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Essential Resources and Strategies for Antibiotic Stewardship Programs in the Acute Care Setting

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Background. Antibiotic stewardship programs improve clinical outcomes and patient safety and help combat antibiotic resistance. Specific guidance on resources needed to structure stewardship programs is lacking. This manuscript describes results of a survey of US stewardship programs and resultant recommendations regarding potential staffing structures in the acute care setting.

Methods. A cross-sectional survey of members of 3 infectious diseases subspecialty societies actively involved in antibiotic stewardship was conducted. Survey responses were analyzed with descriptive statistics. Logistic regression models were used to investigate the relationship between stewardship program staffing levels and self-reported effectiveness and to determine which strategies mediate effectiveness.

Results. Two-hundred forty-four respondents from a variety of acute care settings completed the survey. Prior authorization for select antibiotics, antibiotic reviews with prospective audit and feedback, and guideline development were common strategies. Eighty-five percent of surveyed programs demonstrated effectiveness in at least 1 outcome in the prior 2 years. Each 0.50 increase in pharmacist and physician full-time equivalent (FTE) support predicted a 1.48-fold increase in the odds of demonstrating effectiveness. The effect was mediated by the ability to perform prospective audit and feedback. Most programs noted significant barriers to success.

Conclusions. Based on our survey's results, we propose an FTE-to-bed ratio that can be used as a starting point to guide discussions regarding necessary resources for antibiotic stewardship programs with executive leadership. Prospective audit and feedback should be the cornerstone of stewardship programs, and both physician leadership and pharmacists with expertise in stewardship are crucial for success.

Keywords. antibiotic stewardship; antimicrobial stewardship; resources; effectiveness; survey.

Antibiotic resistance threatens human health and safety on a global scale and is a key priority of the Centers for Disease Control and Prevention (CDC) and the World Health Organization [1–4]. Antibiotic stewardship programs (ASPs), designed to promote appropriate use of antibiotics, are a major component of the strategy to combat antibiotic resistance, and regulatory bodies such as the Joint Commission [5] in the United States have established standards outlining requirements for ASPs in the acute care setting. These requirements provide important incentives for hospitals to implement ASPs, which have been shown to decrease antibiotic resistance and improve quality of care [6–8]. There is a growing body of evidence supporting the beneficial impact of ASPs in the acute care setting; however, further practical guidance on staffing ratios and resources needed to carry out these recommendations will enhance available information [9–12]. Compared to the United States, European guidelines provide concrete full-time equivalent (FTE)–to-bed ratios, though translating this guidance to the US hospital structure is challenging [13–15].

In April 2016, the Infectious Diseases Society of America (IDSA), along with members of the Society for Healthcare Epidemiology of America (SHEA) and the Pediatric Infectious Diseases Society (PIDS), convened a joint task force to identify resources to assist infectious diseases (ID) specialists interested in initiating and sustaining ASPs. The group consisted of 13 physicians from a variety of backgrounds, including academia and the private sector. The group designed and distributed an electronic survey of ASPs within the United States to better understand existing structures, activities, resources, and gaps.

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This paper describes our survey results and potential staffing structures for the implementation and sustainability of successful ASPs across diverse acute care hospital settings.

METHODS

Survey

A cross-sectional survey of members of IDSA, SHEA, and/or PIDS actively involved in antibiotic stewardship was conducted. Inclusion criteria required membership in at least 1 of the 3 societies with patient care, epidemiology, or administration listed as a primary responsibility. Exclusion criteria were (1) degrees other than doctor of medicine (MD), bachelor of medicine, bachelor of surgery (MBBS), doctor of osteopathic medicine (DO), or doctor of pharmacy (PharmD); (2) trainee status; (3) members outside the United States; (4) employment affiliation listed as industry, public health, or other business; or (5) no affiliated facility listed. To avoid duplicates, the resultant lists were grouped by institution to identify the most appropriate member, as determined by title. Physicians were chosen over pharmacists when both were available. The list was then sorted by state to avoid duplications and to identify cases where members indicated their institution in different ways (eg, UCSF vs UC San Francisco). The list was manually searched to further identify duplicates.

