However, our study has several limitations. Given its retrospective before-and-after study design, several confounding factors likely contributed to changes in EOS use and antibiotic use over time. We tried to account for these by tracking changes in the corresponding standalone ASP EOS as well as nonembedded ASP EOS. We found minimal change in standalone ASP EOS use, which supported our hypothesis that embedding EOS increased its uptake. Other limitations of our study include not being able to assess the percentage use of embedded ASP EOSs in relation to the number of patients diagnosed with CAP, UTI, and cellulitis as well as not undertaking an audit on appropriateness of diagnosis and antibiotic selection for patients with embedded ASP EOS orders. There is a no specific discharge code for CAP nor codes for the UTI and cellulitis cases of interest, and we were unable to address these study limitations. Future studies on a similar intervention should consider the inclusion of these outcomes.

To fully optimize ASPs and to achieve a long-term sustainable impact on patient outcomes, information technology must be employed. The approach of embedding ASP EOSs into a more frequently used EOS has the potential to improve antibiotic prescribing using existing resources with minimal cost.

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References

1. Barlam TF, Cosgrove SE, Abbo LM *et al.* Implementing an antimicrobial stewardship program: guidelines by the Infectious Disease Society of America and the Society for Healthcare Epidemiology. *Clin Infect Dis* 2016;62(10):e51–e77.
2. Cresswell K, Mozaffar H, Shah S, Sheikh A. Approaches to promoting the appropriate use of antibiotics through hospital electronic prescribing systems: a scoping review. *Int J Pharm Pract* 2017;25:5–17.
3. Hecker MT, Fox CJ, Son AH, *et al.* Effect of a stewardship intervention on adherence to uncomplicated cystitis and pyelonephritis guidelines in an emergency department setting. *PloS One* 104;9(2):e87899.
4. Brown KE, Johnson KJ, DeRonne BM, *et al.* Order set to improve the care of patients hospitalized for an exacerbation of chronic obstructive pulmonary disease. *Ann Am Thorac Soc* 2016;13:811–815.
5. Forrest GN, van Schooneveld TC, Kullar R, *et al.* Use of electronic health records and clinical decision support systems for antimicrobial stewardship. *Clin Infect Dis* 2014;59 suppl 3:S122–S133.
6. Thaler RH, Sunstein CR. *Nudge: improving decisions about health, wealth, and happiness*. New Haven, CT: Yale University Press; 2008.

Improved empiric antibiotic prescribing for acute cystitis with use of local urinary antibiogram and clinical decision support system

Christopher J. Shoff MD[1], Mary L. Townsend PharmD[1,2], L. Gayani Tillekeratne MD, MSc[1,2], Ryan D. Schulteis MD[1,2], Michael E. Yarrington MD[1], Nicholas A. Turner MD, MHSc[1], Christopher W. Woods MD, MPH[1,2] and Christopher J. Hostler MD, MPH[1,2]

[1]Division of Infectious Diseases, Department of Medicine, Duke University School of Medicine, Durham, North Carolina and [2]Infectious Diseases Section, Medicine Service, Durham Veterans' Affairs Health Care System, Durham, North Carolina

Acute cystitis accounts for a significant proportion of ambulatory care visits every year in the United States. Empiric antibiotic selection varies widely among providers, even those working within the same health system. Current Infectious Diseases Society of America guidelines emphasize the use of local susceptibility data for determining initial antimicrobial therapy.[1] Previous findings suggest that site-specific antibiograms (ie, urine, blood, etc) may result in improved empirical therapy.[2] We collated a local urinary antibiogram to promote recommended empiric antibiotic therapies for the treatment of cystitis. A clinical decision support system (CDSS) and order set were nested within the electronic medical record to encourage guideline-concordant prescribing. Using a quasi-experimental time series analysis, we assessed the impact of this intervention on β-lactam and fluoroquinolone prescribing rates for outpatient acute cystitis.

