Infection Control & Hospital Epidemiology (2020), **41**, 102–112
doi:10.1017/ice.2019.294

Review

Antimicrobial stewardship staffing: How much is enough?

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Abstract

Antimicrobial stewardship improves patient care and reduces antimicrobial resistance, inappropriate use, and adverse outcomes. Despite high-profile mandates for antimicrobial stewardship programs across the healthcare continuum, descriptive data, and recommendations for dedicated resources, including appropriate physician, pharmacist, data analytics, and administrative staffing support, are not robust. This review summarizes the current literature on antimicrobial stewardship staffing and calls for the development of minimum staffing recommendations.

(Received 5 June 2019; accepted 21 September 2019; electronically published 15 November 2019)

Antimicrobial resistance (AMR) is a critical patient safety and public health crisis emphasized by the Centers for Disease Control and Prevention (CDC) and the World Health Organization (WHO).[1,2] Calls for a coordinated approach to antibiotic stewardship emerged in the literature more than 40 years ago.[3] The Infectious Diseases Society of America (IDSA) and the Society for Healthcare Epidemiology of America (SHEA) first recommended antibiotic stewardship in acute-care hospitals (ACH) in 1997 then updated guidelines for implementation in 2007.[4,5] In 2012, SHEA, IDSA, and the Pediatric Infectious Diseases Society (PIDS) urged for antibiotic stewardship programs (ASPs) to be required through regulatory mechanisms.[6]

In 2014, the Presidential Executive Order—Combating Antibiotic-Resistant Bacteria (CARB)—called for a comprehensive antibiotic stewardship plan, and the CDC's "7 Core Elements" for a successful hospital ASP.[7,8] The following year, the National Action Plan directed all ACHs to establish ASPs by 2020 and to expand antibiotic stewardship across the healthcare continuum.[9] The National Quality Forum and the Joint Commission's standards incorporated the CDC core elements, 3 of which refer directly to resource allocation: dedicated human, financial, and information technology resources.[8,10,11] However, the degree of resources required for a successful ASP at a given institution is not standardized and is influenced by numerous variables including bed size, case-mix index, healthcare delivery model, level of training, and number of support pharmacists. These factors were specifically acknowledged in a recent multisociety white paper.[12]

Mounting evidence demonstrates that ASPs can optimize individual patient outcomes, improve the quality of care, and provide critical patient safety processes while reducing antimicrobial-associated adverse events (eg, acute kidney injury and *C. difficile* infection rates), length of stay, and AMR development.[8,13,14] Antibiotic stewardship strategies can be implemented in any healthcare setting, and they are often cost-saving for institutions. Multidisciplinary engagement and myriad interventions from allergy management to rapid diagnostic review have demonstrated profound success.

Researchers have studied optimal provider staffing, including physicians, nurses, and pharmacy and quality personnel, in diverse healthcare settings, often demonstrating improved patient outcomes with appropriate staffing standards, particularly in intensive care units (ICUs).[15–22] This review describes the existing literature on antibiotic stewardship staffing, builds on the historical parallel of infection prevention staffing standardization, and concludes with a call to action for formal antibiotic stewardship staffing standards.

The infection prevention parallel

Infection prevention programs serve as an important model for leveraging ASP infrastructure and implementation resources.[23] Reviewing the timeline reveals similar struggles with establishing formal staffing guidelines and appropriate funding mechanisms (Fig. 1). One of the first infection prevention studies addressing staffing was an 18-month evaluation of time required to "carry out a surveillance program of at least intermediate effectiveness (p 314)" in 6 community hospitals from 1965 to 1966.[24] The outcomes informed the initial CDC infection prevention staffing recommendation of 1 infection preventionist full-time equivalent (FTE) per 250 occupied beds.[25] The CDC's landmark Study on the Efficacy of Nosocomial Infection Control (SENIC) project demonstrated that several foundational infection prevention activities and a ratio of 1 infection preventionist for every 250 beds yielded a 32% reduction in nosocomial infection (Table 1).[26] Further analysis to explore a more "lenient" staffing ratio confirmed these findings: infection reductions "declined sharply" as the number of occupied beds per infection preventionist rose above 250.

