ORIGINAL ARTICLE

Empiric Antibiotic Prescribing Decisions Among Medical Residents: The Role of the Antibiogram

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OBJECTIVE. To assess general medical residents' familiarity with antibiograms using a self-administered survey.

DESIGN. Cross-sectional, single-center survey.

PARTICIPANTS. Residents in internal medicine, family medicine, and pediatrics at an academic medical center.

METHODS. Participants were administered an anonymous survey at our institution during regularly scheduled educational conferences between January and May 2012. Questions collected data regarding demographics, professional training; further open-ended questions assessed knowledge and use of antibiograms regarding possible pathogens, antibiotic regimens, and prescribing resources for 2 clinical vignettes; a series of directed, closed-ended questions followed. Bivariate analyses to compare responses between residency programs were performed.

RESULTS. Of 122 surveys distributed, 106 residents (87%) responded; internal medicine residents accounted for 69% of responses. More than 20% of residents could not accurately identify pathogens to target with empiric therapy or select therapy with an appropriate spectrum of activity in response to the clinical vignettes; correct identification of potential pathogens was not associated with selecting appropriate therapy. Only 12% of respondents identified antibiograms as a resource when prescribing empiric antibiotic therapy for scenarios in the vignettes, with most selecting the UpToDate online clinical decision support resource or *The Sanford Guide*. When directly questioned, 89% reported awareness of institutional antibiograms, but only 70% felt comfortable using them and only 44% knew how to access them.

CONCLUSIONS. When selecting empiric antibiotics, many residents are not comfortable using antibiograms as part of treatment decisions. Efforts to improve antibiotic use may benefit from residents being given additional education on both infectious diseases pharmacotherapy and antibiogram utilization.

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The development of antibiograms has been identified as a core element of antibiotic stewardship programs by the Centers for Disease Control and Prevention, and several infectious disease guidelines advocate the use of local susceptibility data to guide empiric antibiotic selection.[1–4]

Despite widespread endorsement by the infectious diseases community to integrate antibiogram data into practice, it is unclear whether clinicians outside of the infectious diseases field receive sufficient training to do so. A recent survey of students enrolled at 3 medical schools in the United States revealed that only 34% of students felt adequately prepared to interpret antibiograms, and surveys of physicians indicate that this gap may persist as students enter practice.[5,6] The extent to which medical residents incorporate antibiograms in their decision-making processes when prescribing empiric antibiotics, and what else influences these decisions, are unclear. The purpose of this study was to assess primary-care residents' familiarity with and use of institutional antibiograms (1) indirectly through clinical vignettes designed to mimic real-world practice and (2) directly using closed-ended questions. The clinical vignettes were also used to evaluate residents' infectious diseases knowledge and prescribing decisions.

METHODS

Design, Setting, and Participants

We conducted a cross-sectional, single-center survey designed to evaluate medical residents' knowledge and attitudes related

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PREVIOUS PRESENTATION. These data were presented in part at the American Society of Health-System Pharmacists 47th Annual Midyear Clinical Meeting on December 3, 2012, in Las Vegas, Nevada.

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to antibiogram use and antibiotic selection. The survey was administered to residents at Oregon Health and Science University (OHSU) and was approved by the OHSU Institutional Review Board. At OHSU, antibiograms are provided electronically and can be accessed via the institutional intranet. For adults, population-specific antibiograms include outpatients, inpatients, and patients in intensive care units. The pediatric antibiogram combines inpatient and outpatient culture data. Cost information for common antibiotics is also provided as a relative scale.

Between January and May 2012, study personnel visited regularly scheduled educational conferences for family medicine, internal medicine, and pediatrics residents to administer paper surveys to attendees. We selected these residency programs to sample because these residents not only have general medical service responsibilities but also work in the outpatient primary care setting, where the bulk of antibiotic use occurs. While the survey was directed towards residents, all conference attendees were allowed to complete surveys. Survey respondents were offered a coupon redeemable for coffee or tea at our institution to incentivize participation.

Survey Instrument

The survey instrument consisted of 21 items, including both multiple-choice and short-answer questions (see Supplementary Appendix). Questions assessed information related to the respondent's demographics and professional training and gauged their knowledge and perceptions related to antibiograms. The survey included 2 clinical vignettes designed to probe clinical decision making by evaluating residents' understanding of expected pathogens, information sources used to support decisions, and empiric antibiotic regimens chosen. The final survey section directly queried respondents about their awareness of our institution's antibiograms, where to access them, and what population-specific antibiograms were available. The survey instrument was developed by study investigators then pilot tested among pharmacists and nonresident internal medicine, family medicine, and pediatrics physicians at our institution. Feedback from pilot testing was incorporated into the final version of the survey.

