

Learning Experiences Within Infectious Diseases Pharmacy Residency Programs in the United States: A Cross-Sectional Survey

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Background. Pharmacists with residency training in infectious diseases (ID) optimize antimicrobial therapy outcomes in patients and support antimicrobial stewardship (AS) programs. Although most ID residencies are accredited and assessed by certain standards, the degree to which these programs are similar is not known.

Methods. A 19-item, cross-sectional, multicentered, electronic survey was distributed via e-mail to pharmacy residency program directors (RPDs) of all 101 second-year postgraduate (PGY-2) ID residency programs in the United States.

Results. Survey responses were collected from 71 RPDs (70.3%); 64.8% were associated with an academic medical center and 97.2% focused primarily in adult ID. Rotations in the microbiology laboratory, adult AS, and adult ID consult were required in 98.6% of residency programs. Only 28.2% of responding programs required pediatric AS and pediatric ID consult rotations. Programs at academic medical centers were more likely to offer immunocompromised host ID consult ($P = .003$), pediatric ID consult ($P = .006$), and hospital epidemiology ($P = .047$) rotations but less frequently offered outpatient AS ($P = .003$), viral hepatitis clinics ($P = .001$), and travel medicine clinics ($P = .007$) rotations compared to programs at nonacademic medical centers. Residents were frequently involved in AS committees (97.2%), pharmacokinetic dosing of antimicrobials (83.1%), precepting pharmacy trainees (80.3%), and performing research projects (91.5%).

Conclusions. The PGY-2 ID pharmacy residency programs demonstrated consistency in required adult ID consult, antimicrobial management activities, committee service, and teaching and research opportunities. Pediatric experiences were less common. The PGY-2 ID residency programs prepare pharmacists to become antimicrobial stewards for adult patients.

Keywords. antimicrobial stewardship; education; infectious diseases; pharmacist; pharmacy residency.

Antimicrobial resistance remains a growing global public healthcare concern with significant impacts on healthcare expenditure and patient outcomes [1]. Infections due to resistant organisms are more difficult to treat, associated with increased hospital length of stay, and have been shown to be a significant cause of morbidity and mortality [2–4]. The Centers for Disease Control and Prevention estimates that at least 2 million people acquire an antibiotic-resistant infection, and approximately 23 000 deaths occur annually due to resistant organisms in the United States [5]. A surveillance report published by the World Health Organization also highlights the severity and burden

of antimicrobial resistance globally [6]. Inappropriate use of antimicrobials contributes to the development of antimicrobial resistance with estimates showing up to 50% of antimicrobials being misused in the hospital setting [7–9]. Even higher rates of inappropriate antimicrobial use occur in outpatient settings [10, 11]. A key strategy to mitigate this issue is promoting the judicious and appropriate use of antimicrobials through antimicrobial stewardship programs (ASPs). Numerous studies have shown ASPs to be an effective strategy to combat antimicrobial resistance while decreasing antibiotic expenditures, length of stay, and mortality rates [7, 11, 12].

Joint guidelines published by the Infectious Diseases Society of America and the Society of Healthcare Epidemiology of America recognize infectious diseases (ID) physicians and ID-trained pharmacists as core members of the antimicrobial stewardship team [12]. The Society of Infectious Diseases Pharmacists (SIDP) and the American College of Clinical Pharmacy (ACCP) recommend that pharmacists who wish to become specialized in ID pharmacotherapy complete first-year postgraduate (PGY-1) and second-year postgraduate (PGY-2) residencies in ID, followed by board certification [13].

