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# Regional and statewide antibiograms as targeted interventions against antibiotic resistance

John G Plante BS[1], Hana R Winders PharmD[2], P. Brandon Bookstaver PharmD[2,3], Majdi N Al-Hasan MBBS[1,4], Julie Ann Justo PharmD, MS[2,3], Katie S Waites MPH[5] and Sharon Weissman MD[1,4]

[1]University of South Carolina School of Medicine, Columbia, South Carolina, [2]Department of Clinical Pharmacy and Outcomes Sciences, University of South Carolina College of Pharmacy, Columbia, South Carolina, [3]Department of Pharmacy, Prisma Health Richland, Columbia, South Carolina, [4]Department of Medicine, Prisma Health University of South Carolina Medical Group, Columbia, South Carolina and [5]South Carolina Department of Health and Environmental Control, Columbia, South Carolina

*To the Editor*—Antibiotic resistance is becoming an increasingly heavy burden on our nation, leading to significant patient morbidity, mortality, and healthcare expenditures.[1] Antibiotic misuse may be considered a primary driver of resistance, and recent studies suggest that ~20%–30% of inpatient antibiotics and 30%–40% of ambulatory antibiotics were inappropriately prescribed.[2,3] According to the Centers for Disease Control and Prevention's (CDC's) 2019 Threats Report,[1] >2.8 million resistant infections and 35,000 associated deaths are reported annually in the United States. Although this has been accompanied by a 27% reduction in the number of resistant nosocomial infections, the total number of annual resistant infections has increased, highlighting the need for additional community-focused antimicrobial stewardship interventions.[1]

The impact of several statewide and regional antibiograms on clinical management and stewardship efforts has previously been described.[4,5] Here, we discuss regional and statewide antibiograms in South Carolina. The Antimicrobial Stewardship Collaborative of South Carolina (ASC-SC) was established in 2016 with support from the CDC. This organization coordinates a variety of statewide antimicrobial stewardship initiatives, including the statewide antibiogram project presented in this letter. This endeavor represents the continuation of a smaller-scale pilot project conducted from 2007 to 2011 through a collaboration between the South Carolina Department of Health and Environmental Control and the University of South Carolina College of Pharmacy.

From 2007 to 2011 and from 2015 to 2017, hospitals and nursing homes throughout South Carolina were asked to submit their annual facility-specific and ambulatory antibiograms to ASC-SC. Each antibiogram was deconstructed into individual isolates and combined into one statewide and multiple regional antibiograms annually. Most of the data consisted of isolates from acute-care hospitals. The yearly cumulative antibiograms were redistributed for use by healthcare facilities across the state.

The compiled statewide antibiogram contains 2017 isolate data from 49 institutions (Fig. 1). Statewide susceptibility rates for the 2017 year were compared to the 2015 year. We used $\chi^2$ analysis to assess significance at an $\alpha$ level of 0.05.

Overall, *Escherichia coli* was the most frequently reported organism (33,848 isolates in 2017). From 2015 to 2017, *Acinetobacter baumannii* demonstrated increased susceptibility

**Author for correspondence:** Hana R. Winders, Email: hwinders@cop.sc.edu
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2017 South Carolina Statewide Antibiogram[1]