Clinical Vignettes

The first vignette described a hypothetical patient with a history of anaphylactic reaction to penicillin who returns to the hospital 2 weeks post-appendectomy with fever, chills, loss of appetite, dehydration, abdominal pain, and purulent drainage from the surgical wound. The second vignette presented a hypothetical patient with a 15-year history of neurogenic bladder requiring self-catheterization 3–4 times per day. The patient has a history of urinary tract infections with *Proteus mirabilis*– and *Providencia stuartii*–positive urine cultures. In this case, the patient presents with increased urinary frequency, urgency, and flank pain. For both vignettes, survey respondents were asked to identify pathogens to cover with antimicrobial therapy, name any resources they would reference during the clinical decision-making process, and recommend specific antibiotic regimens for the patient. The described cases were adapted to similar pediatric scenarios for use among pediatrician respondents.

Data Analysis

Data from all completed paper surveys were transcribed into an electronic spreadsheet (Microsoft Excel, Redmond, WA) by a study investigator (R.V.T.). Four other study personnel (G.B.T., J.E.T., D.T.B., J.C.M.) assessed clinical vignette responses and categorized target pathogens and suggested whether antibiotic regimens were correct or incorrect. The final determination was based on majority consensus. For all analyses, data were limited to responses from medical residents. Demographic data were summarized using descriptive statistics. Responses between residency programs were compared using the χ^2 and the Fisher exact test as appropriate. The χ^2 test for trend was used to compare responses by year of residency training. All statistical analyses were performed using SAS version 9.4 software (SAS Institute, Cary, NC).

RESULTS

A total of 122 surveys were distributed during the educational conferences, and 120 were returned, for an overall survey response rate of 98.4%. We excluded 11 responses from medical students and 3 from practicing physicians from analysis, leaving a final sample of 106 residents. Most respondents (71.6%) were in their first or second year of residency, and 68.9% were internal medicine residents (Table 1). Pediatric and internal medicine residents were more likely than those in family medicine to have completed a rotation in infectious diseases; only 1 family medicine resident had infectious diseases training. Most residents who had experience with infectious diseases had also completed a critical-care rotation.

Resident performance in the clinical vignettes is described in Table 2. Overall, 8 residents (7.5%) did not provide an antibiotic regimen in the first vignette; in the second vignette 11 residents (10.4%) did not identify pathogens to target and 32 residents (30.2%) did not select an antibiotic regimen. In the first clinical vignette, correct antibiotic selection differed significantly between residency programs ($P < .001$). Performance on the vignettes was otherwise similar across all residency programs, and these results were unchanged when missing responses were included as incorrect responses (data not shown). Correct identification of the pathogens for which empiric antibiotic therapy should be targeted was not associated with selecting an appropriate antimicrobial regimen for the first ($P = .73$) or second ($P = .09$) vignette. In addition, 14 residents (13.2%) recommended a penicillin antibiotic in the first clinical vignette despite the patient having a history of anaphylaxis to penicillin, with significant differences between internal medicine residents (n = 5, 6.9%), family medicine residents (n = 4, 21.1%), and pediatric residents (n = 5, 35.7%; $P = .007$). Notably, neither

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TABLE 1. Demographic Information by Department

Characteristic	Total (n = 106)	Internal Medicine (n = 73)	Family Medicine (n = 19)	Pediatric Medicine (n = 14)
Female[a]	59 (55.6)	35 (47.9)	13 (68.4)	11 (78.6)
Year in residency[a]				
1	40 (37.7)	28 (38.4)	7 (36.8)	5 (35.7)
2	36 (33.9)	24 (32.9)	8 (42.1)	4 (28.6)
3 or later	29 (27.4)	20 (27.4)	4 (21.1)	5 (35.7)
Clinical rotations completed				
Infectious disease	58 (54.7)	46 (63.0)	1 (5.3)	11 (78.6)
Critical care	96 (90.6)	72 (98.6)	17 (89.5)	7 (50.0)
Both	54 (50.9)	46 (63.0)	1 (5.3)	7 (50.0)

[a]1 missing response.

