
Beta-lactams				Quinolones		Others					Cephalosporins		Lincosamide	Macrolide	Beta-lactams		Glycopeptide
Ampicillin	Ampicillin sulbactam	Piperacillin	Piperacillin-tazobactam	Ciprofloxacin	Levofloxacin	Aztreonam	Imipenem	Nitrofurantoin	Tetracycline	Trimethoprim-sulfamethoxazole	Cefotaxime	Ceftriaxone	clindamycin	erythromycin	Oxacillin	Penicillin	vancomycin
—	59	29	44	36	—	—	99	—	70	59	—	—	—	—	—	—	—
—	62	63	83	84	85	72	100	93	81	78	—	—	—	—	—	—	—
—	28	78	76	92	89	57	100	40	83	88	—	—	—	—	—	—	—
58	63	66	94	92	92	75	100	98	74	82	—	—	—	—	—	—	—
—	71	80	94	95	96	73	99	65	92	90	—	—	—	—	—	—	—
78	85	84	95	68	59	92	99	—	—	60	—	—	—	—	—	—	—
—	—	85	90	66	—	59	85	—	—	—	—	—	—	—	—	—	—
—	—	81	83	94	94	81	87	—	27	96	—	—	—	—	—	—	—
—	—	27	35	32	—	—	—	—	—	94	—	—	—	—	—	—	—
79	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
73	—	—	—	52	48	—	—	98	32	—	—	—	—	—	—	92	90
—	—	—	—	54	49	—	—	98	95	97	—	—	62	41	59	10	100
—	—	—	—	41	30	—	—	97	86	56	—	—	60	27	25	6	100
—	—	—	—	—	98	—	—	—	85	57	75	93	85	52	—	49	100

authors (D.C.H.) had gathered antibiograms, which included 1995 to 2000 susceptibility data, from most of the hospitals in the Jacksonville area and had published a CWA for organisms associated with community-acquired pneumonia (4). The author subsequently approached the Director of Pharmacy and Clinical Coordinator for Adult Services at her hospital to explore the possibility of expanding the network and opening the lines of communication with pharmacists in the community. With their assistance, a multidisciplinary users group composed of microbiologists, clinical pharmacists, infectious disease specialists, and infection control practitioners from 10 hospitals serving the greater Jacksonville, Fla., area was formed to exchange susceptibility data and formulary decisions, compare laboratory practices, and develop a multicenter antibiogram. Potential participants were contacted via memorandum, electronic mail, and/or telephone. Our first meeting met with great enthusiasm. We were able to identify a sponsor who provided funding for a dinner meeting at a local restaurant. During this first meeting an in-service on antimicrobial resistance and methods of detection was provided. We gathered contact information for each of the participants and identified our expectations and goals for the group. The intention of the group was not to have closed meetings but rather to open the meeting to other individuals in our community with a strong interest in infectious diseases and control of antimicrobial resistance. Participating hospital laboratories completed a comprehensive survey to determine susceptibility methods used and how antibiograms were reported and to assess whether they followed the NCCLS M100-S12 (11) and M39-A (10) standards for performing susceptibility testing and antibiogram preparation, respectively. Consensus in our approach to performing and reporting susceptibility results was not a significant issue, since we had been meeting regularly prior to the formation of this multidisciplinary group, resulting in the use of similar and standardized procedures among the participating laboratories. A comprehensive nine-hospital antibiogram was developed based on 2001 susceptibility data for empirical therapy and as a basis to develop a strategy for preventing further community or regional resistance.

The results of the comprehensive survey are listed in Table 1. Additional survey questions pertained to monitoring resistance development in specific pathogens and the ability of participating institutions to break out antibiogram data by source, patient location, and/or length of hospitalization. In 9 of 10 hospitals, the microbiologist was responsible for antibiogram preparation. An automated system, i.e., Vitek or MicroScan, was used as the primary method for susceptibility testing in most participating hospitals. Cumulative data from each hospital were generated exclusively by using the laboratory information system and/or automated testing instrument. We did not attempt to separate inpatient and outpatient data, since other investigators have found that susceptibilities between the two groups were comparable (3). The M39 guidelines were followed with rare exceptions. Unfortunately, not all laboratory information systems within our community were programmed to exclude duplicate isolates from a given patient within a year. Data are presented from 13 genera, with a maximum of 31,774 isolates tested against 25 antimicrobial agents (Table 2). A CWA for each organism-drug combination was calculated by averaging the percent susceptibility results submitted by each hospital (18). To avoid artificially lowering or inflating the cumulative percent susceptibility on the CWA, we excluded data provided from our local pediatric hospital because certain key organisms, e.g., *Staphylococcus aureus* and *Streptococcus pneumoniae*, were historically more susceptible or resistant, respectively, then observed in the adult population. According to several reports (2, 9, 13, 14, 16, 17; J. F. Hindler, and L. R. Gibson, Abstr. 103rd Gen. Meet. Am. Soc. Microbiol., abstr C-066, 2003), including the NCCLS M39-A document (10), duplicate isolates should not be included when calculating percent susceptibility by using the criterion of time or antibiotic susceptibility (14). Because of concern that resistance reflected on the CWA might be artificially inflated due to inclusion of duplicate isolates, data from five of the hospitals contributing two-thirds of the CWA data and participating in the surveillance network (TSN) (15) were extracted by using TSN pre-M39 rule of eliminating duplicate results from the same patient within a 5-day period as well as by using the

