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Review

All aboard!: Involvement of medical and pharmacy trainees in antimicrobial stewardship

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Abstract

Antimicrobial stewardship (AS) involves the appropriate selection of antimicrobials. Antimicrobial stewardship programs are mandated in hospitals and are expanding to involve outpatient arenas. Multiple articles have been published describing the need for AS education for medical and pharmacy students, beginning early in the students' career to develop into competent AS practitioners. Additionally, publications have described the role and impact of medical and pharmacy trainees on AS programs. Here, we review the published evidence describing medical and pharmacy trainees' involvement in AS and call for future research in this area.

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A major global public health threat today is the development of antimicrobial resistance, which can emerge through the inappropriate use of antimicrobial agents. Up to 50% of antimicrobial use is inappropriate in the hospital setting.[1,2] In an effort to reduce the rates of antimicrobial resistance, the Joint Commission mandates that all hospitals and critical-access hospitals establish an evidence-based antimicrobial stewardship program.[2] Antimicrobial stewardship programs are an effective strategy to prevent the development of antimicrobial resistance, and antimicrobial stewardship programs have significant benefit in reducing mortality, length of stay, and healthcare costs.[3–7]

Antimicrobial stewardship programs should be led by infectious diseases–trained physicians and pharmacists[1,3]; however, this demand is challenging to meet. The National Resident Matching Program revealed that 51 of the 151 (33.8%) training positions in infectious diseases medical fellowship programs in the United States remained unfilled in 2018.[8] This high percentage is consistent with previous years.[9] The declining rate of applicant interest for a career in infectious diseases is concerning and may be attributed to factors such as a growing number of hospital-based positions, lack of mentorship in infectious diseases, and lower salary compared to other subspecialties.[10,11] Likewise, current infectious diseases training opportunities, such as residencies, fellowships, and certificate programs for pharmacists in the United States are considered inadequate to meet the demand for pharmacists with advanced training in antimicrobial stewardship (AS).[12] Due to the demand, lack of infectious diseases training programs and personnel, and high prevalence of infections, it is likely that all physicians, pharmacists, and trainees will be involved with AS to some degree.

Therefore, healthcare practitioners should receive education on AS principles and practices during their didactic studies and throughout their postgraduate training. By receiving sufficient education and learning experiences, practitioners gain the knowledge and ability to perform AS during their training and as independent practitioners. Although specific AS education and curricula of trainees is not explored, this review summarizes the implementation of various AS practices by physician and pharmacist trainees.

Search strategy and selection criteria

An electronic search through PubMed was conducted (January 2000 to June 2018) using the following terms: antimicrobial stewardship, antibiotic stewardship, trainees, students, postgraduate education, medical education, fellowship, and education. All articles available in English and their references were reviewed for additional publications as well. All articles identified were included in this review.

Trainee definitions

Medical trainees can be classified as residents (including interns) or fellows. For the purposes of this article, medical residents are those trainees who are completing an internal medicine residency (usually post graduate years [PGY] 1–3) and fellows are those completing an infectious diseases fellowship after satisfactory completion of an internal medicine residency (PGY4 and up).[13]

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The American Society of Health-System Pharmacists, the organization that accredits most pharmacy residencies, clearly differentiates between pharmacy residencies and pharmacy fellowships.[14] Pharmacy residencies are postgraduate training programs in an area of pharmacy practice, while pharmacy fellowships are postgraduate training programs designed to prepare the individual to be a researcher. Pharmacy residencies are further divided by year: PGY1 residencies usually focus on general clinical pharmacy practice; PGY2 residencies are focused on a single area of practice (eg, infectious diseases, critical care, ambulatory care).

Results

Role of medical trainees in AS

In total, we identified 6 publications that describe the use of medical trainees in AS activities.[15–20] Table 1 lists the details of 4 of the publications.[15–18] Medical trainees were used to conduct AS activities in diverse patient populations (eg, hematology/oncology and medical ICU) with differing outcomes, and all publications were from academic medical centers or veterans affairs hospitals. The most common AS strategies used by medical trainees in these publications were streamlining and/or de-escalation of therapy and prospective audit with intervention and feedback. Strategies with no published studies in medical trainees were guidelines and clinical pathways and antimicrobial order sets.

Additionally, Graber et al[19] evaluated AS activities at all 130 Veterans Affairs (VA) medical centers with acute-care services in 2012. Based on these results, the VA National Antimicrobial Stewardship Task Force and the VA Healthcare Analysis and Information Group assessed for common variables because there is no common model among all VA centers. The variables associated with decreased inappropriate antibiotic use were (1) postgraduate physician/pharmacy training programs (although they did not specifically identify infectious disease programs), (2) general ward teams that involved pharmacists and/or infectious disease attendings, (3) the involvement of infectious disease attendings and/or fellows in antibiotic approvals, and (4) formally AS-trained pharmacist at the facility. A similar analysis by Chou et al[20] further described AS activities in postgraduate training programs at VA acute-care centers. A 9% reduction in antibiotic use occurred if the facility had an infectious disease fellowship program and a 10% reduction occurred with an infectious disease trained pharmacist. However, no details were given about the activities that trainees performed within the AS programs, only details about the activities that the programs performed as a whole.