TABLE 2. Performance on Clinical Vignettes by Department

Vignette Outcome	Total (n = 106)	Internal Medicine (n = 73)	Family Medicine (n = 19)	Pediatric Medicine (n = 14)	*P* Value
Case 1: Postsurgical intra-abdominal infection					
Correct pathogen identification	76 (71.7)	55 (75.3)	11 (57.9)	10 (71.4)	.32
Correct empiric antibiotics[a]	48/98 (49.0)	43/68 (63.2)	4/17 (23.5)	1/13 (7.7)	< .001
Case 2: Recurrent pyelonephritis					
Correct pathogen identification[b]	53/95 (55.8)	33/63 (52.4)	11/18 (61.1)	9/14 (64.3)	.63
Correct empiric antibiotics[c]	57/74 (77.0)	41/52 (78.8)	6/11 (54.5)	10/11 (90.9)	.18

[a]8 missing responses.
[b]11 missing responses.
[c]32 missing responses.

year of residency training nor completion of an infectious diseases rotation was associated with correctly identifying pathogens to cover or recommending appropriate therapy in either clinical vignette (data not shown).

For each of the 2 clinical vignettes, respondents were asked what additional resources they would use, if any, in choosing an empiric antibiotic regimen; the question was intentionally formatted as a short-answer response to prevent influencing the respondent. Only 13 residents (12.3%) identified antibiograms as a resource, with significant variation across residency programs ($P = .003$) (Table 3). Overall, the most common references mentioned by residents were *The Sanford Guide* (71.7%) and the UpToDate online clinical decision support resource (https://www.uptodate.com) (58.5%). Use of *The Sanford Guide* was most frequent among family medicine residents, with different usage patterns among residency programs ($P < .001$). Conversely, use of UpToDate was most prevalent among pediatric residents, although these data did not reach statistical significance. Moreover, 96 residents (90.6%) used at least 1 infectious diseases-focused source of information (*The Sanford Guide*, IDSA guidelines, *Johns Hopkins ABX Guide*, a local infectious diseases physician, antibiogram, or culture data).

When directly queried, 95 residents (89.6%) responded that they were aware of institutional antibiograms, but less than half knew how to access them (Table 4). In general, positive responses to antibiogram questions were most common among pediatric residents and least common among family medicine residents. However, only comfort with using antibiograms differed between programs ($P = .04$). Respondents who completed an infectious diseases rotation reported higher previous antibiogram use compared to those without an infectious diseases rotation (62.5% vs 35.7%; $P = .02$), but they were not more likely to feel comfortable using the institutional antibiograms or to know how to access them. Residents in the first year of training were less likely to have used the antibiogram compared to those in the second or third and later years (60.5%, 72.2%, and 88.5%, respectively; $P = .05$). However, awareness of antibiograms and knowledge of how to access the antibiogram did not differ across year of training (data not shown).

DISCUSSION

In this survey of primary-care residents at an academic medical center, we found that antibiograms are infrequently recognized as a resource when making antibiotic prescribing decisions. When asked an open-ended question about the resources they would draw from to select appropriate empiric antibiotic regimens for the clinical vignettes, only 12.3% identified the antibiogram as a reference despite the majority (89.6%) subsequently reporting being aware of this tool. Only ~70% of residents felt comfortable using an antibiogram or

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TABLE 3. Information Sources for Selection of Empiric Antibiotics by Department

Information Resource	Total (n = 106)[a]	Internal Medicine (n = 73)	Family Medicine (n = 19)	Pediatric Medicine (n = 14)
Any ID-specific reference	96 (90.6)	68 (93.2)	18 (94.7)	10 (71.4)
The Sanford Guide	76 (71.7)	54 (74.0)	18 (94.7)	4 (28.6)
IDSA Guidelines	22 (20.8)	17 (23.3)	2 (10.5)	3 (21.4)
Johns Hopkins ABX Guide	17 (16.0)	16 (21.9)	1 (5.3)	0 (0.0)
ID physician	14 (13.2)	10 (13.7)	1 (5.3)	3 (21.4)
Antibiogram	13 (12.3)	4 (5.5)	4 (21.1)	5 (35.7)
Culture data	7 (6.6)	5 (6.9)	2 (10.5)	(0.0)
UpToDate	62 (58.5)	40 (54.8)	11 (57.9)	11 (78.6)
Drug reference	18 (17.0)	10 (13.7)	5 (26.3)	3 (21.4)
Pediatric reference book	11 (10.4)	0 (0.0)	0 (0.0)	11 (78.6)
Pharmacist	8 (7.5)	5 (6.8)	3 (15.8)	0 (0.0)
Culture data	7 (6.6)	5 (6.8)	2 (10.5)	0 (0.0)
Patient records	6 (5.7)	2 (2.7)	2 (10.5)	2 (14.3)
Non-ID physician	3 (2.8)	3 (4.1)	0 (0.0)	0 (0.0)
Other Reference	16 (15.1)	8 (11.0)	7 (36.8)	1 (7.1)

NOTE. ID, infectious disease; IDSA, Infectious Diseases Society of America.
[a]Totals may not add up to 100% because respondents could report multiple resources.