TABLE 3. Comparison of antibiogram data calculated by using the first patient isolate tested (M39) and patient isolates retested after 5 days (TSN)

Organism(s), method	No. of isolates tested	% Susceptible to:								
		Aminoglycosides			Cephalosporins					
		Amikacin	Gentamicin	Tobramycin	Cefazolin	Cefepime	Cefotaxime	Ceftazidime	Ceftriaxone	Cefuroxime
Acinetobacter spp., M39	276	96	37	78		32	28	39	18	
Acinetobacter spp., TSN	305	95	34	77		28	24	35	16	
Citrobacter spp., M39	363	99	89	89	43	96	83	80	82	82
Citrobacter spp., TSN	378	99	87	89	42	96	86	80	82	79
Enterobacter spp., M39	770	98	91	91	3	94	79	76	76	53
Enterobacter spp., TSN	856	98	89	90	3	94	75	74	74	52
E. coli, M39	5,123	99	94	94	88	99	98	97	99	95
E. coli, TSN	5,223	99	93	94	87	99	98	97	99	95
Klebsiella spp., M39	417	100	98	99	89	100	100	97	100	92
Klebsiella spp., TSN	1,606	99	94	94	87	98	97	96	97	92
P. mirabilis, M39	1,371	97	73	79	90	96	99	96	99	100
P. mirabilis, TSN	1,442	97	77	78	89	96	99	96	99	100
P. aeruginosa, M39	1,699	91	70	86		78		81		
P. aeruginosa, TSN	2,018	88	66	83		72		77		
Serratia marcescens, M39	235	99	94	84		96	86	91	92	
Serratia marcescens, TSN	253	98	93	84		96	84	89	91	
S. maltophilia, M39	188	24								
S. maltophilia, TSN	222	24								
Enterococcus spp., M39	2,057									
Enterococcus spp., TSN	2,147									
S. aureus, M39	3,376		90		54					
S. aureus, TSN	3,677		90		53					
Coagulase-negative *staphylococci*, M39	165		64		26					
Coagulase-negative *staphylococci*, TSN	965		63		24					
S. pneumoniae, M39	277									49
S. pneumoniae, TSN	275									49

M39-A first-isolate rule (Table 3). A major difference in percent susceptibility between TSN and M39 extracted data was observed with *Klebsiella* and piperacillin (20%). Shannon et al. (16) also observed a major difference with *Klebsiella* and gentamicin, a reflection of acquired resistance during hospitalization and repeat isolates over time.

In order to identify resistance trends of greatest concern within our community, we compared data collected between 1995 and 2000 (4) with our current 2001 CWA data for oxacillin-resistant *S. aureus* and for penicillin-, cefotaxime-, ceftriaxone-, and macrolide-lincosamide-streptogramin B-susceptible *S. pneumoniae* (Table 4). We also compared CWA *S. pneumoniae* data with 2002 Trust 6 South Atlantic data to determine whether regional susceptibility results could be used to predict local patterns. Only 49% of our *S. pneumoniae* isolates were penicillin susceptible, compared to 62% in the region. This underscores the importance of determining local resistance patterns rather than relying on regional data. As seen in Table 4, ceftriaxone appeared to be more active than cefotaxime. Interestingly, this same pattern has been observed for several years in our local pediatric population (data not shown). A recent study of 1,000 clinical isolates of *S. pneumoniae* derived from medical laboratories distributed around the United States also investigated this observation. That study confirmed that differential MICs of ceftriaxone and cefotaxime in some isolates of *S. pneumoniae* were independent of the susceptibility test method. In addition, isolates which demonstrated differential MICs were frequently clonally related, although they comprised several clonal types. This phenomenon was noted particularly in southern U.S. states (Mark E. Jones [Focus Technologies Inc., Herndon, Va.], personal communication). A review of erythromycin and clindamycin susceptibility results from 1995 to 2001 revealed that erythromycin susceptibilities decreased from 80 to 52% over the 7-year period, whereas clindamycin susceptibilities remained relatively stable. This pattern of susceptibility would be compatible with a greater prevalence of *mefA* rather than *ermB* gene expression in our population. Although all hospitals screened *Klebsiella* and *Escherichia coli* isolates for the presence of extended-spectrum β-lactamases (ESBLs), we were unable to extract information regarding the incidence of ESBLs from our hospital databases. With ceftazidime-resistant *Klebsiella* used as an indicator of activity (11), 4% of our isolates appeared to be potential ESBL producers.