Participation in the CDC's National Nosocomial Infections Surveillance (NNIS) system is limited to hospitals with a minimum of 1 infection preventionist FTE for the first 100 occupied beds

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Cite this article: Greene MH, Nesbitt WJ, and Nelson GE. (2020). Antimicrobial stewardship staffing: How much is enough?. *Infection Control & Hospital Epidemiology*, 41: 102–112, https://doi.org/10.1017/ice.2019.294

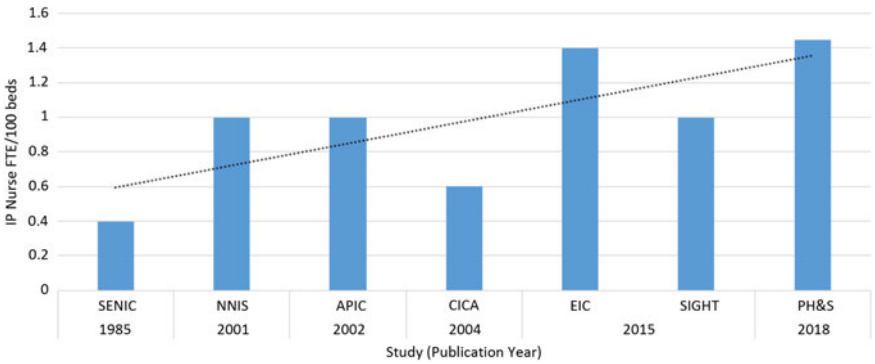

Fig. 1. Recommended Infection Prevention Staffing Resources. IP, Infection Prevention; FTE, full-time equivalent; SENIC, Study on the Efficacy of Nosocomial Control; NNIS, National Nosocomial Infections Surveillance; APIC, Association for Professionals in Infection Control and Epidemiology; CICA, Canadian Infection Control Alliance; EIC, European Infection Control; SIGHT, Systematic Review and Evidence-Based Guidance on Organization of Hospital Infection Control Programmes; PH&S, Providence Health and Services.

Table 1. Selected Studies of Infection Prevention Resources

First Author	Year Published	Study	IP Nurse FTE/100 beds	Recommendation/ Observation
United States, Inpatient				
Haley[26]	1985	SENIC	0.4	Recommendation – Based on infection surveillance data
Richards[27]	2001	NNIS	1	Recommendation – Requirement for participation
O'Boyle[28]	2002	APIC	1	Recommendation
Stone[29]	2014	P-NICER	1.2	Observation
Bartles[35]	2018	Providence Health & Services	1.45	Recommendation – Needs assessment "aggregated across the organization"
Non-United States, Inpatient				
Morrison[30]	2004	Canadian Infection Control Alliance	0.6	Recommendation
Zingg[31]	2015	SIGHT	1	Recommendation – Systematic review
Rodriguez-Bano[33]	2015	European infection control	1	Recommendation – Expert review
Hansen[32]	2015	PROHIBIT	0.4	Observation
Dickstein[34]	2016	ESCMID survey	0.8	Observation

Note. IP, infection prevention; FTE, full-time equivalent; SENIC, Study on the Efficacy of Nosocomial Control; NNIS, National Nosocomial Infections Surveillance; APIC, Association for Professionals in Infection Control and Epidemiology; P-NICER, Prevention of Nosocomial Infections and Cost Effectiveness Refined; SIGHT, Systematic Review and Evidence-Based Guidance on Organization of Hospital Infection Control Programmes; PROHIBIT, Prevention of Hospital Infections by Intervention and Training; ESCMID, European Society of Clinical Microbiology and Infectious Diseases.

(and 1 FTE for each additional 250 beds).[27] The increasing volume and complexity of infection prevention activities prompted the Association for Professionals in Infection Control and Epidemiology (APIC) to re-evaluate infection preventionist staffing ratios. Using the Delphi method, a panel of 45 infection preventionists reported 40 of the 46 "essential" tasks identified were not regularly completed, citing many barriers foreshadowing antibiotic stewardship concerns, namely "competing responsibilities" and "access to resources (p 998)." [28] The APIC then recommended 1 infection preventionist FTE per 100 occupied beds, nearly double that of the existing SENIC guidelines and similar to NNIS staffing directives.

The 2011 Prevention of Nosocomial Infections and Cost Effectiveness Refined (P-NICER) study of 975 hospitals and 1,534 ICUs provided the most comprehensive evaluation of infection prevention program structure and support in the United States after SENIC; it reported an average of 1.2 infection preventionists per 100 beds.[29] The authors concluded that the current recommendation of "0.8 to 1 infection preventionist per 100 hospital beds . . . are most likely out of date due to the complexity and responsibilities of infection prevention in hospitals today (p 97)" and staffing was "not consistent with published guidelines (p 98)."