A 73-question electronic survey was developed and distributed via email (Qualtrics, Provo, Utah; see Supplementary Material File 1). Respondents were instructed to forward the survey to the stewardship lead at their institution if they had not been correctly identified. Only 1 response per hospital was accepted. No incentives were provided for participation. Respondents working in stewardship at >1 hospital or as part of a health system were instructed to answer the questions for the hospital where they spent the majority of their time. Survey responses were collected from 29 June to 3 August 2016, with regular reminders sent out to nonresponders.

Definitions

Definitions for cascade reporting of antibiotics, computerized decision support, antibiotic time-out, formulary restriction/prior authorization, and prospective audit and feedback (PAF) are taken from the IDSA/SHEA guidelines for implementation of antimicrobial stewardship and the CDC Core Elements of Hospital Antibiotic Stewardship Programs [9, 16]. Technology add-on was defined as a computer program apart from or in addition to the main electronic medical record that is designed to aid with antibiotic stewardship. The Clinical and Laboratory Standards Institute definition for antibiogram [17] was used.

Analysis

Survey results were analyzed using Stata SE version 14.2 software (StataCorp LP, College Station, Texas), using descriptive statistics to summarize responses. Comparisons among groups were performed using Pearson χ^2 test for categorical variables and 1-way analysis of variance for continuous variables.

Logistic regression analysis was performed to evaluate whether combined physician and pharmacist FTE support was associated with the ability of a program to demonstrate effectiveness. The main outcome was ASP effectiveness, defined as a positive survey response to at least 1 of the following: demonstrated cost savings, decreased antibiotic utilization, or decreased rate of multidrug-resistant organisms (MDROs) within the past 2 years. The main predictor was a continuous measurement of summed physician and pharmacist FTE, hereafter referred to as combined FTE. Stepwise regression analysis with a priori *P* value cutoffs for retention in the multivariable model was conducted. Bed size was locked in the model a priori. Sensitivity analyses included 2 models: the first using forward and backward selection with the same variables but without forcing bed size into the model, and the second retaining all covariates without stepwise selection. Marginal probabilities of effectiveness were calculated for levels of combined FTE and were graphed with 95% confidence intervals.

A second logistic regression analysis, using identical covariates and effectiveness outcomes, evaluated the impact of pharmacist FTE and physician FTE separately, defined as continuous variables.

A third logistic regression analysis was designed to determine which stewardship strategies act as mediators of the relationship between combined FTE and ASP effectiveness. A sensitivity analysis included all strategies listed above, plus use of a technology add-on.

Determination of Proposed Recommended FTE-to-Bed Ratio

Using the results of the survey responses for the number of existing FTE positions paired with the number of FTE perceived by respondents to be needed, the Task Force developed a consensus recommendation for a minimum FTE-to-bed ratio proposed to staff an ASP adequately in the acute care setting.

Prototype Program

A subgroup of the Task Force defined attributes of a prototype ASP and compared FTE support for programs overall and by attribute. This analysis is presented in Supplementary Material File 2.

RESULTS

Survey Demographics

Two hundred forty-four of 1989 (12%) invitees (189 physicians, 52 pharmacists) completed the survey. Table 1 illustrates the characteristics of the respondents' ASPs. ASPs had been present for a median of 5 years (interquartile range, 1–10 years). Respondents came from 43 states. Most practiced stewardship at academically affiliated hospitals (46%) or major academic centers (21%). Of the physicians, 55 (29%) worked in private

Table 1. Characteristics of Antibiotic Stewardship Program Setting and Scope (N = 244)