Author for correspondence: Christopher J. Shoff, E-mail: christopher.shoff@duke.edu

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Methods

We performed a quasi-experimental, interrupted time series analysis to evaluate the effect of a local antibiogram-guided order set on antibiotic class selection for the treatment of outpatient urinary tract infections. Patients were treated in the Durham Veterans' Affairs Health Care System (DVAHCS) from April 2016 through October 2019. Encounters were identified retrospectively using the following criteria: outpatient visits with appropriate *International Classification of Disease, Ninth Revision* (ICD-9) or ICD-10 documentation for acute cystitis, a collected urine culture, and an antibiotic prescription filled within 24 hours of visit through the DVAHCS pharmacy. Prescribing data were associated with the appropriate encounter. In total, 5,517 prescriptions were analyzed.

The study consisted of a preintervention phase (April 2016 through July 2018), an intervention period (August 2018), and a postintervention phase (September 2018 through October 2019). During the preintervention phase, a local urinary antibiogram, stratified by admission status, was created from all urine cultures across DVAHCS to inform empiric antibiotic choices. *Escherichia coli* was the most commonly isolated pathogen (n = 531 isolates, 41% of all outpatient urine cultures), with the following susceptibility profile: cefazolin 91%, ciprofloxacin 71%, and trimethoprim-

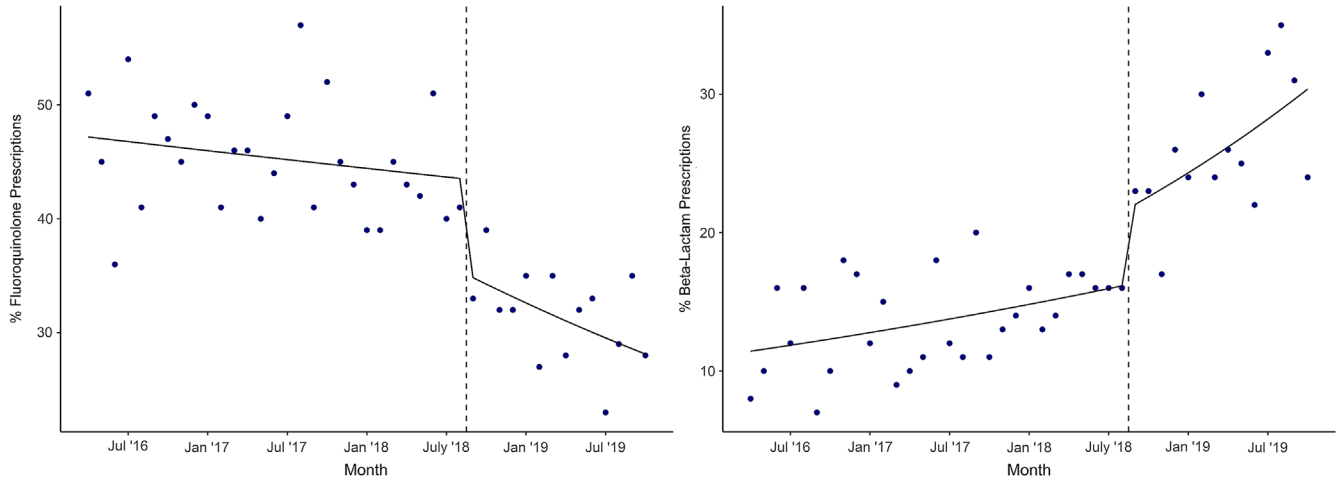

Fig. 1. Monthly antibiotic selection as a proportion of all antibiotics prescribed for cystitis. The data points represent the observed proportions and the solid line represents the Poisson regression model.

sulfamethoxazole 77%. We then developed a CDSS highlighting nitrofurantoin and β-lactams (cephalexin, amoxicillin-clavulanate) as preferred agents over fluoroquinolones for the treatment of uncomplicated acute cystitis. In August 2018, the CDSS was integrated within the facility-wide computerized patient record system (CPRS).

The primary outcomes measured were changes in monthly proportions of antibiotic classes prescribed for cystitis. Classes were defined as fluoroquinolones (ciprofloxacin and levofloxacin), β-lactams (cephalexin, cefuroxime, amoxicillin, and amoxicillin-clavulanate), nitrofurantoin, and trimethoprim-sulfamethoxazole. Median monthly proportions and interquartile ranges were compared by unpaired Wilcoxon rank-sum test. Antibiotic concordance was compared in a subset of prescriptions with cultures using Fisher's exact test. To control for unmeasured factors, we performed a segmented interrupted time series (ITS) analysis using a Poisson generalized linear regression model to assess changes in antibiotic prescribing associated with the intervention. All statistical analyses were performed using R version 3.6.3 software (R Foundation for Statistical Computing, Vienna, Austria).