TABLE 4. Antibiogram Knowledge and Attitudes by Department

Survey Question	Total (n = 106)	Internal Medicine (n = 73)	Family Medicine (n = 19)	Pediatric Medicine (n = 14)	*P* Value
Aware of antibiogram	95 (89.6)	63 (86.3)	18 (94.7)	14 (100.0)	0.38
Know how to access antibiogram	47 (44.3)	30 (41.1)	7 (36.8)	10 (71.4)	0.19
Feel comfortable using antibiogram	74 (69.8)	51 (69.9)	10 (52.6)	13 (92.9)	0.04
Used antibiogram before for prescribing decisions	73 (68.9)	49 (67.1)	11 (57.9)	13 (92.9)	0.14
Aware of population-specific antibiograms	17 (16.0)	7 (9.6)	6 (31.6)	4 (28.6)	0.07
Cost is a factor for inpatient prescribing	52 (49.1)	35 (47.9)	9 (47.4)	8 (57.1)	0.75
Cost is a factor for outpatient prescribing	92 (86.8)	60 (82.2)	18 (94.7)	14 (100.0)	0.55
Aware antibiogram provides cost information	23 (21.7)	13 (17.8)	3 (15.8)	7 (50.0)	0.09

had used one before to aid in prescribing decisions, and less than half knew how to access the institutional antibiogram. Individuals with infectious diseases experience were more likely to have used the institutional antibiogram previously but were equally uncomfortable as other residents with using antibiograms in practice. Evaluation of the other responses to the clinical vignettes suggested weaknesses in respondents' ability to determine appropriate empiric antibiotic regimens in scenarios where clinical guidelines and treatment pathways do not provide explicit recommendations for the specific patient case. In our survey, the clinical vignettes were developed to require some degree of clinical judgment beyond what could be identified in the relevant guidelines and resources. Furthermore, we refrained from directly asking questions regarding antibiograms until the final page of the survey to limit influencing respondents.

Our findings are consistent with a previous survey of medical residents and fellows at an academic center that revealed that 64% of respondents had never used the hospital's antibiogram and that 61% did not know how to find it.[7] Similar results were observed with physicians and medical students, suggesting that the observed lack of comfort and familiarity with antibiograms may arise in medical school and persists as students become residents and, later, autonomous physicians.[5,6,8] Our survey provides greater context to these findings with the addition of clinical vignettes to assess residents' antibiotic prescribing decisions in hypothetical cases. In these cases, only 12.3% of residents recognized antibiograms as a possible resource for guiding antibiotic prescribing, highlighting a disconnect between awareness (89.6% of respondents) and use. In addition to issues of accessibility, the limited antibiogram use by the residents in our study may be due to a perceived lack of need. Compared to many other urban facilities across the United States, our institution has relatively low rates of resistance to most antimicrobials. As such, medical residents may not feel that

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consulting an antibiogram is beneficial because many antibiotics may provide adequate empiric coverage. However, antibiogram use may encourage residents to prescribe empiric therapy with narrower-spectrum agents; thus, antibiograms may be used as a tool to support antimicrobial stewardship efforts.

While resident performance on the clinical vignettes was not the primary objective of the survey, we observed several important patterns in the responses. Approximately half of residents did not specify all the pathogens against which to direct empiric antibiotic therapy or recommend antibiotic regimens with appropriate coverage. Furthermore, there was no association between successfully identifying which bacteria to target and providing an appropriate antibiotic regimen. Several factors may influence the prescribing patterns we observed in the clinical vignettes. Surveys of medical students in the United States and Europe indicate that students feel insufficiently prepared to describe the spectrum of different antimicrobials or to select the best one for a specific infection and that additional training in this area is desired.[5,9] However, 61% of respondents in our sample were in their second or later year of training, and approximately half had completed an infectious diseases rotation. While those who had completed an infectious diseases rotation were more likely to have used an antibiogram previously, they were no more likely to provide appropriate responses to either clinical vignette. This finding suggests that potential gaps in medical school curricula may persist inresidency and current resident training in infectious diseases does not sufficiently close these gaps. Enhancing education focused on infectious diseases pharmacotherapy and antibiogram interpretation throughout the medical curriculum and postgraduate training may be needed to improve antibiogram interpretation skills and antimicrobial prescribing decisions. Nori et al[10] recently described a strategy of recurring case-based lectures coupled with distribution of antibiograms as a way to provide postgraduate education related to antimicrobial use; this approach resulted in a sustained improvement in antibiotic appropriateness over 20 months. This program was part of a larger education initiative that may not be feasible at all institutions. Other experts have suggested that antimicrobial education should be part of physician revalidation and accreditation and that antimicrobial stewardship teams should incorporate education into audit and feedback activities.[11]