Infection preventionist staffing standards are coming into focus throughout the globe; recent data suggesting that current recommendations may still be below actual labor needs.[30–34] Recently, Providence Health and Services, a large healthcare organization comprising 34 hospitals, performed a multifaceted evaluation including literature review, current infection prevention time allocation assessment, regional meetings with key stakeholders, and a quantitative needs assessment. These measures resulted in a staffing model developed to address priorities and gaps individualized to regions and hospitals. They concluded that the ideal benchmark should be 1 infection preventionist per 69 occupied beds if outpatient and long-term care (LTC) settings are included.[35] Unfortunately, hospital surveys often demonstrate poor "real world" adherence to staffing recommendations despite consensus regarding their impact on patient safety—a phenomenon also evident in the antibiotic stewardship literature. The barriers and progress in infection preventionist staffing and resource allocation serve as an ideal framework through which to view ASP development.

Surveys describing stewardship staffing and financial needs and barriers

A recent white paper on behalf of IDSA, SHEA, and PIDS recommends that compensation for ASPs be distinct from funds dedicated to infection prevention, with protected time afforded to antibiotic stewardship physicians and staff "appropriately scaled to facility size (p 998)."[12] Unfortunately, surveys of budding and active ASPs routinely cite insufficient financial resources, time, and staff as barriers to program success.[36–38] A 1999 survey of Emerging Infections Network (EIN) members—a network of US infectious diseases providers established by the CDC—found that 50% of respondents performed antimicrobial prior authorization

https://doi.org/10.1017/ice.2019.294 Published online by Cambridge University Press

but only 18% received remuneration for this effort (Table 2).[39] An accompanying commentary emphasized the value of this monitoring despite "little or no pay" and suggested that antibiotic stewardship physicians receive a global fee for "non–patient-care activities," which can be justified by an annual report to hospital administration.[40,41]

Following the 2007 IDSA/SHEA antibiotic stewardship guidelines, 52% of health professionals surveyed lacked an ASP; personnel shortages (55%) and financial considerations (35%) were cited as the top 2 barriers to program implementation,[42] which was confirmed in a separate 2009 survey with similar results.[43] A follow-up EIN survey in 2009 demonstrated only a modest increase ASP presence, with 25% of ASPs lacking physician involvement and only 52% of physicians receiving compensation for antibiotic stewardship activities.[44]

Pediatric ASPs have faced similar resource challenges. In a 2008 EIN survey, only 33% of pediatric facilities featured an ASP, and >50% of respondents cited funding and personnel insufficiencies as barriers to ASP implementation.[45] A subsequent 2011 survey of freestanding children's hospitals demonstrated similar results: 38% had a formal ASP and 36% were planning implementation. Identical support barriers were voiced among those without an ASP.[46] For existing ASPs, the median number of total FTE support was only 0.63 (median bed size, 295) even though total FTE support, particularly pharmacist FTE, correlated with the number of monitored antibiotics. More recently, the Sharing Antimicrobial Reports for Pediatrics Stewardship (SHARPS) collaborative reported data on their 36 participating hospitals with an overall antibiotic stewardship FTE of only 0.75 (median bed size, 284).[47]

In 2011, 5 years after California Senate Bill 739 mandated all state ACHs develop an ASP,[48] only 50% of facilities had complied with only 73% of physicians and 80% of pharmacists receiving any dedicated antibiotic stewardship FTE support.[49] Subsequent California legislation in 2014 (Senate Bill 1311) went further, requiring inpatient ASPs to have at least 1 physician or pharmacist leader.[50] Missouri passed a similar legislative mandate (Senate Bill 579), also requiring National Healthcare Safety Network (NHSN) antimicrobial use reporting though staffing and funding mechanisms were not clarified.[51]

The first NHSN survey accounting for antibiotic stewardship practices in the United States was conducted in 2014. Only 32% of the 4,184 ACHs surveyed provided antibiotic stewardship salary support despite both the 2014 and 2015 NHSN surveys demonstrating salary support to be an independent predictor for achieving all 7 CDC core elements.[52,53] The theme of limited resources for antibiotic stewardship continues to ripple through the movement's timeline, with particular impact on smaller, community hospitals.[44,54] Small community hospitals (<200 beds) represent 72% of US nonfederal hospitals, but only 31% of hospitals with <50 beds and 26% of critical-access hospitals (<25 beds) have an ASP featuring all 7 CDC core elements.[55–57] Despite these substantial barriers, successes have been demonstrated in the community setting by optimizing available resources.[54,57–60]

Even among *US News and World Reports* (USNWR) highest-ranking hospitals, a recently published 2016 survey reported that fewer than half of institutions (48%) have a dedicated ASP budget.[61] Most of these hospitals (65%) have ≤0.5 physician FTE, and 48% of programs feature only 0.51–1.0 pharmacist FTE. For surveyed ASPs with a budget, most fell within the range of $50,000–$250,000 per year. However, as an example, pediatric hospital ASP budgets ranged from $17,000 to $388,500 annually, without correlation to hospital size, which demonstrates the inconsistencies in hospital ASP funding.