Characteristic	No. (%)
Location	
Northeast	56 (23.0)
Midwest	63 (25.8)
South	62 (25.4)
West	60 (24.6)
Unknown	3 (1.2)
No. of hospitals where respondent works	
1	158 (64.8)
2	50 (20.5)
≥3	36 (14.8)
No. of beds at primary hospital	
<100	15 (6.2)
100–300	91 (37.3)
301–500	82 (33.6)
501–1000	45 (18.4)
>1000	11 (4.5)
Primary hospital's teaching status	
Major academic medical center	71 (29.1)
Academic affiliation	114 (46.7)
Nonteaching	54 (22.1)
Other	5 (2.1)
Primary hospital's specialty services	
Level 1 trauma center	89 (36.5)
Burn unit	36 (14.8)
Solid organ transplant program	84 (34.4)
Bone marrow transplant program	66 (27.1)
Primary hospital part of a health system	191 (78.3)
System- vs hospital-level ASP	
Hospital-level stewardship	93 (48.7)
Mixed system- and hospital-level stewardship	79 (41.4)
Stewardship centralized at health system level	19 (10.0)
Noninpatient settings covered by ASP	
Outpatient	35 (14.3)
Emergency department	135 (55.3)
Long-term care facility	21 (8.6)
ASP provides telestewardship	30 (12.3)

Abbreviation: ASP, antibiotic stewardship program.

practice, 129 (68%) as employees of healthcare systems, and 52 (28%) as salaried academic employees. One hundred fifty-nine (84%) took care of adults, with the remainder split between pediatricians (10%) and those trained in both medicine and pediatrics (6%). While almost all physician respondents were ID board certified or eligible (99%), only 44% of pharmacists were ID residency trained, with another 27% of those without residency training having a certificate in antibiotic stewardship. Respondents' ASPs were generally led by physicians (56%) or co-led by physicians and pharmacists (36%). Nineteen programs (8%) lacked accountable physician leaders.

Leadership Commitment

One-hundred eighty-four (75%) respondents reported a written stewardship policy at their main institution, while 57% of physicians (107/189) and 73% of pharmacists (38/52) noted stewardship as part of their job description. Table 2 shows current physician and pharmacy FTE support at sampled programs along with additional FTEs that respondents felt were needed to operate effectively. A combined sum of FTE is reported for each size hospital.

Nearly all programs (97%) reported the presence of electronic medical records, and 156 (64%) reported having information technology add-ons to assist with stewardship, with the most common ones being Theradoc (Premier, Inc), Epic ICON (Infection Control) module, Sentri7 (Wolters Kluwer), and MedMined (Becton Dickinson). Data analytics support was available at 40 programs (16%), with an average FTE of 0.25. Administrative support for ASPs was available in 32 programs (13%), with mean FTE of 0.16.

Action

Broad Interventions

Most ASPs reported performing prior authorization for select antibiotics (81%) and antibiotic reviews with PAF (84%), while a minority of programs reported having computerized decision support systems at the time of antibiotic prescription (32%) or an antibiotic time-out (33%). There was a significant increase in the proportions of programs reporting PAF with increasing combined FTE. Only 27 (60%) programs in the <0.5 combined FTE category reported performing PAF as compared to 48 (86%) in the 0.5 to <1.0 category, 74 (90%) in the 1.0–1.5 category, and 57 (93%) in the >1.5 category ($P < .001$).

Pharmacists performed PAF 72% of the time, with attending ID physicians participating 22% of the time. Accordingly, physician respondents reported spending on average 4.5 hours per week doing PAF while pharmacists reported 19.5 hours. The most common strategy for selecting patients for PAF was based on selected target antibiotics (79% of programs performing PAF). Other common strategies for identifying patients on whom to intervene included laboratory-based (eg, drug levels, microbiology [48%]) and guideline-based triggers (eg, duration for indication [35%]). The numbers of patients reviewed and on whom feedback was provided rose with increasing FTE ($P = .003$ and $P = .01$, respectively). Most programs (71%) reported providing feedback on ≤15 patients per day. Recommendations were documented in the chart by 81 (39%). When conflicts occurred, most programs (57%) defer to the primary service. However, 29 programs (14%) mandate consultation, and another 37 (18%) have no official policy. Only 5 programs (2%) report the ASP has authority to override the primary service.