Several limitations should be considered when interpreting the results of this study. Because our survey was distributed to a small sample of residents attending educational conferences and response was voluntary, our findings may be susceptible to response bias. While our response rate for disseminated surveys was 98%, respondents may differ from residents who did not attend educational conferences and thus could not participate in the survey. Another limitation is the generalizability of our findings. This is a small, cross-sectional survey of trainees at a single institution, and we limited our survey to primary-care residents in family medicine, internal medicine, and pediatric medicine. Consequently, our results may not apply to other resident cohorts, nonresident physicians, or other health systems. Furthermore, most respondents in our survey were from the internal medicine program, so any application of our results to family medicine and pediatric residents should be done cautiously, recognizing their relatively small representation in our data. Because this was a cross-sectional study, we could not assess improvements in antibiogram use and clinical performance over time. While we did evaluate relationships between antibiogram knowledge and year of residency, our lack of any significant improvements with time may be due to differences between residency classes rather than a lack of change over time. Future studies should consider including trainees from multiple training programs and institutions and assess responses throughout residency. Additional studies should also include more targeted questions to better identify and understand barriers to antibiogram use beyond that of accessibility. Finally, when evaluating residents' performance in the clinical vignettes, it is important to remember that the clinical vignettes were composed of hypothetical case scenarios and may not represent actual clinical scenarios in which antibiotics are prescribed.

In conclusion, our results indicate that medical residents are aware of hospital antibiograms, but many have never used one or are not comfortable using it to guide antibiotic prescribing. More importantly, less than half of respondents were even aware of how to access the institutional antibiogram. While efforts to improve antibiogram accessibility and increase proficiency with their use may improve antibiogram utilization and appropriate empiric antibiotic prescribing, broader efforts focused on providing more applied education about infectious disease therapies may be needed to maximize the utility of antibiograms and meaningfully affect antibiotic prescribing decisions.

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SUPPLEMENTARY MATERIAL

To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2018.28

REFERENCES

1. Centers for Disease Control and Prevention. *Core Elements of Hospital Antibiotic Stewardship Programs*. Atlanta, GA: US Department of Health and Human Services, CDC; 2014.
2. Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program: guidelines by the Infectious

Diseases Society of America and the Society for Healthcare Epidemiology of America. *Clin Infect Dis* 2016;62:e51–e77.
3. Kalil AC, Metersky ML, Klompas M, et al. Management of adults with hospital-acquired and ventilator-associated pneumonia: 2016 clinical practice guidelines by the Infectious Diseases Society of America and the American Thoracic Society. *Clin Infect Dis* 2016;63:e61–e111.
4. Solomkin JS, Mazuski JE, Bradley JS, et al. Diagnosis and management of complicated intra-abdominal infection in adults and children: guidelines by the Surgical Infection Society and the Infectious Diseases Society of America. *Clin Infect Dis* 2010;50: 133–164.
5. Abbo LM, Cosgrove SE, Pottinger PS, et al. Medical students' perceptions and knowledge about antimicrobial stewardship: How are we educating our future prescribers? *Clin Infect Dis* 2013;57:631–638.
6. Giblin TB, Sinkowitz-Cochran RL, Harris PL, et al. Clinicians' perceptions of the problem of antimicrobial resistance in health care facilities. *Arch Intern Med* 2004;164:1662–1668.
7. Mermel LA, Jefferson J, Devolve J. Knowledge and use of cumulative antimicrobial susceptibility data at a university teaching hospital. *Clin Infect Dis* 2008;46:1789.
8. Evans CT, Rogers TJ, Burns SP, Lopansri B, Weaver FM. Knowledge and use of antimicrobial stewardship resources by spinal cord injury providers. *PM R* 2011;3:619–623.
9. Dyar OJ, Pulcini C, Howard P, Nathwani D, Policies ESGAP (ESCMID Study Group for Antibiotic Policies). European medical students: a first multicentre study of knowledge, attitudes and perceptions of antibiotic prescribing and antibiotic resistance. *J Antimicrob Chemother* 2014;69:842–846.
10. Nori P, Madaline T, Munjal I, et al. Developing interactive antimicrobial stewardship and infection prevention curricula for diverse learners: a tailored approach. *Open Forum Infect Dis* 2017;4:ofx117.
11. Abbo L, Sinkowitz-Cochran R, Smith L, et al. Faculty and resident physicians' attitudes, perceptions, and knowledge about antimicrobial use and resistance. *Infect Control Hosp Epidemiol* 2011;32:714–718.

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