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Currently, there are considerable differences in the level of integration and depth of antimicrobial stewardship topics delivered in colleges of pharmacy [14]; however, both medical and pharmacy students believe that strong antimicrobial knowledge is important for their careers and desire more education on ID and appropriate antimicrobial use [15, 16]. Hence, residency programs serve as a mechanism for pharmacists to receive formalized postgraduate pharmacotherapy training, and it is recommended that residency training serve as a prerequisite for entry into pharmacy practice [17, 18]. Both the American Society of Health-System Pharmacists (ASHP) and ACCP recommend that PGY-2 training be completed for pharmacists caring for highly specialized and complex patient populations, including infectious syndromes [17–19]. Accredited PGY-2 ID residency programs provide pharmacists the knowledge, skills, and attitudes necessary to participate as a core member of an ASP and to educate pharmacy trainees [17, 19]. The ASHP provides general guidance regarding core competencies and objectives for accredited PGY-2 ID pharmacy residencies [20]; however, the ID pharmacotherapy topics covered and level of residents' involvement have yet to be described. This study aims to identify the learning experiences, program directors' credentials, antimicrobial stewardship principles discussed, and extent of residents' contributions during PGY-2 ID pharmacy residency programs in the United States. In addition, available learning experiences among academic and nonacademic PGY-2 ID residency programs were compared.

METHODS

Study Design, Setting, and Population

This was a cross-sectional, multicenter, electronic survey study of PGY-2 ID pharmacy residency programs in the United States. The survey was designed to capture the program characteristics and determine the opportunities offered. All accredited and nonaccredited PGY-2 ID pharmacy residency programs listed on the ASHP, ACCP, and SIDP residency directories as of January 2018 were included in the study. Incomplete surveys, defined as surveys with 1 or more missing responses, were excluded from the study. This study was approved by The University of Texas at Tyler's Institutional Review Board.

Survey Instrument

A 19-item survey instrument was developed to collect information about the learning experiences offered during a PGY-2 ID pharmacy residency program. This survey was created based on expert opinions of ID pharmacists, faculty, residency program directors (RPDs), and the ASHP Required Educational Outcomes, Goals, and Objectives for PGY-2 ID Residencies [20]. Information collected from the survey included the following: practice setting, geographic location by state, accreditation status, funding source, number of residents accepted annually, length of establishment, number of ID-trained

preceptors, primary focus area of the residency program, learning experiences offered, rotation format, and residents' average scholarly contributions over the past 5 years. Geographic location was further grouped into West, Midwest, Northeast, and South regions as defined by the US Census Bureau [21]. Rotation formats were categorized into (1) required or elective rotations and (2) block or longitudinal experiences. Survey respondents were able to select multiple responses for learning experiences that were offered as both required and elective rotations. Characteristics of RPDs, including years of experience, training, and credentials were also captured. Responses pertaining to the frequency of stewardship activities discussed, teaching opportunities available, and frequency of disease state management by the resident were formatted via a 5-point Likert scale, where 1 = never and 5 = always. Before dissemination, the survey was pilot tested by the investigators, 2 ID pharmacists (ID PharmDs), and 4 pharmacy residents to assess for readability, length, and logistical integrity.

Survey Administration

Infectious diseases pharmacy RPDs were individually contacted to participate in the study. Contact information for the RPDs was obtained from the ASHP, ACCP, and SIDP residency directories or through an online search of the residency program's website. Surveys were distributed via e-mail directly to the RPDs from February to April 2018 and were conducted using Qualtrics survey software (Qualtrics, Inc., Provo, UT). An e-mail reminder to nonresponders was sent by investigators every 4 weeks as needed during the data collection period.

Statistical Analysis

Data analysis was conducted using SPSS Statistics, version 24 (IBM, Armonk, NY). Descriptive statistics were used to summarize and depict demographic information of the pharmacy residency program, qualifications and experience of the RPD, and training opportunities offered. Institutions were classified into 2 groups: academic medical centers and nonacademic medical centers. Fisher's exact test was used to evaluate differences in categorical data between groups including clinical rotation formats, learning experiences, and scholarly contributions by the resident. Wilcoxon rank-sum test was used to analyze differences in ordinal data between groups including teaching experiences and frequency of disease state management by the resident. All statistical tests were 2-tailed, with the alpha-level set a priori to 0.05.