International antimicrobial stewardship staffing

Much of the concrete guidelines for antibiotic stewardship resources have been provided by stewardship colleagues abroad (Table 3). Nevertheless, international ASPs still struggle to meet policy recommendations. The French Ministry of Health has mandated public reporting of each hospital's antibiotic policy since 2007.[62,63] Data from the 2007 antibiotic policy questionnaire produced a composite index (ICATB) to assess appropriate antimicrobial use.[64] In 2015, using the previously developed ICATB indices, a French AMR task force surveyed 65 French facilities to assess the human resources required to implement recommended ASP activities. Ultimately, they recommended 3.6 antibiotic supervisor FTE, 2.5 pharmacist FTE, and 0.6 microbiologist FTE per 1,000 acute-care beds—a dramatic increase from prior staffing targets.[65]

In 2011, the Australian Commission on Safety and Quality in Health Care required all hospitals to implement an ASP by 2013.[66] However, surveys in 2012 demonstrated that implementation was lagging with only 5% of hospitals in Victoria and 19% of Queensland hospitals reporting a dedicated ASP.[67,68] Lack of educational training in antimicrobial use and insufficient pharmacy resources were leading barriers.

An internet-based survey distributed to 660 hospitals in 67 countries by the European Society of Clinical Microbiology and Infectious Diseases (ESCMID) in 2012 sought to characterize global AS.[69] Respondents were mostly European from tertiary teaching hospitals (48%) with >500 beds (52%). National antibiotic stewardship standards existed in 52% of countries, dominated by Europe (81%), but formal ASPs were present in only 58% of hospitals, ranging from 67% in North America to 14% in Africa. The number of resource hours per week varied dramatically between countries; lack of funding and personnel were reported as the major barriers to implementation by all respondents.

In Canada, antibiotic stewardship has been required in ACHs since 2013.[70] Given the lack of clarity around necessary human resources required and the complexity of petitioning hospital administration, the Association of Medical Microbiology and Infectious Diseases Canada (AMMI) recently published a "business case" for ACH ASPs through expert consensus. They proposed 1 physician FTE, 3 pharmacist FTE, 0.5 administrative staff FTE, and 0.4 data analyst FTE per 1,000 ACH beds, with a minimum requirement of 0.1 physician FTE and 0.3 pharmacist FTE regardless of institutional size. Nevertheless, a recent survey of 97 organizations in Ontario found that only 50% of hospitals had designated antibiotic stewardship resources; teaching hospitals reported 0.57 physician FTE and 2.16 pharmacist FTE per 1,000 beds. Small community hospitals averaged only 0.006 pharmacist FTE and 0 physician FTE.[71]

In 2017, Pulcini[72] et al summarized the proposed minimum staffing standards by countries with mandatory hospital antimicrobial stewardship: Australia (4 FTE per 1,000 acute-care beds), Austria and Germany (2 FTE per 1,000 beds), Canada (4.9 FTE per 1,000 acute-care beds), France ("optimal" goal of 6.7 FTE per 1,000 acute-care beds), and The Netherlands (3 FTE for bed size >750).[65,70,72–75] This summary also commented that ASPs remain understaffed or nonexistent in most countries, with almost exclusive inpatient focus despite the fact that most global antimicrobial use originates in the outpatient environment. The 2017

https://doi.org/10.1017/ice.2019.294 Published online by Cambridge University Press