Results

Patient age, race, and gender were similar before and after the intervention (Supplementary Table 1 online). Prior to implementation, monthly fluoroquinolone prescriptions accounted for a median of 45.0% of all antibiotics prescribed for outpatient treatment of acute cystitis (IQR, 41.0–49.0). After the intervention, fluoroquinolone prescriptions comprised a median of 32.0% (IQR, 28.9–35.1) of all antibiotics prescribed for cystitis monthly ($P < .001$). Conversely, prescriptions for β-lactams increased from a monthly median of 14.0% (IQR, 11.5%–16.5%) of all chosen antibiotics preintervention to a median of 24.5% of antibiotic prescriptions (IQR, 21.6%–27.4%; $P < .001$). Nitrofurantoin and trimethoprim-sulfamethoxazole prescribing were unaltered by implementation of the acute cystitis order set. In the ITS, CDSS implementation resulted in a −20.7% level change (95% CI, −33.8% to −7.5%; $P = .002$) and −1.4% change in slope (95% CI, −3.0% to 0.2%; $P = .09$) in fluoroquinolone prescribing for cystitis. The ITS demonstrated a 28.5% level change (95% CI, 15.5% to 41.7%; $P < .001$) and 1.2% change in slope (95% CI, −0.3% to 2.8%; $P = .13$) with regard to β-lactam prescriptions (Fig. 1). In a subset of patients treated in the emergency department, microbiological concordance was unchanged (79.1% vs 77.1%; $P = .6514$) (Supplementary Table 2 online).

Discussion

Prior to our intervention, fluoroquinolones accounted for the plurality of antibiotics prescribed for acute cystitis, despite an unfavorable susceptibility profile. CDSS implementation resulted in significant changes in prescribing patterns of fluoroquinolones and β-lactams for treatment of acute cystitis, resulting in greater concordance with the local urinary antibiogram. As nitrofurantoin and trimethoprim-sulfamethoxazole prescribing remained constant, we hypothesize that β-lactam therapies replaced fluoroquinolones for the treatment of uncomplicated cystitis. This intervention most likely succeeded by leveraging order entry, allowing providers to easily select guideline-recommended antibiotics, while simultaneously discouraging fluoroquinolone use.

Our results are consistent with those of prior studies demonstrating a positive effect of CDSS on antibiotic prescribing.[3,4] To our knowledge, however, our study is the first to assess the impact of this intervention across the entire ambulatory network of a healthcare system.

This study has several limitations: (1) It was conducted at a single institution with a predominantly male cohort, these findings lack generalizability to other settings. (2) The provider-level data regarding utilization of the CDSS were not available, preventing a direct linkage between CDSS usage and antibiotic choice. (3) The use of ICD codes may have over- or underestimated the true frequency of acute cystitis associated with antibiotic prescriptions; however, any discrepancy likely remained constant throughout the study period, and the observed trends are not likely related to this limitation.

In summary, CDSS combined with local urine antibiograms, even without prescriber education or audit and feedback, can be an effective tool for antimicrobial stewardship.

Supplementary material. To view supplementary material for this article, please visit https://doi.org/10.1017/ice.2020.357

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References

1. Gupta K, Hooton TM, Naber KG, *et al.* International clinical practice guidelines for the treatment of acute uncomplicated cystitis and pyelonephritis in women: a 2010 update by the Infectious Diseases Society of America and the European Society for Microbiology and Infectious Diseases. *Clin Infect Dis* 2011;52(5):e103–e120.
2. Marsh KJ, Mundy L, Holter JJ, Johnson JR. Analysis of urine-specific antibiograms from veterans to guide empiric therapy for suspected urinary tract infection. *Diagn Microbiol Infect Dis* 2019;95:114874.
3. Hecker MT, Fox CJ, Son AH, *et al.* Effect of a stewardship intervention on adherence to uncomplicated cystitis and pyelonephritis guidelines in an emergency department setting. *PLoS One* 2014;9(2):e87899.
4. Patros C, Sabol M, Paniagua A, Lans D. Implementation and evaluation of an algorithm-based order set for the outpatient treatment of urinary tract infections in the spinal cord injury population in a VA Medical Center. *J Spinal Cord Med* 2018;41:192–198.