| Gram Negative Organisms | # isolates | Ampicillin | Ampicillin/sulbactam | Amoxicillin/clavulanate | Piperacillin/tazobactam | Cefazolin | Cefuroxime | Ceftriaxone | Ceftazidime | Cefepime | Aztreonam | Meropenem | Gentamicin | Tobramycin | Amikacin | Ciprofloxacin | Levofloxacin | Trimeth/sulfa | Nitrofurantoin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Acinetobacter baumannii* | 507 | | 87 | | 79 | | | 47 | 68 | 83 | | 92 | 90 | 95 | 98 | 81 | 83 | 83 | |
| *Enterobacter aerogenes*[2] | 996 | | | | 85 | | 50 | 83 | 87 | 98 | 84 | 100 | 99 | 98 | 99 | 96 | 97 | 97 | 19 |
| *Enterobacter cloacae* | 1930 | | | | 82 | | 42 | 77 | 82 | 94 | 79 | 98 | 95 | 96 | 100 | 90 | 94 | 88 | 35 |
| *Escherichia coli* | 33848 | 50 | 53 | 83 | 96 | 85 | 89 | 94 | 95 | 95 | 91 | 100 | 90 | 90 | 100 | 75 | 75 | 74 | 95 |
| *Klebsiella oxytoca* | 621 | | 64 | 86 | 91 | 49 | 86 | 89 | 95 | 93 | 83 | 100 | 95 | 95 | 100 | 95 | 97 | 90 | 78 |
| *Klebsiella pneumoniae* | 9800 | | 82 | 93 | 93 | 89 | 90 | 94 | 95 | 94 | 89 | 99 | 96 | 94 | 99 | 94 | 94 | 89 | 42 |
| *Proteus mirabilis* | 5020 | 85 | 94 | 98 | 99 | 90 | 97 | 98 | 98 | 98 | 92 | 100 | 93 | 93 | 100 | 77 | 80 | 81 | |
| *Pseudomonas aeruginosa* | 5211 | | | | 91 | | | | 88 | 87 | 73 | 92 | 89 | 97 | 96 | 80 | 77 | | |

| Gram Positive Organisms | # isolates | Oxacillin/nafcillin | Penicillin G | Ceftriaxone | Gentamicin (synergy) | Rifampin (synergy) | Levofloxacin | Clindamycin | Erythromycin | Tetracycline | Trimeth/sulfa | Nitrofurantoin | Linezolid | Vancomycin | Daptomycin |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MSSA | 5181 | 100 | 19 | | 97 | 100 | 62 | 77 | 58 | 92 | 99 | 91 | 100 | 100 | 99 |
| MRSA | 6630 | | | | 95 | 96 | 30 | 70 | 13 | 93 | 93 | 84 | 100 | 100 | 99 |
| Total *Staphylococcus aureus*[3] | 14647 | 50 | 9 | | 97 | 98 | 52 | 73 | 36 | 93 | 96 | 89 | 100 | 100 | 99 |
| *Streptococcus pneumoniae* | 609 | | 87 | 93 | | | 99 | 81 | 48 | 78 | 74 | | 100 | 100 | |
| *S. pneumoniae* (meningitis) | 510 | | 60 | 89 | | | | | | | | | | | |

ASC-SC
Antimicrobial Stewardship Collaborative of South Carolina

**Fig. 1.** 2017 South Carolina statewide antibiogram.
[1]This figure contains isolate data from 49 institutions across the state of South Carolina. Numbers represent percent susceptibility. Blank cells correspond to insufficient data or lack of antibiotic testing. Not all reported drugs were tested against every available isolate.
[2]*Enterobacter aerogenes* is now *Klebsiella aerogenes*.
[3]Differences between the total number of *Staphylococcus aureus* isolates versus MSSA plus MRSA isolates are due to variations in facility-specific reporting. Note. Trimeth/sulfa, trimethoprim/sulfamethoxazole; # isolates, number of isolates; MSSA, methicillin-sensitive *Staphylococcus aureus*; MRSA, methicillin-resistant *Staphylococcus aureus.*

to cefepime (70% vs 83%, $P < .001$). Susceptibility to ceftazidime and meropenem did not change significantly. Most Enterobacterales exhibited high susceptibility to third- and fourth-generation cephalosporins, and all were highly susceptible to meropenem. *Enterobacter* spp proved most resistant, but susceptibility significantly improved for ceftriaxone: *E. aerogenes*: 78% versus 83% ($P = .01$) and *E. cloacae*: 72% versus 77% ($P = .002$). Despite relatively high resistance rates to levofloxacin and trimethoprim-sulfamethoxazole overall, a slight improvement in susceptibility was observed in *E. coli* isolates for both levofloxacin (73% vs 75%; $P < .001$) and trimethoprim-sulfamethoxazole (73% vs 74%; $P = .01$).