Table 2. Selected Surveys Reporting Antimicrobial Stewardship Program Resources

First Author	Year Published	Respondents, No.	Population Surveyed	Respondents with ASP, %	Budgeted Support if ASP present, %	Factors associated with ASP	Top 2 Barriers Reported
United States, Inpatient							
Sunenshine[39]	2004	502	EIN	50 (preauthorization)	18	Teaching hospitals	. . .
Pope[42]	2009	357	SHEA membership	48	. . .	Pharmacy driven de-escalation and dose optimization	Personnel Financing
Hersh[45]	2009	147	Pediatric EIN	33	60 (pharmacist) 40 (physician)	. . .	Funding Time
Septimus[59]	2011	568	HealthTrust Purchasing Group	15 (“antimicrobial committee”)	. . .	. . .	. . .
Johannsson[44]	2011	522	EIN	61	48	Less likely in community hospitals and <200 beds	Funding Personnel
Doron[43]	2013	406	Yankee and Premier Healthcare Alliance	51	. . .	Teaching hospitals and higher bed number	Staffing Funding
Abbo[144]	2013	82	Florida Hospital Association	55	35 (programs with >0.5 physician FTE)	Facilities >250 beds	Funding Personnel
Trivedi[49]	2013	223	California ACHs	50	73 (pharmacist) 80 (physician)	Less likely in rural areas and <200 beds	Staffing Funding
Newland[46]	2014	38	Children’s Hospital Association[a]	38	42	Inpatient bed number and transplant patients	Funding Personnel
Pollack[52]	2016	4184	NHSN	39 (meeting all CDC core elements)	32	Major teaching hospitals and >200 beds	. . .
O’Leary[53]	2017	4569	NHSN	48 (meeting all CDC core elements)	. . .	Teaching status and >200 beds	. . .
Newland[47]	2017	36	SHARPS Pediatric Collaborative	. . .	83	. . .	. . .
Nhan[61]	2019	101	USNWR highest-ranking hospitals	82	48	. . .	. . .

Note. ASP, antimicrobial stewardship program; EIN, Emerging Infections Network; SHEA, Society for Healthcare and Epidemiology of America; ACH, acute-care hospital; NHSN, National Healthcare Safety Network; SHARPS, Sharing Antimicrobial Reports for Pediatric Stewardship; USNWR, United States News and World Report; FTE, full-time equivalent.

[a]Survey sent to freestanding children’s hospitals that are members of Children’s Hospital Assocation.

Table 3. Selected Antimicrobial Stewardship Program Staffing Proposals

First Author	Year Published	Group/Nation	Physician FTE(s)/100 Beds	Pharmacist FTE(s)/ 100 Beds	IT FTE(s)/ 100 Beds	Other FTE(s)/ 100 Beds	Total FTE(s)/ 100 Beds
United States, Inpatient							
Federal Register[90]	2016	CMS	0.08	0.2	0.04	...	0.32
Echevarria[88]	2017	VHA ASTF	0.25	1	...	...	1.25
Doernberg[36a]	2018	IDSA, SHEA, PIDS					
		100–300 beds	0.2	0.5	...	...	0.7
		301–500 beds	0.1	0.3	...	...	0.4
		501–1000 beds	0.08	0.27	...	...	0.35
		>1000 beds	0.1	0.3	...	...	0.4
Non-United States, Inpatient							
Duguid[73]	2011	Australia	0.1	0.3	...	...	0.4
Le Coz[65]	2016	France	0.36	0.25	...	0.06 (microbiologist)	0.67
de With[74]	2016	Germany/Austria	...	...	...	...	0.2
Plachouras[76]	2017	ECDC	...	...	...	...	0.2–0.6
Morris[70]	2018	Canada	0.1	0.3	0.04	0.05 (administrative)	0.49
Ten Oever[75]	2018	Netherlands	...	...	...	...	≈0.3[b]

Note. FTE, full-time equivalent; IT, information technology; CMS, Centers for Medicare and Medicaid Services; VHA, Veterans' Health Administration; ASTF, antimicrobial stewardship task force; IDSA, Infectious Diseases Society of America; SHEA, Society for Healthcare Epidemiology of America; PIDS, Pediatric Infectious Diseases Society; ECDC, European Centre for Disease Prevention and Control.

[a]Physician, pharmacist and total FTE/100 beds calculated from average bed size per given range (eg, 200 for 100–300 range, 400 for 301–500, 750 for 501–1,000) except for >1,000 beds, which was calcuated per 1,000 beds.

[b]Approximated from recommended range for "optimal staffing standards during the first few years of implementing an ASP" of 1.25 FTE per 300 beds to 3.18 FTE per 1,200 beds (ie, 0.27–0.42 FTE per 100 beds).