RESULTS

One hundred one survey instruments were e-mailed to PGY-2 ID pharmacy residency programs in the United States. Of the 74 responses received, 3 were discarded due to incomplete data resulting in a response rate of 70.3% (71 of 101). Overall, 64.8% of residency programs were associated with an academic medical

center, 15.5% were associated with a community teaching hospital, 9.9% were associated with a Veterans Affairs or government institution, 7% were associated with a community nonteaching hospital, and 2.8% were associated with a college of pharmacy. Programs were geographically well distributed with 25.4% located in the Northeast, 26.8% located in the Midwest, 32.4% located in the South, and 15.5% located in the Western regions. The primary funding source for 78.9% of programs was solely by the institution/practice site. When comparing residency programs affiliated with academic medical centers ($n = 46$) versus nonacademic medical centers ($n = 25$), there were no statistically significant differences in accreditation status, funding source, number of residents admitted into the program, length of program establishment, and primary focus area (Table 1). The RPD's years of experience, training, and credentials were also similar among the 2 groups. Approximately 80% of program directors practiced as an ID PharmD for ≥ 6 years, 78.9% completed a PGY-2 ID residency or ID fellowship program, and 77.4% were board certified pharmacotherapy specialists with added qualifications in ID, demonstrating appropriate training and expertise of program directors. The ASHP recommends that RPDs should be pharmacists that completed an ASHP-accredited PGY-2 residency program, maintains an active practice in the respective area for at least 3 years after their postgraduate training, and obtains board certification in the specific practice area. Residency programs at academic medical centers were more likely to have 4 or more ID PharmD preceptors (52.2% vs 24%, $P = .026$), whereas those at nonacademic medical centers were more likely to have 1 ID PharmD preceptor (20% vs 2.2%, $P = .018$). Infectious diseases physician fellowship programs were also more commonly found at academic medical centers (82.6% vs 40%, $P < .001$).

Clinical rotations offered by PGY-2 ID pharmacy residency programs are shown in Table 2. Adult ID (97.2%) remained the primary area of focus for most programs. Almost all programs (98.6%) required residents to complete adult antimicrobial stewardship, microbiology laboratory, and adult ID consult rotations; pediatric antimicrobial stewardship and pediatric ID consult rotations were required in 28.2% of programs. The majority of programs required residents to participate in research (85.9%), adult human immunodeficiency virus (HIV) (83.1%), and infection prevention/control (57.7%) rotations. Rotation formats (block or longitudinal) were consistent between program practice settings. Sepsis (97.2%), lower respiratory tract (97.2%), skin and soft tissue (97.2%), urologic (90.1%), and intra-abdominal infections (87.3%) were managed regularly by the ID pharmacy resident (Table 3). Sixty-nine (97.2%) residents were either often or always involved with antimicrobial stewardship committees, 59 (83.1%) with antimicrobial dosing, and 46 (64.8%) with infection control committees (Table 4). A minority of residents were involved with penicillin skin testing services (35.2%), off-hour antimicrobial stewardship

Table 1. Demographics and Characteristics of Postgraduate Year-2 Infectious Diseases Pharmacy Residency Programs and Program Directors

Characteristics	N = 71 (%)
ASHP Accreditation Status	
Accredited	53 (76.6)
Candidate	14 (19.7)
Precandidate	3 (4.2)
Not accredited	1 (1.4)
Funding Source	
Fully funded by the institution/practice site	56 (78.9)
Fully funded by the college of pharmacy	4 (5.6)
Split funded by the practice site and college of pharmacy	8 (11.3)
Other	3 (4.2)
Number of Residents in Program	
1	65 (91.6)
>1	6 (8.4)
Residency Program Years in Existence	
<1	3 (4.2)
1–5	30 (42.3)
6–10	13 (18.3)
>10	25 (35.2)
Number of ID Pharmacist Preceptors	
1	5 (7)
2	18 (25.4)
3	17 (23.9)
>3	31 (43.7)
ID Physician Fellowship Program Available?	
Yes	48 (67.6)
No	23 (32.4)
Primary Area of Focus	
Adult ID	69 (97.2)
Pediatric ID	1 (1.4)
Other (eg, HIV, viral hepatitis)	1 (1.4)
Years as the Residency Program Director	
1–5	43 (60.6)
6–10	18 (25.4)
>10	10 (14.1)
Years Practicing as an ID Pharmacist	
1–5	14 (19.7)
6–10	27 (38)
11–15	16 (22.5)
>15	14 (19.7)
Program Director's Training and Credentials	
PGY-2 ID pharmacy residency	49 (69)
ID pharmacy fellowship	7 (9.9)
BCPS (AQ-ID)	55 (77.4)
Fellow of a national pharmacy organization	10 (14.1)
Fellow of a national ID organization	4 (5.6)