The susceptibility of *Pseudomonas aeruginosa* to meropenem increased slightly (91% vs 92%; $P = .03$) but did not change significantly to cephalosporins or aminoglycosides. The proportion of methicillin-susceptible *Staphylococcus aureus* increased slightly (48% vs 50%; $P = .009$). Nonmeningeal *Streptococcus pneumoniae* exhibited increased susceptibility to penicillin (73% vs 87%; $P < .001$) but decreased susceptibility to ceftriaxone (96% vs 93%; $P = .03$). Susceptibility to erythromycin did not change significantly (49% vs 48%; $P = .91$).

A statewide antibiogram may serve as a valuable clinical tool for several reasons. First, an understanding of regional variability in resistance rates could encourage more appropriate empiric antibiotic selection.[4,6] For example, first-line empiric treatment options for acute pyelonephritis include oral fluoroquinolones, unless community resistance is >10%, or oral trimethoprim-sulfamethoxazole, if the isolate is known to be susceptible.[7] Our antibiogram demonstrates *E. coli*'s poor susceptibility to these agents, and this could guide practitioners, especially in the outpatient setting, to administer a single parenteral dose of a long-acting agent such as ceftriaxone and to more carefully consider patient-specific risk factors for resistance.[7-9] In patients with acute cystitis, empiric prescribing may be improved by observing the increased susceptibility of nitrofurantoin relative to other oral options.

According to recent guidelines,[10] macrolides should only be prescribed as empiric monotherapies for community-acquired pneumonia if local resistance to *S. pneumoniae* is known to be <25%. However, our antibiogram shows minimal organism-specific macrolide susceptibility, thereby encouraging outpatient providers to select a more appropriate empiric treatment (eg, amoxicillin or doxycycline).[10]

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As illustrated herein, evolving trends in resistance patterns may be easily identified, and this may lead to more targeted, robust infection prevention and control responses.[7] Individual facilities may also use these data to compare self-reported resistance rates with those in the region. Finally, institutions without access to local antibiograms, including certain outpatient centers and nursing homes, may find this tool especially beneficial to improve prescribing practices and antibiotic stewardship.[5]

Regional and statewide antibiograms have several limiations. Most of our data were gathered from hospitals; relatively few ambulatory antibiograms were submitted. Even though inpatient antibiograms include patients admitted with community-acquired infections, community resistance rates are likely underrepresented. These factors may have led to overestimated community rates, a relevant issue considering the growing concern of resistance in this setting.[1,6]

Despite efforts to standardize antibiogram creation procedures, little evidence supports adherence to these guidelines. Reports therefore undoubtedly vary across institutions, limiting the ability to compare interfacility susceptibility rates.[6,7] Furthermore, although antibiograms may provide general guidance, other patient-specific factors must be considered to make an informed clinical decision, including the type and severity of the current infection and previous antibiotic use.[7]

In conclusion, statewide and regional antibiograms may be effective strategies in targeting antibiotic resistance. Even though they must be viewed within the scope of their limitations, they should be considered valuable assets in future antibiotic stewardship endeavors.

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# Zoonotic brucellosis from the long view: Can the past contribute to the present?

Robin Bendrey PhD[1] and Guillaume Fournié PhD[2]

[1]School of History, Classics and Archaeology, University of Edinburgh, Edinburgh, Scotland and [2]Veterinary Epidemiology, Economics and Public Health group, Department of Pathobiology and Population Sciences, Royal Veterinary College, University of London, Hatfield, England

*To the Editor*—Zoonotic brucellosis is an endemic disease in many regions of the world, including the Zagros Mountains of Iran and Iraq, as Abdi et al[1] lay out in a recent article in *Infection Control and Hospital Epidemiology*. Abdi et al touch upon the history of farming in the Zagros Mountains to contextualize the deep time dimension of brucellosis risk for communities within this region. Building on this, we highlight the context of this early history and the contribution that long-term perspectives of evolving

**Author for correspondence:** Robin Bendrey, E-mail: robin.bendrey@ed.ac.uk

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