Of the 179 programs (73%) who had local antibiotic guidelines for common clinical conditions, those for pneumonia (92%), surgical prophylaxis (86%), urinary tract infection (68%), and skin and soft tissue infection (66%) were popular. Pharmacy-driven interventions, including automatic dose

Table 2. Full-time Equivalent (FTE)–to-Bed Ratio: Existing and Needed FTEs Reported by Programs (N = 244)

	Bed Size				
FTE	<100 (n = 15)	100–300 (n = 91)	301–500 (n = 82)	501–1000 (n = 45)	>1000 (n = 11)
Existing MD FTE	0.27 (0–0.87)	0.24 (0–1.2)	0.26 (0–1.0)	0.37 (0–1.0)	0.46 (0.2–1.4)
Additional MD FTE needed	0.11 (0–0.8)	0.15 (0–1.0)	0.15 (0–1.0)	0.19 (0–1.5)	0.42 (0–2.4)
Total combined MD FTE	0.38 (0–1.4)	0.39 (0–1.7)	0.41 (0–2.0)	0.56 (0–2.1)	0.88 (0.2–2.8)
Existing PharmD FTE	0.61 (0–2.0)	0.63 (0–2.0)	0.89 (0–3.0)	1.2 (0–2.0)	1.5 (0.5–3.1)
Additional PharmD FTE needed	0.28 (0–2.0)	0.32 (0–1.4)	0.31 (0–2.0)	0.52 (0–2.5)	1.18 (0–7.0)
Total combined PharmD FTE	0.89 (0.2–4.0)	0.95 (0–2.8)	1.20 (0–4.0)	1.69 (0–4.5)	2.68 (0.8–9.0)
Total MD and PharmD overall FTE	1.27 (0.3–5.4)	1.34 (0–3.3)	1.61 (0–6.0)	2.24 (0.43–5.5)	3.56 (1.5–11.8)

Data are presented as mean (range).

Abbreviations: FTE, full-time equivalent; MD, doctor of medicine; PharmD, doctor of pharmacy.

adjustment, pharmacokinetic monitoring, and intravenous to oral conversions, were common across all sizes of hospital and did not vary significantly by FTE (data not shown).

Microbiological Interventions

Antibiograms were produced by 243 programs (99%), and 125 (51%) performed cascade reporting of antibiotic susceptibilities. Rapid diagnostics were widely available, with 153 (63%) using respiratory viral panels, 116 (48%) rapid diagnostic testing of blood specimens (any platform), and 114 (47%) rapid identification of *Staphylococcus aureus*. Procalcitonin testing was available at 128 (53%) hospitals. There were no notable differences in availability of microbiology interventions based on FTE support (data not shown). Rapid viral testing and rapid testing of blood cultures were significantly more common (P = .001 and P = .005, respectively) at larger hospitals.

Tracking and Reporting

Two-hundred thirty-nine (98%) programs reported monitoring at least 1 metric, including 66 (27%) who endorsed reporting to the National Healthcare Safety Network's Antimicrobial Use and Resistance option. The majority of reports (79%) were prepared by pharmacists with a minority prepared by physicians (11%) or data analysts (5%). These reports were most frequently presented at pharmacy and therapeutics (79%) and/or infection control (57%) committees and were infrequently presented to front-line clinicians (25%).

Outcomes

Two hundred eight (85%) programs reported demonstrating some measure of effectiveness in the past 2 years. More specifically, 164 programs (67%) reported cost savings, 168 (69%) reported decreased antibiotic utilization, and 49 (20%) reported a decrease in rates of drug-resistant organisms. In a multivariate model using stepwise selection of confounders including bed size, there was a consistent dose-response relationship between combined FTE and ability to demonstrate effectiveness in any domain (Table 3). Each 0.50 increase in combined FTE availability resulted in a 1.48-fold increase in the odds of demonstrating effectiveness (95% confidence interval, 1.06–2.07). This finding remained significant when the outcome of interest was limited only to demonstrating decreased antibiotic use, a metric more reliably related to ASP efforts (data not shown), as well as 2 sensitivity analyses utilizing different rules for covariate