Abbreviations: ASHP, American Society of Health-System Pharmacists; AQ-ID, added qualifications in infectious diseases; BCPS, Board Certified Pharmacotherapy Specialist; HIV, human immunodeficiency virus; ID, infectious diseases; PGY-2, postgraduate year-2.

coverage (32.4%), and review of emergency department cultures (43.7%). In regards to research and education, 65 (91.5%) residents frequently performed longitudinal research projects, 43 (60.6%) completed medication use evaluations, 57 (80.3%) served as preceptors to pharmacy students or PGY-1 pharmacy residents, and 39 (54.9%) provided multidisciplinary teaching

Table 2. Learning Experiences Offered During the Postgraduate Year-2 Infectious Diseases Pharmacy Residency Program

Rotations Offered	Rotation Availability N = 71 (%)			Format N = 71 (%)	
	Required	Elective	Not Offered	Block	Longitudinal
Antimicrobial Stewardship (adults)	70 (98.6)	4 (5.6)	-	50 (70.4)	21 (29.6)
Antimicrobial Stewardship (pediatrics)	20 (28.2)	26 (36.6)	27 (38)	40 (56.3)	4 (5.6)
Adult ID Consult	70 (98.6)	3 (4.2)	1 (1.4)	65 (91.5)	5 (7)
Pediatric ID Consult	20 (28.2)	27 (38)	24 (33.8)	45 (63.4)	2 (2.8)
Adult HIV (inpatient)	25 (35.2)	7 (9.9)	40 (56.3)	21 (29.6)	9 (12.7)
Pediatric HIV (inpatient)	1 (1.4)	4 (5.6)	66 (93)	4 (5.6)	1 (1.4)
ICHS ID Consult	32 (45.1)	14 (19.7)	25 (35.2)	45 (63.4)	1 (1.4)
Oncology	7 (9.9)	41 (57.7)	23 (32.4)	46 (64.8)	2 (2.8)
Solid Organ Transplant	9 (12.7)	41 (57.7)	21 (29.6)	50 (70.4)	-
Bone Marrow Transplant	9 (12.7)	35 (49.3)	28 (39.4)	42 (59.2)	1 (1.4)
Critical Care (adults)	34 (47.9)	38 (53.5)	-	70 (98.6)	-
Critical Care (pediatrics)	1 (1.4)	26 (36.6)	44 (62)	25 (35.2)	2 (2.8)
Emergency Medicine	11 (15.5)	44 (62)	17 (23.9)	50 (70.4)	4 (5.6)
Outpatient Antimicrobial Stewardship	6 (8.5)	12 (16.9)	53 (74.6)	10 (14.1)	8 (11.3)
Adult HIV Clinic	59 (83.1)	9 (12.7)	4 (5.6)	19 (26.8)	48 (67.6)
Pediatric HIV Clinic	2 (2.8)	9 (12.7)	60 (84.5)	7 (9.9)	4 (5.6)
Viral Hepatitis Clinic	20 (28.2)	18 (25.4)	33 (46.5)	18 (25.4)	20 (28.2)
Outpatient Parenteral Antimicrobial Therapy (OPAT)	24 (33.8)	9 (12.7)	38 (53.5)	15 (21.1)	18 (25.4)
Sexually Transmitted Diseases Clinic	5 (7)	6 (8.5)	60 (84.5)	4 (5.6)	7 (9.9)
Travel Medicine Clinic	7 (9.9)	10 (14.1)	54 (76.1)	4 (5.6)	13 (18.3)
State Health Department	1 (1.4)	4 (5.6)	66 (93)	4 (5.6)	1 (1.4)
Tuberculosis Clinic	2 (2.8)	5 (7)	64 (90.1)	3 (4.2)	4 (5.6)
Microbiology Laboratory	70 (98.6)	1 (1.4)	-	64 (90.1)	7 (9.9)
Infection Prevention/Control	41 (57.7)	13 (18.3)	17 (23.9)	23 (32.4)	31 (43.7)
Hospital Epidemiology	20 (28.2)	7 (9.9)	44 (62)	11 (15.5)	15 (21.1)
Informatics	2 (2.8)	11 (15.5)	58 (81.7)	11 (15.5)	2 (2.8)
Drug Information	6 (8.5)	11 (15.5)	54 (76.1)	6 (8.5)	10 (14.1)
Leadership/Management	34 (47.9)	12 (16.9)	25 (35.2)	16 (22.5)	30 (42.3)
Global and Public health	1 (1.4)	9 (12.7)	61 (85.9)	9 (12.7)	1 (1.4)
Academia	15 (21.1)	38 (53.5)	20 (28.2)	33 (46.5)	18 (25.4)
Research	61 (85.9)	11 (15.5)	2 (2.8)	22 (31)	67 (94.4)

