Antimicrobial Stewardship & Healthcare Epidemiology (2024), **4**, e223, 1–5
doi:10.1017/ash.2024.461

SHEA

Original Article

Hospital antimicrobial stewardship funding and resourcing impact on broad-spectrum antibiotic use: a cross-sectional study

Megan Tu BHSc[1], Zong Heng Shi PharmD[2], Valerie Leung BScPhm[3], Kevin A Brown PhD[4], Kevin L Schwartz MD[4], Nick Daneman MD[5] and Bradley J Langford PharmD[4]

[1]McMaster University, Hamilton, ON, Canada, [2]Sunnybrook Health Sciences Centre, Toronto, ON, Canada, [3]Public Health Ontario, Michael Garron Hospital, Toronto, ON, Canada, [4]Public Health Ontario, Dalla Lana School of Public Health, Toronto, ON, Canada and [5]Public Health Ontario, Institute for Health Policy Management and Evaluation, Sunnybrook Health Sciences Centre, Toronto, ON, Canada

Abstract

Background: Antimicrobial stewardship programs (ASPs) aim to mitigate antimicrobial resistance (AMR) by optimizing antibiotic use including reducing unnecessary broad-spectrum therapy. This study evaluates the impact of ASP funding and resources on the use of broad-spectrum antibiotics in Ontario hospitals.

Methods: We conducted a cross-sectional study of antimicrobial use (AMU) across 63 Ontario hospitals from April 2020 to March 2023. The Ontario ASP Landscape Survey provided data on ASP resourcing and antibiotic utilization. The main outcome was the proportion of all antibiotics that were broad-spectrum, defined as: fluoroquinolones; third-generation cephalosporins; beta-lactam/beta-lactamase inhibitors; carbapenems; clindamycin; and parenteral vancomycin. Secondary outcomes included the proportions of individual antibiotic classes listed above and anti-pseudomonal agents. Statistical analysis involved logistic regression to determine the odds ratio (OR) of the association between ASP funding/resourcing and broad-spectrum antibiotic use.

Results: Among 63 hospitals, 48 reported designated ASP funding/resources. Median broad-spectrum antibiotic use was 52.5%. ASP funding/resources was not associated with overall broad-spectrum antibiotic use (0.97, 95% CI: 0.75–1.25, $P = 0.79$). However, funding was associated with lower use of fluoroquinolones (OR 0.67, 95% CI: 0.46–0.96, $P = 0.03$), clindamycin (OR 0.69, 95% CI: 0.47–1.00, $P = 0.05$), and anti-pseudomonal agents (OR 0.76, 95% CI: 0.59–0.98, $P = 0.03$).

Conclusion: The presence of designated funding and resources for hospital ASPs is linked to reduced use of specific broad-spectrum antibiotics but not overall broad-spectrum antibiotic use. Enhancing ASP resourcing may be an important factor in limiting targeted antibiotic use, thereby increasing the effectiveness of efforts to mitigate AMR.

(Received 9 August 2024; accepted 23 October 2024)

Introduction

One key aim of antimicrobial stewardship programs (ASPs) is to limit the breadth of the spectrum of antimicrobial activity to reduce selective pressure for antimicrobial resistance.[1] Although no standard definition exists for broad-spectrum antibiotic therapy, antimicrobials with activity against clinically relevant pathogens and human microbiota beyond the target pathogen may be associated with a greater risk of antimicrobial resistance and *C. difficile* infections.[2–4]

There is wide variability in antibiotic prescribing across hospitals in terms of both the volume and type of antibiotics prescribed. For example, a study from Ontario, Canada, found a 7.4-fold difference between the hospital with the lowest use and the hospital with the highest use. The variation in use persisted even after adjusting for population characteristics that predict antibiotic use. This suggests an opportunity to reduce practice variation and improve antibiotic prescribing to reduce the risk of harm to hospitalized patients.[5–7] Although hospital ASPs have been widely implemented to improve the quality of antimicrobial prescribing, the extent of program implementation, particularly regarding the level of resourcing and funding for program operation, varies substantially across hospitals.[8,9]

We have previously shown that the presence of designated funding and resources for ASPs is associated with a 13% lower risk-adjusted volume of antimicrobial use (AMU) compared to programs without these resources.[10] However, to our knowledge, the impact of ASP resourcing on hospital-wide broad-spectrum antibiotic use has not been previously evaluated. Our objective was to investigate whether the presence of designated funding and resources for ASPs is associated with a lower proportion of broad-spectrum antibiotic use in hospitals