DISCUSSION

A multidisciplinary users group comprised of microbiologists, clinical pharmacists, infectious disease specialists, and infection control practitioners from 10 Jacksonville, Fla., area hospitals met on a quarterly basis to open lines of communication and share information. A portion of each meeting was used to discuss topics related to antimicrobial resistance, identify laboratory tools to identify resistance, and review standards in the M39 document (10). An initial goal identified by the group was to develop a CWA to be used by physicians in the community for empirical therapy (particularly those seeing patients at multiple hospitals in the Jacksonville area), to de-

TABLE 3—*Continued*

% Susceptible to:																	
Beta-lactams				Quinolones		Others					Cephalosporins				Beta-lactams		
Ampicillin	Ampicillin-sulbactam	Piperacillin	Piperacillin-tazobactam	Ciprofloxacin	Levofloxacin	Aztreonam	Imipenem	Nitrofurantoin	Tetracycline	Trimethoprim-sulfamethoxazole	Cefotaxime	Ceftriaxone	Lincosamide clindamycin	Macrolide erythromycin	Oxacillin	Penicillin	Glycopeptide vancomycin
	60	33	45	36	36		96			44							
	59	30	41	34	33		95			40							
	66	48	90	83	85	83	100	88		79							
	66	47	90	83	85	83	100	88		79							
	43	75	80	90	89	81	100	42		89							
	40	72	77	89	88	78	100	41		88							
56	59	61	97	93	92	92	100	96		82							
56	59	60	97	92	91	92	100	96		82							
	74	89	92	96	95		100	58		92							
	81	69	94	95	95	91	100	57		89							
73	84	84	100	66	61	88	100			59							
72	83	83	100	65	59	89	100			58							
		85	90	67	58	60	86										
		83	87	65	54	54	81										
		78	82	91	92	88	100			95							
		77	82	91	92	88	100			94							
		22	15	30	78					95							
		22	15	28	76					95							
89				47	55			99						0		93	92
88				47	54			99						0		93	91
				53	56			100	96	98			55	35	46	8	100
				53	55			100	96	98			54	34	45	7	100
				40	40			99	88	56			53	27	25	7	100
				39	39			99	88	56			51	26	24	6	100
					99		58		83	55	61	80	89	54		48	100
					99		55		81	55	61	81	88	52		49	100

velop a strategy to decrease resistance, and to provide a model for other communities to implement. Since we already had cumulative data for 1995 to 2000 for organisms causing community-associated pneumonia, we were able to compare our current CWA with previously collected data.

In order to avoid interlaboratory variation when generating the CWA data collected from multiple hospitals, a survey of laboratory practices within the community was distributed to ensure that NCCLS standards were followed. Since not all participating laboratories were collecting susceptibility results from the first isolate for each patient as described in the M39 standard (10), we proceeded to analyze data from 5 of the 10 hospitals by using both the 5-day and M39 rules for each organism included in the CWA to avoid skewing the susceptibility results. With rare exceptions, there were no major differences observed for this population of organisms. Future goals include reviewing and developing empirical and standard treatment protocols, assessing the need for instituting infection control policies, determining and implementing interventions to improve antimicrobial resistance, and monitoring the impact of these interventions.

TABLE 4. CWA resistance trends for *S. aureus* and *S. pneumoniae*, 1995 to 2001[a]

Yr	% Susceptible					
	S. aureus, oxacillin	*S. pneumoniae*[b]				
		Penicillin	Cefotaxime	Ceftriaxone	Erythromycin	Clindamycin
1995	64	70	83	81	91	NA[c]
1996	58	63	80	85	82	NA
1997	58	62	79	83	70	NA
1998	54	57	78	91	69	NA
1999	51	57	75	92	64	86
2000	43	51	79	90	65	94
2001	59	49	75	93	52	85

[a] Data for 1995 to 2000 are cumulative published (4) and unpublished data excluding pediatric isolates.

[b] Cefotaxime and ceftriaxone results were calculated by using meningeal breakpoints (≤1, 2, and ≥4 μg/ml) prior to implementation of 2002 NCCLS breakpoint changes for nonmeningeal isolates (11).

[c] NA, not available.

In summary, development of a multidisciplinary users group has the following advantages: (i) it provides a forum for active communication and updates among healthcare workers, (ii) it fosters intrahospital and interhospital cooperation, (iii) it offers a mechanism to benchmark laboratory and pharmacy practices, (iv) it provides a vehicle to collect data from all participating hospitals for the development of a CWA that can be distributed to the medical community, (v) it allows participating hospitals to post their internal antibiograms as well as the CWA on their hospital intranets, (vi) it enables hospitals to compare their antibiogram data with the CWA data to assess the need for developing targeted surveillance programs, (vii) it provides the opportunity to develop intervention strategies for decreasing antimicrobial resistance in the community, (viii) it requires no financial outlay to support activities of the multidisciplinary group, and (ix) it avoids any commercial or industrial influences that might bias data.

Establishment of local surveillance systems is advocated for improving appropriate antimicrobial use and containing anti-

microbial resistance. To ensure that reliable data are presented to the community, institution of a standardized, consistent, and straightforward mechanism to generate, collect, and collate data at the local level is required. The M39 standard for collection, collation, and analysis of data should be followed. In order to ensure appropriate interpretation of the CWA, limitations of data collection should be identified and reflected in the data presentation. The information generated from a local forum should facilitate decision-making, interventions, and follow-up monitoring on a community-wide level.

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