Table 3. Predictors of Ability to Demonstrate Effectiveness

Variable	Univariate OR (95% CI)	Primary aOR (95% CI)	Sensitivity Analysis 1 aOR (95% CI)	Sensitivity Analysis 2 aOR (95% CI)
Combined PharmD and MD FTE, 0.50 increase	1.60 (1.17–2.20)	1.48 (1.06–2.07)	1.50 (1.09–2.06)	1.42 (1.00–2.02)
Bed size				
0–300	0.78 (.36–1.73)	1.04 (.46–2.38)	…	0.95 (.39–2.33)
301–500	Reference	Reference	…	Reference
>501	1.75 (.58–5.27)	1.20 (.38–4.32)	…	1.09 (.29–4.07)
ASP technology add-on	2.57 (1.25–5.28)	2.04 (.96–4.32)	2.05 (.98–4.32)	2.23 (1.01–4.98)

The primary multivariate model used forward and backwards stepwise selection with bed size categories locked into the model; sensitivity analysis 1 used forward and backwards stepwise selection with no variables locked into the model; sensitivity analysis 2 locked all covariates into the model, including bed size, training of the ASP team, age of the ASP program, presence of an ASP policy, member of a health system, teaching status, presence of a burn unit, presence of a trauma unit, solid organ transplantation and bone marrow transplantation, and ASP technology add-on availability.

Abbreviations: aOR, adjusted odds ratio; ASP, antibiotic stewardship program; CI, confidence interval; FTE, full-time equivalent; MD, doctor of medicine; OR, odds ratio; PharmD, doctor of pharmacy.

selection. Availability of a technology add-on was a strong predictor in univariate models of ability to demonstrate effectiveness, though it fell short of statistical significance in multivariate models. Figure 1 shows the likelihood of demonstrating effectiveness based on combined FTE status.

Table 4 shows the impact of increasing physician and pharmacist FTE separately on the ability to demonstrate effectiveness. While there was an increased numerical odds of effectiveness with increasing physician FTE, this was not statistically significant. The effect of increasing pharmacist FTE on effectiveness was significant for both the primary model and the first sensitivity analysis but fell just shy of statistical significance for the second sensitivity analysis, with each 0.50 increase in FTE resulting in a 58% increase in the odds of a program being effective.

Potential mediators of effectiveness are shown in Table 5. PAF appears to be the strongest mediator of ASP success. For a program with all of these actions plus technology add-ons, the probability of being able to demonstrate effectiveness is 93% if the combined FTE support is a mean 1.1, rising to 98% at a combined FTE level of 3.5.

Education

Overall, 229 programs (94%) provided education to at least 1 group of stakeholders, most commonly physicians (87%) or pharmacists (77%), and less often to nurses (40%) or patients (9%).

Barriers

One hundred fifty-one (62%) programs somewhat or strongly disagreed with the statement "the financial resources for my program are adequate." The most commonly cited barriers to implementation of a successful ASP were lack of time (66%),

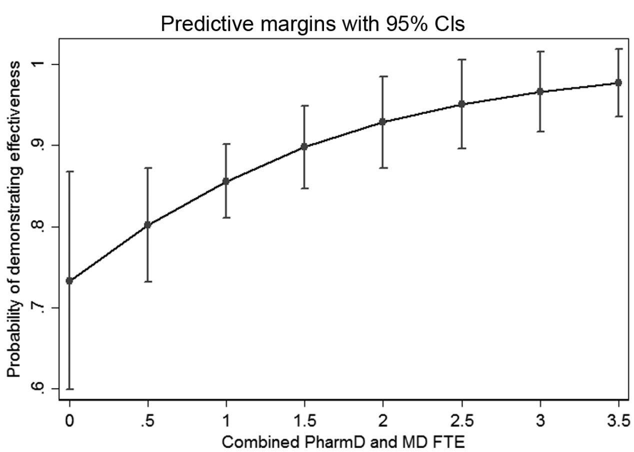

Figure 1. Predicted effectiveness based on staffing levels. A program having 0 full-time equivalent has no financial support for antibiotic stewardship program physician or pharmacist staff but may still perform stewardship activities. Abbreviations: CI, confidence interval; FTE, full-time equivalent; MD, doctor of medicine; PharmD, doctor of pharmacy.

financial resources (63%), and information technology issues (61%). Only 18 programs (7%) reported no barriers. In programs lacking PAF, the most common barrier was lack of physician and/or pharmacist time (84%). Another 58% reported lack of ID or stewardship expertise as a barrier, while 42% noted that implementation of such a program did not appear to be an institutional priority.