European Centre for Disease Prevention and Control (ECDC) technical report proposed 0.5–1.5 FTE for antibiotic stewardship activities per 250 acute-care beds, citing the French and German recommendations.[76]

Comparing ASP FTE between individual countries is complicated by varying expectations and definitions of antibiotic stewardship activity in a given nation and by differing funding streams (eg, private vs national health system).[72,77,78] Importantly, much of the world's antimicrobial overuse occurs in low- and middle-income countries with scant resources for antibiotic stewardship.[79,80] The United Nations General Assembly high-level AMR meeting in 2016 inspired calls for a "Global Antimicrobial Conservation Fund" to provide transitional financial and technical support to build ASP capacity in the developing world.[81,82]

Unfortunately, most international stewardship literature—regardless of nation—does not comment on ASP team composition nor provide FTE data, leading some to propose that human resources be added to the reporting checklist for epidemiologic studies on AMR (STROBE-AMS).[83,84]

Proposed staffing ratios in the United States

Within the United States, the Veterans' Health Administration (VHA) has led the way in promoting antibiotic stewardship implementation and staffing requirements, creating the antibiotic stewardship initiative in 2010, followed by the National Antibiotic Stewardship Task Force (ASTF) in 2011.[55,85] In 2012, the VHA Healthcare Analysis and Information Group (HAIG) surveyed all 130 VHA facilities to characterize antibiotic stewardship structure and practices.[86] At the time, 38% of hospitals had an ASP defined as at least a physician and clinical pharmacist. In 2014, VHA Directive 1031 mandated every VHA facility implement antibiotic stewardship paired with annual ASP evaluations.[85,87] Following this directive, 89% of facilities had a defined ASP by 2015 (compared to 41% in 2011), with a 12% decrease in inpatient antimicrobial use compared to 2010.[87]

Next, the VHA ASTF partnered with the Clinical Pharmacy Practice Office, a national program that previously developed standardized clinical pharmacy staffing models, to create a staffing calculator based on time-in-motion tracking studies from 12 facilities in 2014 for both clinical interventions and program management activities.[88] The ASTF found that a median of 2.62 FTE (1.01 FTE per 100 occupied beds) were required. After excluding outliers, the group proposed 1 pharmacist FTE per 100 occupied beds (Fig. 2). Though not extrapolated from this study, the group also proposed 0.25 physician FTE per 100 occupied beds. They concluded that a minimum of 0.25 physician FTE and 0.5 pharmacist FTE should be allotted for hospitals with <100 beds. In 2017, VHA Directive 1131 required minimum physician and pharmacist FTE staffing in keeping with this study's findings based on facility complexity.[89]

A 2016 cross-sectional electronic survey of 244 members of IDSA, SHEA, and PIDS actively involved in antibiotic stewardship reported on "self-reported effectiveness" in relation to staffing levels, defined as demonstrating ≥1 of the following: cost savings, decreased antimicrobial use or decreased rate of multidrug-resistant organisms in the prior 2 years.[36] Multivariate analysis accounting for bed size showed a 1.48-fold increase in program

https://doi.org/10.1017/ice.2019.294 Published online by Cambridge University Press

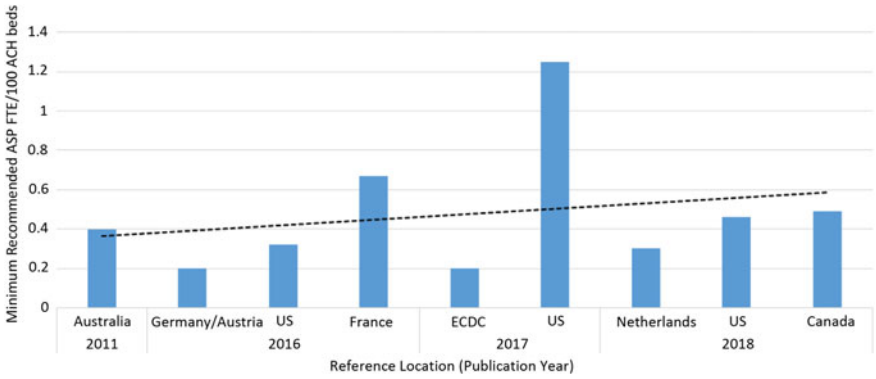

Fig. 2. Selected Antimicrobial Stewardship Program Staffing Proposals. ASP, Antimicrobial Stewardship Program; FTE, full-time equivalent; ACH, Acute Care Hospital; US, United States; ECDC, European Centre for Disease Prevention and Control.

effectiveness for every additional combined 0.5 FTE support. These authors proposed minimum combined FTE support of 1.4 FTE for hospitals with 100–300 beds, 1.6 FTE for 301–500 beds, 2.6 FTE for 501–1,000 beds, and 4 FTE for settings with >1,000 beds. Furthermore, they proposed a physician-to-pharmacy ratio of 1:3 for the "highest-value use of resources."