Abbreviations: HIV, human immunodeficiency virus; ICHs, immunocompromised hosts; ID, infectious diseases.

to other healthcare professionals. Pharmacy residents also engaged in scholarly activities: 66 (93%) presented a scientific poster at international or national conferences, 64 (90.1%) presented a poster at regional or state meetings, and 52 (73.2%) authored at least 1 original research manuscript. Review articles (50.7%), case reports (50.7%), and letters to the editor (15.5%) were less commonly published. There were no statistically significant differences found in relation to scholarly contributions made by residents when comparing program practice settings. Antimicrobial stewardship activities discussed with the resident did not differ among academic and nonacademic institutions with appropriate de-escalation of antimicrobials, duration of antimicrobial therapy, antimicrobial dose optimization, and antimicrobial stewardship principles being a few of the key elements consistently discussed (Table 5).

Slight differences in learning experiences between residency programs affiliated with academic medical centers versus nonacademic medical centers were found. Those associated with academic medical centers had a higher likelihood of offering

required rotations related to ID consults for immunocompromised hosts (58.7% vs 20%, $P = .003$) and pediatric ID consults (39.1% vs 8%, $P = .006$) (Table 2). They were also more likely to offer elective rotations in hospital epidemiology (15.2% vs 0%, $P = .047$), oncology (76.1% vs 24%, $P < .001$), solid organ transplant (71.7% vs 32%, $P = .002$), bone marrow transplant (63% vs 24%, $P = .003$), and pediatric critical care (47.8% vs 16%, $P = .010$). Programs at nonacademic medical centers had a higher likelihood of requiring outpatient antimicrobial stewardship (20% vs 2.2%, $P = .018$), emergency medicine (28% vs 8.7%, $P = .043$), viral hepatitis clinic (52% vs 15.2%, $P = .002$), and travel medicine clinic (24% vs 2.2%, $P = .002$) rotations as learning experiences for residents. Residents at academic medical centers more frequently managed central nervous system infections ($P < .001$), tuberculosis ($P < .001$), opportunistic infections in immunocompromised hosts ($P < .001$), neutropenic fever ($P = .011$), fever of unknown origin ($P = .019$), and parasitic infections ($P = .031$) (Table 3). Coverage of on-call antimicrobial stewardship services by the resident occurred more often in academic medical centers (median