Corresponding author: Bradley J Langford; Email: brad.langford@gmail.com
Cite this article: Tu M, Shi ZH, Leung V, *et al.* Hospital antimicrobial stewardship funding and resourcing impact on broad-spectrum antibiotic use: a cross-sectional study. *Antimicrob Steward Healthc Epidemiol* 2024. doi: 10.1017/ash.2024.461

Methods

General study design

We conducted a cross-sectional study on AMU among Ontario hospitals as part of the Ontario Hospital ASP Landscape Survey. Details regarding this periodic survey are provided elsewhere.[9] Briefly, this voluntary online survey is conducted by Public Health Ontario every 2–3 years and collects data about program structure (including designated funding and/or resources), activities, and AMU. The relevant question from this survey asks "Are there designated funding/resources for your ASP?". This question was designed to capture the presence of allocated resources to their stewardship program whether or not there was a specific budget allocation for these resources. The survey was available from 3 October 2023 to 29 December 2023 and was disseminated via targeted e-mails to all acute care, inpatient rehabilitation and complex continuing care (CCC) hospitals across the province. There was no incentive offered for participation; however, there were multiple e-mail and telephone reminders to encourage response. All AMU data were self-reported by hospitals using a standardized spreadsheet.

Eligibility

Hospitals were included if they provided at least six months of complete AMU data. Hospitals were excluded if they did not provide data on any of the broad-spectrum antibiotics or the total antibacterial AMU data. Specific data points (eg, AMU data of an antibiotic during a specific fiscal period) were excluded if they were implausible (eg the use data of a specific antibiotic is higher than total antibiotic use data).

Data on antibiotic utilization

Hospital ASPs provided total and class-specific AMU aggregated across the fiscal years from April 2020 to March 2023 as either defined daily dose (DDD or days of therapy (DOT) for all systemic antibacterials (World Health Organization (WHO) Anatomical Therapeutic Chemical Classification J01)[11] administered via the enteral or parenteral route as well as the following selected classes of antibiotics, which for the purposes of this study were defined as broad spectrum: fluoroquinolones (ciprofloxacin, levofloxacin, and moxifloxacin), third-generation cephalosporins (ceftriaxone, cefotaxime, and ceftazidime), beta-lactam/beta-lactamase inhibitor combinations (amoxicillin-clavulanate and piperacillin-tazobactam), carbapenems (ertapenem, meropenem, and imipenem-cilastatin), clindamycin, and parenteral vancomycin. These antibiotics were selected due to their broad spectrum of antimicrobial activity and their potential to increase the risk of *C. difficile* infection. Additionally, most of these antibiotics are classified in the "Watch" category in the WHO Access, Watch, Reserve (AWaRe) list.[12] Hence, careful monitoring of these antibiotics is required to ensure they are used responsibly, preserving their effectiveness and minimizing the emergence and spread of resistant infections.

These antibiotics were further categorized as total broad-spectrum antibiotics (all the antibiotic classes identified above) and anti-pseudomonal antibiotics (ciprofloxacin, levofloxacin, ceftazidime, piperacillin-tazobactam, meropenem, and imipenem-cilastatin).

Survey respondents from corporations with more than one hospital facility provided AMU data for each facility within the organization. If a hospital provided both DOT and DDD data, only the DOT data was used for analysis. The participating hospitals provided the number of patient days (PDs) from inpatient admissions separately as a measure to estimate the volume of patient admissions in the facility.

Exposure

The exposure of interest was ASP funding status which was defined as whether or not hospitals reported having designated funding and/or resources for their program.

Outcomes

The primary outcome was the proportion of all antibiotic use that is broad-spectrum which was calculated by dividing the volume of broad-spectrum AMU (DDD or DOT) by each hospital's total volume of AMU (DDD or DOT) including all J01 antibacterial agents. The calculated proportions were stratified by hospital type (community, teaching, or CCC/rehabilitation) and regions (Toronto, Central, West, East, North-West, and North-East) as defined by the Ontario Ministry of Health.[13] Secondary outcomes include the proportion of AMU for each of the antibiotic classes described above.

Statistical analysis

Descriptive statistics illustrating the median, range, and inter-quartile range were calculated for the proportion of each category of antibiotics. These data were stratified by hospital type and region to account for potential differences in patient populations and epidemiology across different hospitals.