In 2016, the Department of Health and Human Services Centers for Medicare and Medicaid Services (CMS) stated, "(However, we believe that) the burden of implementing and maintaining an AS (program) includes the salaries of the qualified personnel needed to establish and manage such a (CAH) program (p 39474)." They suggested 0.1 physician FTE (preferably trained in infectious diseases), 0.25 pharmacist FTE, and 0.05 data analyst FTE for an average-sized hospital of ~124 beds.[90]

Antimicrobial stewardship team composition: Who "counts?"

Numerous studies and reviews have evaluated different permutations of a successful antibiotic stewardship team, including varied approaches to leadership, team composition, and antibiotic stewardship–specific training.[37,57,58,91–94] The 2012 SHEA, IDSA, and PIDS policy statement recommended that an ASP should include a physician, a pharmacist, a clinical microbiologist, and an infection preventionist.[6] The Joint Commission suggests a multidisciplinary ASP include an infectious disease physician, pharmacist(s), and infection preventionist(s) when available, They allow part-time, consulting, and even telehealth staff.[11] Most proposed FTE metrics refer to either physician or pharmacy personnel; minimal comment or data pertain to information technology (IT) and administrative support. In the previously mentioned 2016 resources survey, only 16% of surveyed programs had data analytics support (average FTE, 0.25) and only 13% featured administrative support (mean FTE, 0.16).[36] AMMI Canada formally recommended designated administrative and data analytic support, though a follow-up survey demonstrated that only 11% of established ASPs had such funding.[71] Despite the potential effectiveness and efficiency of antibiotic stewardship IT systems, resource allocation is often lacking, as is analytic support for the data generated.[37,95–97]

The open question of "who counts" when evaluating antibiotic stewardship staffing is especially important for smaller medical facilities.[54,57] The VHA and other authors have called for future studies to facilitate the recruitment of less "traditional" ASP personnel (including hospitalists, nursing staff and tele-ASPs), particularly for institutions where infectious disease specialists are simply not available, including many long-term care (LTC) settings.[12,85,92,98] Although a variety of staffing models exist, the importance of dedicated support for AS-specific activities cannot be overstated.

Stewardship staffing outside the hospital

The 2012 SHEA, IDSA and PIDS policy statement asks for antibiotic stewardship to be a "fiduciary responsibility for all healthcare institutions across the continuum of care (p 322)." [6] In 2015, the CDC published its *Core Elements of Antibiotic Stewardship for Nursing Homes then the Core Elements of Outpatient Antibiotic Stewardship* in 2016.[99,100] Long-term care ASPs have been required by CMS since November 2017.[101] Most antimicrobial use and expenditure occurs outside the hospital (eg, clinics, emergency departments (ED), hemodialysis units and LTC facilities), and only one-third of outpatient prescriptions are appropriate.[102–104] Data on the prevalence of outpatient antibiotic stewardship activity are scant, clouding our understanding of true staffing needs.[85,105–108]

Outpatient stewardship staffing

Several reviews of evidence-based outpatient antibiotic stewardship interventions exist, but they do not provide guidance on funding mechanisms.[105,109,110] According to one reviewer, compared to inpatient strategy, it is difficult "to justify funding based on reductions in antibiotics expenditures or decreased length of stay (p 458)."[110] Although resource-intensive approaches such as provider feedback demonstrate impact and support outpatient ASP expansions, interventions often focus on educational awareness and IT decision support tools.[105,110–118] Various personnel models for outpatient antibiotic stewardship infrastructure have been suggested, including engaging, training, and incentivizing community pharmacists and public health department personnel and leveraging community collaborations and health systems.[85,110,119] Experts continue to call for research into outpatient ASPs with varying resources as well as "potential policies or incentives" to promote outpatient antibiotic stewardship.[120]

Long-term care stewardship staffing

A comprehensive 2016 review of LTC antibiotic stewardship found that <20% of nursing homes employ full-time physicians and that most medical directors spend only 8–12 hours per week providing direct patient care.[121] An early survey of Nebraska LTC facilities found that 60% had an ASP, though more recent surveys revealed only 23% in Michigan and 28% in Rhode Island where a paltry 15% received budgeted support with mean FTE allocations

https://doi.org/10.1017/ice.2019.294 Published online by Cambridge University Press

for physicians and infectious disease pharmacists of 0.02 and 0.01, respectively.[122–124] A variety of antibiotic stewardship approaches have been employed in LTC facilities to leverage limited available resources, including sharing antibiotic stewardship personnel.[121,125–129] Despite some success, staffing limitations often prohibit more reliable but resource-heavy interventions.[127]