Table 3. Disease State Management Opportunities for the Resident

Disease State	Overall Median (Mean) ^a	Academic Medical Center Median (Mean) ^a	Nonacademic Medical Center Median (Mean) ^a	PValue ^b
Bone and joint infections	4 (4.3)	4 (4.3)	4 (4.2)	.389
Cardiovascular infections	4 (4.2)	4 (4.3)	4 (4)	.053
Central nervous system infections	4 (3.5)	4 (3.8)	3 (3.1)	<.001
Fever of unknown origin	4 (3.7)	4 (3.8)	3 (3.4)	.019
Gastrointestinal infections	4 (4)	4 (4)	4 (4)	.759
Hepatitis B	2 (2.4)	2 (2.4)	2 (2.3)	.565
Hepatitis C	2 (2.8)	2 (2.7)	3 (2.9)	.485
HIV and AIDS	4 (3.7)	4 (3.9)	4 (3.5)	.068
Intra-abdominal infections	5 (4.4)	5 (4.5)	5 (4.3)	.513
Neutropenic fever	4 (3.8)	4 (4)	3 (3.5)	.011
Ophthalmologic infections	3 (2.5)	3 (2.6)	2 (2.3)	.064
Opportunistic infections in ICHs	4 (3.7)	4 (4.1)	3 (3.1)	<.001
Parasitic infections	2 (2.2)	2 (2.3)	2 (2)	.031
Reproductive organ infections	3 (2.7)	3 (2.8)	2 (2.6)	.226
Upper respiratory infections	4 (4)	4 (4)	4 (4)	.864
Lower respiratory infections	5 (4.7)	5 (4.8)	5 (4.7)	.653
Rickettsial infections	2 (2.1)	2 (2.2)	2 (1.9)	.052
Sepsis	5 (4.6)	5 (4.7)	5 (4.6)	.492
Sexually transmitted diseases	3 (2.8)	3 (2.8)	3 (2.8)	.929
Skin and soft tissue infections	5 (4.7)	5 (4.7)	5 (4.6)	.487
Tuberculosis/other mycobacterial infections	3 (2.8)	3 (3.1)	2 (2.4)	<.001
Travel medicine	2 (2.1)	2 (2.1)	2 (2.2)	.658
Urologic infections	5 (4.4)	5 (4.4)	5 (4.4)	.887
<i>Clostridioides difficile</i> infection	4 (4.2)	4 (4.3)	4 (4.1)	.278

Abbreviations: AIDS, acquired immune deficiency syndrome; HIV, human immunodeficiency virus; ICHs, immunocompromised hosts.

^a5-point Likert scale: 1 = never (none); 2 = rarely (every few months); 3 = sometimes (every month); 4 = often (every week); 5 = always (daily).

^bWilcoxon-rank sum test of residency programs affiliated with academic medical centers versus nonacademic medical centers.

Likert score: 4 vs 2, $P = .017$), whereas emergency department culture reviews occurred more frequently in nonacademic medical centers (median Likert score: 3 vs 1, $P = .019$) (Table 4).

DISCUSSION

Infectious diseases-trained pharmacists are recognized as core members of a multidisciplinary antimicrobial stewardship team [12]. Formalized ID pharmacotherapy training through PGY-2 ID pharmacy residencies provide pharmacists with the knowledge, skills, and attitudes necessary to lead antimicrobial stewardship efforts and provide qualified ID pharmacotherapy recommendations [13, 19, 22]. To our knowledge, this is the first multicenter study to describe the learning opportunities, teaching experiences, antimicrobial stewardship principles discussed, and extent of residents' contributions during PGY-2 ID pharmacy residency programs in the United States. The majority of programs focused on adult ID (97.2%) and accepted only 1 resident (91.6%) annually.

Strong foundational knowledge in ID pharmacotherapy and antimicrobial stewardship principles should be provided during pharmacy school to promote the development of future ID PharmDs. A 2018 survey of US pharmacy schools reported that pharmacy students' perceived quality of didactic