To evaluate the relationship between funding status and the proportion of broad-spectrum antibiotic use, we constructed logistic mixed models. The primary explanatory variable in our models was ASP funding status. The outcome was each hospitals proportion of broad-spectrum antibiotic use and a weight for the total volume of AMU. The fixed effect in the models was funding status, while the random effect was the hospital, which accounts for clustering of the outcome within hospitals.[14] This approach enabled us to quantify the extent to which funding status influenced prescribing practices, with the results expressed as odds ratios (OR) with 95% confidence intervals (CI). An adjusted analysis was performed which included fixed effects for hospital type and metric type (DDD vs DOT) in the model. To further explore the association between funding/resourcing status and specific classes of antibiotic use independent of the total volume of use, we performed a sensitivity analysis using the denominator of only broad-spectrum antibiotic use. All statistical analysis and forest plots were generated using R statistical software version 4.4.0 (R Foundation, Vienna, Austria).

Results

The overall survey response rate was 70% (90/129) of hospital corporations in Ontario and 39% of hospitals provided AMU data (79/202). After exclusions, the final cohort included 63 unique sites, representing 31% (63/202) of individual hospitals in the province. This included 9 CCC/rehabilitation, 16 teaching, 15 large community, 15 medium community, and 8 small community hospitals. Representation was predominantly from the southern, more populated regions of the province. Of the 63 hospitals, 48 (76%) reported designated ASP funding or resources. Funding/resourcing was more commonly reported in acute teaching

Table 1. Hospital participation and presence of ASP funding/resources

	All hospitals (n = 63) N	Funding or resources (n = 48) N, %	No funding or resources (n = 15) N, %
Hospital type			
Acute teaching	16	15 (94%)	1 (6%)
Community	38	26 (68%)	12 (32%)
Complex continuing care/ rehabilitation	9	7 (78%)	2 (22%)
Region			
Central	11	9 (82%)	2 (18%)
East	12	10 (83%)	2 (17%)
North East	3	1 (33%)	2 (67%)
North West	1	0 (0%)	1 (100%)
Toronto	13	12 (92%)	1 (8%)
West	23	16 (70%)	7 (30%)
AMU metrics reported			
DOT	51	38 (83%)	13 (17%)
DDD	12	10 (75%)	2 (25%)

hospitals (n = 15, 94%) compared to community hospitals (n = 26, 68%) and CCC and rehabilitation (n = 7, 78%; Table 1).

Overall antibiotic utilization

The median total AMU for hospitals reporting DDD per 1000 PDs was 413 (IQR 275–494; range 62–690) (n = 12), and for hospitals reporting DOT, it was 415 (IQR 305–529; range 109 to 1656) (n = 51).

Broad-spectrum antibiotic utilization

The median proportion of total broad-spectrum AMU for hospitals was 52.5% (IQR 48.4%–59.7%). Anti-pseudomonal agents (median 22.8%, IQR 18.4%–25.8%), third-generation cephalosporins (median 16.3%, IQR 13.4%–21.3%), and beta-lactam/beta-lactamase inhibitors (median 15.6%, IQR: 11.7%–19.0%) were the most commonly represented categories of broad-spectrum antibiotic use (Table 2).

Funding status and broad-spectrum antibiotic use

After adjusting for hospital type and metric type, the presence of ASP funding/resources was not associated with overall broad-spectrum antibiotic use (OR 1.02, 95% CI: 0.83–1.28). However, funding/resourcing was associated with a lower proportion of fluoroquinolones (OR 0.67, 95% CI: 0.46–0.96, $P = 0.03$), clindamycin (OR 0.69, 95% CI: 0.47–1.00, $P < 0.05$), and anti-pseudomonal agents (OR 0.76, 95%CI: 0.59–0.98, $P = 0.03$). Funding/resourcing status was not associated with higher broad-spectrum antibiotic use for any of the classes studied. Table 2 includes the unadjusted and adjusted OR illustrating the association between ASP funding/resourcing and broad-spectrum antibiotic use. The association between funding/resourcing status and lower use of fluoroquinolones, anti-pseudomonal agents, and clindamycin persisted when using the denominator of only total broad-spectrum antibiotic use (Supplemental Table 1).

Discussion

In this province-wide cross-sectional study, we identified variability in broad-spectrum antibiotic prescribing across 63 hospitals, and ASP funding status was not associated with lower total broad-spectrum antibiotic use. However, hospitals with funding and resources for their ASP used lower proportions of fluoroquinolones, anti-pseudomonal agents, and clindamycin.