Correlation of the air–surface nexus of bacterial burden during routine patient care

Werner E. Bischoff MD, PhD[1] and Gregory Russell MS[2]

[1]Internal Medicine, Section on Infectious Diseases, and Infection Prevention and Health System Epidemiology, Wake Forest Baptist Medical Center, Winston-Salem, North Carolina and [2]Department of Biostatistical Sciences, Wake Forest School of Medicine, Winston-Salem, North Carolina

Bacterial pathogens have been detected in the air and can survive on surfaces for extended periods of time.[1–3] Our current understanding of pathogen transmission distinguishes between airborne, droplet, direct (hands) and indirect (surfaces) contact pathways.[4] The 4 transmission pathways appear not to be exclusive, but pathogens can transition between them.[5] Interventions such as air purification or surface cleaning may affect not only 1 pathway, but several.[5,6] This project determines the association between aerosol burden and surface contamination and the impact of a high-efficiency particulate air ultraviolet air recirculation system (HUAIRS) on transmission pathways.

Methods

Sampling was performed in a critical care decision unit (convenience sample) with no patient care activity restrictions. Three 6-stage Andersen samplers were used for air sampling and were placed at the head and foot of a patient's bed along with 1 sampler at the exit doorway.[7] A sedimentation plate (standard petri dish surface area, 56.7 cm^2) was placed next to each Andersen sampler. All samples were collected on blood agar plates (BBL: TSA II with Sheep Blood, Becton Dickinson, Franklin Lakes, NJ).

After completion of 20-minute baseline sampling, the HUAIRS (Aerobiotix Illuvia 500uv system [450 cfm], Aerobiotix, Dayton, OH) was placed within the vicinity of the patient bed and was run for at least 1 complete room air exchange. This procedure was followed by air sampling for 20 minutes with the HUAIRS running. Door openings were recorded. Once completed, plates were incubated for 48 hours at 37 °C. After incubation, the number of colonies congruent with bacterial growth was recorded as colony-forming units (CFU) per plate. No further speciation of bacteria was performed.

Baseline, HUAIRS run, and sedimentation CFU data were summarized and analyzed. Andersen sampler stages were combined into particles <4.7 μm or >4.7 μm. To assess the change between baseline and HUAIRS run data, paired *t* tests were used to determine the magnitude of change, testing the observed versus expected mean of no change (mean of 0). Correlations between aerosol burden and surface contamination were calculated using Spearman coefficients. The impact of door openings on environmental bacterial burden was assessed using Spearman coefficients. Significance was assumed if $P < .05$. We used SAS version 9.4 software (SAS Institute, Cary, NC) for all analyses. The study was approved by the Institutional Review Board of Wake Forest School of Medicine.

Results

In total, 65 participants were enrolled in the study (46% women and 54% men). Two participants were excluded due to unusual activities (eg, door remained open or food served). During HUAIRS use at all locations, a reduction of 58% in aerosol burden was observed: head, −7.1 (95% CI, −10.5 to −3.7; $P < .0001$); foot, −8.3 (95% CI, −12.0 to −4.7; $P < .0001$); and exit, −8.8 (95% CI, −12.0 to −5.5; $P < .0001$). A reduction of 51% in surface contamination was observed: head, −0.6 (95% CI, −1.1 to −0.1; $P = .024$); foot, −0.5 (95% CI, −1.5, 0.3; $P = .17$); and exit, −0.7 (95% CI − 1.3, to −0.1; $P = .016$) (Supplementary Data online). Except at baseline for air burden, door openings were correlated with air burden contamination (baseline Spearman ρ: 0.09, $P = .48$; HUAIRS run, Spearman ρ: 0.18, $P = .16$) and surface burden surface contamination (baseline Spearman ρ: 0.72, $P = .0001$, HUAIRS run: Spearman ρ: 0.35, $P = .0045$). Table 1 presents moderate to strong correlations between aerosol and surface burden for baseline/HUAIRS run samples.

Discussion

To interrupt the chain of transmission of pathogens, one must understand how these pathogens are spread. Our study focused

Author for correspondence: Werner E. Bischoff, E-mail: wbischof@wakehealth.edu

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