DISCUSSION

In a survey of diverse ASPs from various geographical areas, we found an independent relationship between physician and pharmacist FTE and self-reported effectiveness of ASPs. This relationship was mediated mostly through the ability of programs with higher levels of staffing, specifically pharmacist support, to perform PAF. This finding aligns with a recent CDC study that found an association between salary support and the ability of an organization to have a comprehensive ASP [18]. Importantly, even programs with positive outcomes perceive understaffing, and nearly all respondents desired additional FTE support for both pharmacists and physicians. From the results of this survey, we have developed a proposed FTE-to-bed ratio that could be used as a starting point to guide discussions with executive leadership when developing and augmenting ASPs (Table 6) [19]. The intent of this research is to provide useful benchmarks for those currently engaged in ASP programs or those who are working to establish well-resourced ASPs and may inform business plan development. From this ratio, a hospital-specific cost based on salary and benefits could be estimated and, based on this, financial effectiveness goals set for the program. Further evaluation of this ratio in a variety of settings is warranted.

Like any effective program, the right number of qualified individuals for the volume of the organization is critical. The results of this survey demonstrate the integral role of the pharmacist in effective stewardship programs and argue for enhancement in the pipeline of stewardship and ID-trained pharmacists with leadership skills and attitudes to plan, do, study, and act toward improving the use of antibiotics and effectively change behaviors in healthcare settings. Furthermore, a named physician leader responsible for the outcome of the program is necessary for interfacing with the C-suite and other physician/provider groups as well as helping to navigate priority-setting for the organization. It is the conclusion of our group that a physician-to-pharmacist ratio of approximately 1:3 allows for the highest-value use of resources. There are creative ways to distribute these FTEs, especially in small hospitals and complex health systems.

Given the effectiveness of PAF described in this survey, this would be a reasonable starting activity for developing ASPs or those needing to prioritize activities. Although the data are mixed, consistent with our findings, a recent trial suggests that PAF is superior to formulary restriction with prior authorization

Table 4. Effect of Individual Physician and Pharmacist Support on Ability of a Program to Demonstrate Effectiveness

			Sensitivity Analysis 1	Sensitivity Analysis 2
Variable	Univariate OR (95% CI)	Primary aOR (95% CI)	aOR (95% CI)	aOR (95% CI)
MD FTE, 0.50 increase	1.79 (.79–4.05)	1.23 (.52–2.89)	1.25 (.55–2.84)	1.22 (.51–2.93)
PharmD FTE, 0.50 increase	1.77 (1.20–2.60)	1.58 (1.02–2.43)	1.58 (1.06–2.35)	1.48 (.97–2.28)
Bed size				
0–300	0.78 (.36–1.73)	0.90 (.38–2.15)	…	0.97 (.39–2.40)
301–500	Reference	Reference	…	Reference
>501	1.75 (.58–5.27)	1.38 (.42–4.50)	…	1.13 (.27–4.66)
ASP technology add-on	2.57 (1.25–5.28)	2.08 (.97–4.46)	2.03 (.96–4.27)	2.20 (1.00–4.85)
Part of a health system	0.54 (.20–1.46)	0.46 (.16–1.31)	…	0.48 (.16–1.45)
Burn unit	0.67 (.27–1.68)	0.46 (.16–1.30)	…	0.38 (.11–1.29)

The primary multivariate model used forward and backwards stepwise selection with bed size categories locked into the model; sensitivity analysis 1 used forward and backwards stepwise selection with no variables locked into the model; sensitivity analysis 2 locked all covariates into the model, including bed size, training of the ASP team, age of the ASP team, presence of an ASP policy, member of a health system, teaching status, presence of a burn unit, presence of a trauma unit, solid organ transplantation and bone marrow transplantation, and ASP technology add-on availability.