The presence of designated funding and/or resources for hospital ASPs has previously been associated with a lower volume of risk-adjusted antibiotic prescribing.[10] This study builds upon these findings to suggest that funding status may also affect antibiotic selection. The US Centers for Disease Control and Prevention (CDC) highlights the importance of a hospital leadership commitment to ensuring ASPs have adequate human, financial, and technology-related resourcing.[15] Several national recommendations exist to provide targets for optimal staffing of ASPs;[16] however, there is evidence these staffing targets are largely unmet.[9]

In our study, the most notable association of funding status with prescribing relates to fluoroquinolones, clindamycin, and anti-pseudomonal agents. Increasing rates of antimicrobial resistance, several black-box warnings, and an elevated risk of *C. difficile* infection have led ASPs to implement interventions to avoid unnecessary fluoroquinolone use.[17–19] Similarly, clindamycin has exhibited one of the highest odds of inciting *C. difficile* infection, yet is rarely a first-line agent for common infections managed in the hospital.[20] As such, this agent is often used inappropriate and is a potential target for ASPs.[21,22] Our study suggests that targeted initiatives may be more successful if the ASP has designated resources, allowing adequate staffing and time to make impactful changes on prescribing.[23,24]

Strengths of this study include a relatively large sample representing various hospital types from across the province. Limitations include the observational nature of these data, which precludes a definitive assessment of causality. However, unpublished data from our team suggest minimal changes in ASP staffing over the study period, limiting the possibility of reverse causation. We lacked patient-level data to adjust for various confounders linked to broad-spectrum prescribing (eg, patient comorbidities and acuity); however, we used hospital type as a proxy for these factors. Additionally, most of the hospitals included represent community and chronic care facilities which incorporate more homogenous patient populations. Although we did not directly assess antibiotic appropriateness, several of the broad-spectrum classes of antibiotics used represent first-line agents for common community and hospital-acquired infections (eg, ceftriaxone and piperacillin-tazobactam, respectively). As such, the usage of such classes of antibiotics may be largely aligned with clinical practice guidelines and less likely to be affected by the intensity of ASP activities. This observation is consistent with our findings—that the usage of agents that represent first-line therapy (eg, third-generation cephalosporins and beta-lactam beta-lactamase inhibitors) for common infections was not associated with the presence of ASP resources. Although there is no widely accepted definition or metric for "broad spectrum," some researchers have devised spectrum scores largely based on clinical spectrum of activity.[25,26] Future efforts are needed to better define "spectrum" and classify antibiotics based on not only their clinical spectrum, but also their propensity for selecting

Table 2. Antimicrobial stewardship program resourcing and impact on broad-spectrum antibiotic use

Antibiotic category	All (n = 63) Median % (IQR)	Funding or resources (n = 48) Median % (IQR)	No funding or resources (n = 15) Median % (IQR)	Association between funding status and broad-spectrum use Unadjusted OR (95% CI)	Association between funding status and broad-spectrum use Adjusted OR (95% CI)
All broad spectrum	52.5 (48.4 to 59.7)	52.6 (50.0 to 59.9)	53.7 (48.3 to 59.6)	0.98 (0.74 to 1.30)	0.97 (0.75 to 1.25)
Fluoroquinolones	8.9 (7.4 to 12.4)	8.4 (6.9 to 9.9)	13.2 (10.2 to 14.7)	0.66 (0.44 to 1.00)	0.67 (0.46 to 0.96)
Third-generation cephalosporins	16.3 (13.4 to 21.3)	17.2 (13.4 to 22.0)	15.4 (13.4 to 17.5)	0.90 (0.62 to 1.31)	1.03 (0.79 to 1.36)
Beta-lactam/beta-lactamase inhibitors	15.6 (11.7 to 19.0)	15.5 (11.8 to 18.1)	17.5 (11.9 to 19.3)	0.97 (0.78 to 1.20)	0.99 (0.80 to 1.22)
Carbapenems	3.8 (2.7 to 5.3)	3.9 (2.9 to 5.6)	2.8 (2.2 to 4.6)	1.26 (0.91 to 1.73)	1.12 (0.82 to 1.51)
Clindamycin	0.7 (0.4 to 1.0)	0.6 (0.4 to 0.8)	1.1 (0.8 to 1.3)	0.62 (0.42 to 0.93)	0.69 (0.47 to 1.00)
Vancomycin	5.1 (3.8 to 6.7)	4.7 (3.5 to 6.7)	5.7 (5.1 to 6.5)	0.95 (0.59 to 1.54)	0.83 (0.54 to 1.29)
Anti-pseudomonal agents	22.8 (18.4 to 25.8)	21.1 (17.7 to 25.3)	25.2 (23.4 to 26.1)	0.81 (0.61 to 1.08)	0.76 (0.59 to 0.98)