ID education was associated with their career interests in ID [23]. In addition, students with career interests in ID were more likely to become interested in ID during pharmacy school [23]. In a survey of internal medicine physician residents, comparable results were found as experiences during or before medical school influenced their decision to pursue ID fellowship training, and 14.4%–26.4% believed that early exposure to ID would increase ID career interests [24]. However, recent studies demonstrate that improvements in pharmacy and medical ID education are warranted. Although ID had the highest number of devoted contact hours (median 36; interquartile range, 29–60) [25], there were major concerns regarding the lack of time needed to cover the necessary ID materials by ID PharmD faculty [26]. Furthermore, there were considerable differences in the level of integration, pedagogical methods, and depth of antimicrobial stewardship topics delivered in colleges of pharmacy [14, 26]. Abbo et al [15] surveyed fourth-year medical students at 3 US medical schools and found that 90% of respondents desired more education on appropriate antimicrobial use and 79% preferred more instruction on antimicrobial resistance. Although medical students who completed an ID rotation felt they had a higher quality of antimicrobial education (mean Likert score: 3.93 vs 3.44; $P < .001$), only one third of students felt adequately

Table 4. Frequency of Teaching and Learning Experiences for the Resident

Experiences	Overall Median (Mean) ^a	Academic Medical Center Median (Mean) ^a	Nonacademic Medical Center Median (Mean) ^a	PValue ^b
Provide Small Group Didactic Instruction	4 (3.6)	4 (3.7)	3 (3.3)	.142
Provide Large Group Didactic Instruction	3 (3.3)	3 (3.4)	3 (3.3)	.700
Provide Continuing Education Program(s)	3 (3.4)	3 (3.6)	3 (3.1)	.099
Multidisciplinary Teaching to Physicians and Nurses (ie, ID Grand Rounds)	4 (3.7)	3.5 (3.7)	4 (3.7)	.901
Precept Pharmacy Students and/or PGY-1 Pharmacy Residents	4 (4.2)	4 (4.2)	4 (4.2)	.821
Perform Medication Use Evaluation	4 (3.9)	4 (4)	4 (3.8)	.368
Perform Longitudinal Research Project(s)	5 (4.6)	5 (4.7)	5 (4.6)	.428
Publish in Institutional Newsletter(s)	3 (3.1)	3 (3.1)	3 (3.2)	.590
Involvement With Penicillin Skin Testing Services	1 (1.7)	1 (1.6)	1 (2)	.249
Involvement With Emergency Department Culture Review	2 (2.3)	1 (2.1)	3 (2.8)	.019
Coverage of Antimicrobial Stewardship Services Off-Hours (On-Call)	3 (3)	4 (3.3)	2 (2.4)	.017
Involvement With Pharmacokinetic Dosing/Pharmacy to Dose	5 (4.4)	5 (4.4)	5 (4.3)	.549
Involvement With Anti-infective or Antimicrobial Stewardship Committee	5 (4.8)	5 (4.8)	5 (4.9)	.364
Involvement With Infection Control/Hospital Epidemiology Committee	4 (4)	4 (3.9)	4 (4.1)	.570

Abbreviations: ID, infectious diseases; PGY-1, post-graduate year-1.

^a5-point Likert scale: 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always.

^bWilcoxon rank-sum test of residency programs affiliated with academic medical centers vs nonacademic medical centers.

prepared in fundamental principles of antimicrobial use. Similar results were found in a survey of pharmacy students at 12 colleges of pharmacy with approximately 90% and 80% of pharmacy students wanting more education on appropriate

use of antimicrobials and on antimicrobial resistance, respectively [16]. Incorporating medical and pharmacy trainees into antimicrobial stewardship practices may provide invaluable learning opportunities and promote ID career interests [27].

Table 5. Frequency of Antimicrobial Stewardship Activities Discussed With the Resident