Abbreviations: aOR, adjusted odds ratio; ASP, antibiotic stewardship program; CI, confidence interval; FTE, full-time equivalent; MD, doctor of medicine; OR, odds ratio; PharmD, doctor of pharmacy.

with respect to appropriate and guideline-concordant antibiotic use [9, 20]. Given the strong association of technology add-ons with self-reported effectiveness, these programs should be considered in conjunction with an existing ASP. Having access to a technology add-on enhances the ASP but does not replace the manpower required to perform effective PAF and run a successful program.

Several important limitations to this survey should be noted. First, there was a low response rate of 12%. It is unknown whether the nonrespondents were not affiliated with ASPs or just declined to participate; it is unlikely that there are 1900 people doing stewardship in the United States, so many of the nonrespondents may not have been affiliated with ASPs. Because we relied on membership of ID-enriched societies, there was a selection bias for programs employing ID physicians, which do not exist at all hospitals. As a result, there were limited responses from smaller community hospitals, including rural and critical access hospitals. However, our sample did include programs of a variety of sizes and type with representation from all geographical regions. Another limitation is the reliance on self-reported effectiveness; whether this reflects true effectiveness is undefined as we did not validate the responses. In addition, we did not quantify the degree and significance of reported effectiveness, nor did we inquire about the impact of other interventions on *Clostridium difficile* infection and MDRO rates. However, our finding of increasing FTE associated with effectiveness held up even when effectiveness was limited to decreased antibiotic use, a metric less likely affected by other cointerventions such as improved environmental cleaning, hand hygiene campaigns, or new pharmacy purchasing contracts. Last, the survey was designed to inquire about stewardship practices on an institutional level and it asked respondents to focus on the hospital where they spent the most time. Therefore, it is difficult to draw conclusions on staffing recommendations for ASPs that cover >1 hospital or an entire health system.

In the setting of new regulations, repeating this survey in the future will help monitor the changing landscape. Ideally, a repeat survey would be expanded to a larger and more representative population and will have better metrics for measuring success. As ASPs expand outside acute care settings, understanding resources needed to run effective programs in these environments will also be critical. In summary, we have

Table 5. Mediators of the Relationship Between Full-time Equivalent Support and Effectiveness of a Program

Variable	Univariate OR (95% CI)	Primary aOR (95% CI)	Sensitivity Analysis aOR (95% CI)
Combined PharmD and MD FTE, 0.50 increase	1.60 (1.17–2.20)	1.36 (.98–1.90)	1.30 (.94–1.81)
Antibiotic time-out	1.59 (.71–3.56)	1.58 (.68–3.67)	1.60 (.68–3.77)
Cascade reporting	0.82 (.40–1.66)	0.68 (.32–1.46)	0.70 (.33–1.51)
Restricted formulary with prior authorization	1.01 (.41–2.48)	0.81 (.31–2.14)	0.80 (.29–2.16)
Institutional guidelines	1.70 (.80–3.59)	1.35 (.59–3.07)	1.32 (.58–3.02)
Prospective audit and feedback	4.88 (2.21–10.79)	3.92 (1.66–9.30)	3.82 (1.60–9.13)
ASP technology add-on	2.57 (1.25–5.28)	…	1.97 (.91–4.22)

The primary model includes the actions of a prototype program. The sensitivity analysis includes these actions plus presence of an ASP technology add-on.

Abbreviations: aOR, adjusted odds ratio; ASP, antibiotic stewardship program; CI, confidence interval; FTE, full-time equivalent; MD, doctor of medicine; OR, odds ratio; PharmD, doctor of pharmacy.

Table 6. Minimal Full-time Equivalent Support Recommended by Bed Size

Variable	Bed Size			
	100–300	301–500	501–1000	>1000
Pharmacist	1.0	1.2	2.0	3.0
Physician	0.4	0.4	0.6	1.0
Total	1.4	1.6	2.6	4.0

For hospitals with <100 beds, there were limited data to make recommendations.

provided initial recommendations for staffing, structure, and attributes of acute care ASPs, which can be used by hospitals developing and sustaining ASPs.

Supplementary Data

Supplementary materials are available at *Clinical Infectious Diseases* online. Consisting of data provided by the authors to benefit the reader, the posted materials are not copyedited and are the sole responsibility of the authors, so questions or comments should be addressed to the corresponding author.

Notes

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