*Anti-pseudomonal agents include ciprofloxacin, levofloxacin, ceftazidime, piperacillin-tazobactam, meropenem, and imipenem-cilastatin.

antimicrobial resistance. Only about one-third of hospitals in Ontario are able to prepare and submit AMU data. This may have introduced some degree of selection bias. The data included in this study may not be representative of non-participating facilities, many of which are lacking in ASP funding and resources. As such, these findings may underestimate the impact of ASP resourcing on AMU, given that all the programs able to participate had at least sufficient resourcing to prepare and submit their AMU data. Finally, the data collection period overlaps with the COVID-19 pandemic. The pandemic affected ASP activities[9] and antimicrobial prescribing[27]. Ongoing efforts are needed to quantify the impact of ASP resourcing beyond the pandemic period.

In light of the threat of antimicrobial resistance (AMR), the extent of ASP resourcing may be a critically important factor in mitigating the further emergence and spread of these drug-resistant organisms. Future prospective research evaluating various funding models in different healthcare settings may shed light on optimal approaches to leverage resources for effective ASPs. Cost-effectiveness studies that comprehensively assess cost savings of ASPs in terms of avoidance of negative outcomes may provide robust data needed to convince decision-makers of the importance of adequate staffing.

Conclusion

Hospital ASPs with designated funding and resources are associated with reduced proportional use of fluoroquinolones, clindamycin, and anti-pseudomonal agents but not the overall proportion of broad-spectrum prescribing. The escalating prevalence of AMR necessitates efforts to improve resource allocation and evaluate the impact of such resourcing on hospital ASPs.

Supplementary material. The supplementary material for this article can be found at https://doi.org/10.1017/ash.2024.461.

Acknowledgments. This work was carried out as part of routine operations. No additional funding was received. We wish to thank antimicrobial stewards across Ontario for their participation in the Ontario ASP Landscape Survey.

Financial support. None.

Competing interests. None.

References

1. 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:e51–77.
2. Nakai H, Hagihara M, Kato H, *et al.* Prevalence and risk factors of infections caused by extended-spectrum β-lactamase (ESBL)-producing Enterobacteriaceae. *J Infect Chemother* 2016;22:319–26.
3. Brown KA, Khanafer N, Daneman N, Fisman DN. Meta-analysis of antibiotics and the risk of community-associated *Clostridium difficile* infection. *Antimicrob Agents Chemother* 2013;57:2326–32.
4. Coburn B, Daneman N, MacFadden DR, Rooney A. Re: The impact of antibiotics on the Intestinal microbiota needs to be re-defined in order to optimize the antibiotic usage; by Ruppe et al. *Clin Microbiol Infect* 2018;24:783–4.
5. Zanichelli V, Monnier AA, Gyssens IC, *et al.* Variation in antibiotic use among and within different settings: a systematic review. *J Antimicrobial Chemother* 2018;73:vi17–29.
6. Tan C, Vermeulen M, Wang X, Zvonar R, Garber G, Daneman N. Variability in antibiotic use across Ontario acute care hospitals. *JAntimicrobChemother* 2017;72:554–63.
7. Goodman KE, Baghdadi JD, Magder LS, *et al.* Patterns, predictors, and intercenter variability in empiric gram-negative antibiotic use across 928 United States hospitals. *Clin Infect Dis* 2023;76:e1224–35.
8. Leung V, Wu JH, Langford BJ, Garber G. Landscape of antimicrobial stewardship programs in Ontario: a survey of hospitals. *CMAJ Open* 2018;6:E71–6.
9. Leung V, Quirk J, Muir S, Daneman N, Schwartz KL, Langford BJ. A cross-sectional study of hospital antimicrobial stewardship programmes in the COVID-19 era. *JAC-Antimicrobial Resist* 2022;5:dlac134.
10. Langford BJ, Wu JH, Brown KA, *et al.* Assessing the impact of antibiotic stewardship program elements on antibiotic use across acute-care hospitals: an observational study. *Infect Control Hosp Epidemiol* 2018;39:941–6.
11. World Health Organization Collaborating Centre for Drug Statistics Methodology. ATC/DDD Index 2020 [Internet]. Available from: https://www.whocc.no/atc_ddd_index/. Accessed January 21.
12. World Health Organization. 2021 AWaRe classification: WHO access, watch, reserve, classification of antibiotics for evaluation and monitoring of use [Internet]. 2021. Available from: https://www.who.int/publications/i/item/2021-aware-classification. Accessed March 25, 2024.
13. Ontario Ministry of Health. Ministry reports: Master Numbering System [Internet]. 2024. Available from: https://www.ontario.ca/page/ministry-reports-master-numbering-system. Accessed January 10, 2024.