Antimicrobial Stewardship Topic or Activity	Overall Median (Mean) ^a	Academic Medical Center Median (Mean) ^a	Nonacademic Medical Center Median (Mean) ^a	PValue ^b
AS definitions, principles, and purpose	5 (4.8)	5 (4.8)	5 (4.7)	.380
Description of the pharmacist's role in AS	5 (4.7)	5 (4.8)	5 (4.7)	.437
Key personnel and departments of AS team	5 (4.6)	5 (4.7)	5 (4.6)	.828
CDC core elements for ASPs	5 (4.7)	5 (4.6)	5 (4.7)	.812
Core evidence-based AS strategies	5 (4.7)	5 (4.7)	5 (4.8)	.968
Retrospective time outs for specific antimicrobials	4 (3.9)	4 (3.9)	4 (3.8)	.950
Development or use of clinical pathways and guidelines	5 (4.5)	5 (4.5)	5 (4.5)	.864
Parenteral to enteral antimicrobial therapy conversion	5 (4.4)	5 (4.4)	5 (4.5)	.766
Appropriate de-escalation and streamlining of antimicrobials	5 (4.9)	5 (4.9)	5 (4.9)	.524
Duration of antimicrobial therapy	5 (4.8)	5 (4.7)	5 (4.9)	.161
Antimicrobial dose optimization	5 (4.8)	5 (4.9)	5 (4.9)	.690
Rapid diagnostic testing	5 (4.5)	5 (4.6)	5 (4.8)	.739
ASP education and dissemination of knowledge to health-care practitioners	4 (4.2)	4 (4.2)	4 (4.4)	.350
Meetings with AS team leadership	5 (4.5)	5 (4.5)	5 (4.5)	.804
AS team rounds	4 (3.8)	4 (3.8)	4 (3.8)	.929
AS legislative and regulatory aspects	3 (3.4)	3 (3.5)	3 (3.2)	.257
AS reporting for process and outcome measures	4 (3.8)	4 (3.9)	4 (3.8)	.605
Identification and retrieval of key AS resources	4 (4)	4 (4.1)	4 (3.8)	.550

Abbreviations: AS, antimicrobial stewardship; ASP, antimicrobial stewardship program; CDC, Centers for Disease Control and Prevention.

^a5-point Likert scale: 1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = always.

^bWilcoxon rank-sum test of residency programs affiliated with academic medical centers vs nonacademic medical centers.

Our survey indicates that PGY-2 ID residencies consistently teach antimicrobial stewardship skills and involve the residents in various stewardship activities. Based on our survey results, PGY-2 ID pharmacy residents were able to gain the knowledge and skills necessary to help lead antimicrobial stewardship efforts during their residency. Residents were frequently involved in antimicrobial stewardship committees, discussions around antimicrobial stewardship principles and practices, and were responsible for managing various infectious syndromes. In addition, most residents were involved in education through preceptorship, multidisciplinary teaching, continuing education programs, and in small or large group didactic settings. These skills are necessary because ID PharmDs are referred to as knowledgeable resources for antimicrobial use recommendations and key personnel for antimicrobial stewardship [28]. We were not surprised to find that PGY-2 ID pharmacy residency programs at academic medical centers had more available resources through ID PharmD preceptors, interdisciplinary collaboration with ID physician fellowship programs, and offered more rotational and disease state management opportunities for the resident compared with programs at nonacademic medical centers.

One of the strengths of our study was the high survey response rate of 70.3% of all PGY-2 ID pharmacy residency programs and the distributions of programs across different geographic regions in the United States in an effort to minimize the potential for selection bias. In addition, all respondents were RPDs, who are the individuals best suited to accurately complete the survey. A potential limitation of our study is that we only surveyed residency programs listed on ASHP, ACCP, and SIDP residency directories. Data from programs not listed in these directories or other types of formal post-graduate ID programs, such as PGY-2 HIV residencies and clinical fellowships, were not obtained and may limit the comparisons among programs. The average number of scholarly contributions by residents over the previous 5 years were reported by program directors, leaving the potential for recall bias. Finally, although learning experiences and infectious disease states were drafted based on author opinion and the ASHP guidance document for PGY-2 ID residencies, additional educational opportunities or infections managed by residents may not have been captured.

CONCLUSIONS

Our findings show that PGY-2 ID pharmacy residency programs provide residents with adequate and consistent learning and teaching opportunities in relation to ID pharmacotherapy and antimicrobial stewardship for adults. These experiences provide residents with the skills necessary to serve as core members of the antimicrobial stewardship team. Programs may be enhanced by offering residents additional disease state management opportunities and exposure to ID physicians in special populations.

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