Other considerations

Beyond setting size, location, and team composition, additional variables affecting appropriate stewardship staffing are worth considering but are rarely discussed.[12] Care complexity influences resource allocation for high-risk patient populations (eg, transplant recipients or burn patients) who are especially prone to prolonged antibiotic exposure and complications.[128] A 2015 survey of 71 solid-organ hematopoietic stem cell transplant centers in 32 states cited staffing challenges as a barrier for transplant antibiotic stewardship.[129] ASPs presumably require more resources in the "initiation" phase (particularly for IT support) compared to an established program in the "maintenance" phase of program development.[97] Data evaluating how complexity and intensity of care as well as the presence of specialty services are limited, but the effect of these variables on antimicrobial use and need for risk adjustment have been examined previously.[130–132] It follows that staffing ratios would similarly require calibration to reflect differing needs. Whether minimum requirements are tied only to occupied bed count or some other measure warrants further study. Elements of the NHSN's pioneering standardized antimicrobial administration ratio (SAAR) (eg, academic affiliation and ICU bed count) could be utilized for adjusting expected ASP staffing needs.[132,133]

Yet another call to action

The recurring theme in antibiotic stewardship staffing literature is insufficient financial and human resources. Spellberg et al[134] point out the temptation for institutions to "check the box" in response to regulatory requirements yet still understaff the true needs of a robust multidisciplinary ASP. The literature is replete with "real world" examples of this phenomenon in California, Canada, Australia, and beyond. As stated bluntly by Pulcini et al,[72] formal antibiotic stewardship staffing standards are needed and should be linked to sustainable funding mechanisms.

The general movement away from "fee for service" models toward reimbursement for quality of care presents an opportunity for a productive partnership between antibiotic stewardship and hospital administration.[135,136] Conditions of participation in Medicare were recently approved and include language to regulate and incentivize ASP development and references prior 2016 CMS staffing proposals.[137] Specific quality and staffing metrics (some with direct monetary incentives) are emerging in visible national organizations, including the Leapfrog Group, Agency for Healthcare Research and Quality and USNWR.[138] Leapfrog now relies on information collected from the NHSN survey, and the USNWR pediatric survey includes a minimum threshold of 0.4 FTE for pharmacy support, 0.3 FTE for medical director, and 0.2 FTE for analyst support dedicated to ASP.[139,140] Such incentives are likely to help ASPs "compete" for resource allocation in a given institution.[133]

Most inpatient ASP staffing proposals recommend a combined physician and pharmacist FTE of roughly 1 to every 100–250 occupied beds, with a suggested physician-to-pharmacist ratio of 1:3.[36,65,70,72,88] Therefore, a formal recommendation establishing a total of 1 FTE ASP support for every 250 beds, optimally with ~1 physician for every 3 pharmacists, offers a bare minimum expectation for inpatient facilities. Relying on even the most up-to-date staffing recommendations is fraught with limitations because the optimal stewardship FTE-to-bed ratio remains a "moving target." The minimum inpatient recommendation should evolve over time and with facility complexity, just as infection preventionist staffing expectations have matured since SENIC.

Stewardship resource standards are desperately needed for outpatient and LTC settings as well as for accompanying analytic and administrative support. Technology support is required to integrate ASP tools to enhance the vital human components of ASPs, and resources for software as well as support likewise deserve attention.[97] Further studies are needed to characterize human resource parameters for antibiotic stewardship across the healthcare continuum, which should both further refine inpatient standards and prompt yet another call to action for outpatient stewardship staffing benchmarks.[57,141,142]

Zahn et al[143] could not be more right in stating, "Physicians performing infection control and antimicrobial stewardship work should be compensated for these activities (p 355)." Stewardship staffing standards, analogous to evolving infection prevention recommendations, are necessary to provide appropriate resources for ASPs. Just as medical centers, providers, patients, and their families expect robust infection prevention activity to optimize safe and quality care, healthcare entities should sufficiently staff and fund antibiotic stewardship for both inpatients and outpatients to decrease the public threat of antibiotic resistance and adverse antibiotic exposure outcomes.

Acknowledgments. None

Financial support. No financial support was provided relevant to this article.

Conflicts of interest. All authors report no conflicts of interest relevant to this article.

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