14. Harrison XA. Using observation-level random effects to model overdispersion in count data in ecology and evolution. *PeerJ* 2014;2:e616.
15. Core Elements of Hospital Antibiotic Stewardship Programs | Antibiotic Use | CDC [Internet]. 2023. Available from: https://www.cdc.gov/antibiotic-use/core-elements/hospital.html. Accessed January 23, 2024.
16. Greene MH, Nesbitt WJ, Nelson GE. Antimicrobial stewardship staffing: How much is enough? *Infect Control Hosp Epidemiol* 2020;41:102–12.
17. Claeys KC, Hopkins TL, Vega AD, Heil EL. Fluoroquinolone restriction as an effective antimicrobial stewardship intervention. *Curr Infect Dis Rep*. 2018;20:7.
18. Wong-Beringer A, Nguyen LH, Lee M, Shriner KA, Pallares J. An antimicrobial stewardship program with a focus on reducing fluoroquinolone overuse. *Pharmacotherapy* 2009;29:736–43.
19. Langford BJ, Seah J, Chan A, Downing M, Johnstone J, Matukas LM. Antimicrobial stewardship in the microbiology laboratory: impact of selective susceptibility reporting on ciprofloxacin utilization and susceptibility of gram-negative isolates to ciprofloxacin in a hospital setting. *JClinMicrobiol* 2016;54:2343–7.
20. Miller AC, Arakkal AT, Sewell DK, *et al.* Comparison of different antibiotics and the risk for community-associated *Clostridioides difficile* infection: a case–control study. *Open Forum Infect Dis* 2023;10:ofad413.
21. Lawes T, Lopez-Lozano JM, Nebot CA, *et al.* Effect of a national 4C antibiotic stewardship intervention on the clinical and molecular epidemiology of Clostridium difficile infections in a region of Scotland: a non-linear time-series analysis. *Lancet Infect Dis* 2017;17:194–206.
22. Feihl S, Querbach C, Hapfelmeier A, *et al.* Effect of an intensified antibiotic stewardship program at an orthopedic surgery department. *Surg Infect (Larchmt)*. 2022;23:105–12.
23. López-Cortés LE, Delgado-Valverde M, Moreno-Mellado E, *et al.* Efficacy and safety of a structured de-escalation from antipseudomonal β-lactams in bloodstream infections due to Enterobacterales (SIMPLIFY): an open-label, multicentre, randomised trial. *Lancet Infect Dis* 2024;24:375–85.
24. Tabah A, Cotta MO, Garnacho-Montero J, *et al.* A Systematic review of the definitions, determinants, and clinical outcomes of antimicrobial de-escalation in the intensive care unit. *Clin Infect Dis* 2016;62:1009–17.
25. Madaras-Kelly K, Jones M, Remington R, Hill N, Huttner B, Samore M. Development of an antibiotic spectrum score based on veterans affairs culture and susceptibility data for the purpose of measuring antibiotic de-escalation: a modified Delphi approach. *Infect Control Hosp Epidemiol* 2014;35:1103–13.
26. Gerber JS, Hersh AL, Kronman MP, Newland JG, Ross RK, Metjian TA. Development and application of an antibiotic spectrum index for benchmarking antibiotic selection patterns across hospitals. *Infect Control Hosp Epidemiol* 2017;38:993–7.
27. Elligsen M, Wan M, Lam PW, *et al.* Trends in hospital antibiotic utilization during the Coronavirus disease 2019 (COVID-19) pandemic: a multicenter interrupted time-series analysis. *ASHE*. 2022;2:e128.