Role of pharmacy trainees in AS

Overall, 5 articles specific to pharmacy trainee involvement in AS were identified.[21–25] Table 2 describes 4 of the articles in detail. The most common AS strategies used by pharmacy trainees in these publications were dose optimization and prospective audit with intervention and feedback. Strategies with no published studies in pharmacy trainees were guidelines and clinical pathways and antimicrobial order sets. The published studies showed significant process outcomes (ie, interventions made and accepted) as well as clinical outcomes (ie, reduced drug costs and days of therapy).

Additionally, the fifth article found in the search was a review by Chahine et al[21] that focused on the currently available published data on pharmacy trainees (students, PGY1 residents, PGY2 infectious diseases residents, and fellows) in AS activities; they also proposed a model to further engage pharmacy trainees in AS. Because of the limited clinical studies published at the time, most of the article reviewed academic standards for students and postgraduate trainees as they applied to AS activities. They proposed that even early on in training, pharmacy students completing their introductory pharmacy practice experiences (IPPE) could be involved in some aspects of AS (eg, education, dose optimization, and parenteral-to-oral conversion). Accordingly, as pharmacy students advance through advanced pharmacy practice experiences (APPE), they could also participate in creating guidelines and clinical pathways and antimicrobial order forms, as wells as recommending streamlining and/or de-escalation of antimicrobial therapy. The authors proposed that postgraduate pharmacy trainees (PGY1 residents, PGY2 infectious diseases residents, and PGY2/3 infectious diseases fellows) be incorporated into all aspects of AS, including prospective audit with feedback and formulary restriction/preauthorization.

Discussion

Recent studies show that improvements in AS education for trainees are warranted. Abbo et al[26] surveyed fourth-year students at various medical schools in the United States and found that 90% of respondents would prefer more education on appropriate antimicrobial use. Although medical students who finished a clinical infectious diseases rotation felt they had a higher quality of AS-related education compared to those who did not (mean Likert score, 3.93 vs 3.44; $P = .0003$), only one-third of students felt adequately prepared in fundamental principles of antimicrobial use. Justo et al. surveyed the knowledge and attitudes of graduating pharmacy students at various colleges of pharmacy in the United States toward appropriate antimicrobial use.[27] Roughly 90% and 80% of pharmacy students wanted more education on appropriate use of antimicrobials and on antimicrobial resistance, respectively. Approximately two-thirds of pharmacy students felt that their education related to antimicrobial therapy initiation and selection was satisfactory. Additionally, only 68% of US doctor of pharmacy programs integrated AS education into the required didactic curricula. Notably, there are wide variances in AS principles taught.[28] Similar results were found in studies assessing AS-related knowledge and perceptions of medical and pharmacy students across international programs.[29–32]

Luther et al[33] captured the perspectives of adult infectious diseases medical fellowship directors in the United States regarding their fellows' AS training. Although 50% of programs had a formal curriculum dedicated to AS, only 20% of directors were either very or extremely satisfied with the medical fellow's training. Also, 12% of fellowship directors felt that their fellows were either very or extremely well prepared to initiate an antimicrobial stewardship program. Approximately 75% of fellowship directors were very or extremely satisfied with their fellow's ability to serve as a leader in an existing antimicrobial stewardship program and incorporate AS principles during their own practice. The lack of improvement of their fellow's training was attributed to the deficit of curricular materials related to AS. Improvements to the core curriculum and trainee's programs related to AS content are necessary to develop future AS leaders and promote optimal AS practices.

The studies reviewed in this article demonstrate the impact medical and pharmacy trainees can have in relation to AS.

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Table 1. Publications About Medical Trainees' Involvement in Antimicrobial Stewardship Efforts[15–18]

Study	Setting[a]	Level of Trainee[b]	AS Strategy/ Strategies Employed	AS-Related Intervention Details	Outcomes (If Applicable)
Foral et al[15]	2 academic medical centers	ID fellow, medical resident, medical student, pharmacy resident, APPE pharmacy student	Prospective audit with intervention and feedback; dose optimization; education; streamlining/ de-escalation of therapy; IV to PO conversion	Educational seminars to admitting teams; the trainees completed a monitoring form of identified patients receiving antimicrobials. The trainees discussed each case and possible interventions during daily multidisciplinary AS rounds. Trainees used motivational interviewing to help convey recommendations to the primary medical teams.	2,266 interventions were made with 90.5% acceptance rate by primary team over a 2-y period
Lee et al[16]	Academic medical center (2 internal medicine units)	Medical resident	Prospective audit with intervention and feedback; dose optimization; education; streamlining/ de-escalation of therapy	Senior medical residents on the admitting team reviewed/audited patients receiving carbapenems, moxifloxacin, piperacillin/ tazobactam, or vancomycin twice per week using a checklist. The residents were educated prior to the intervention by ID-trained specialists.	80% audit adherence rate involving 679 patients. There was a change in therapy in approximately 15% of the audits. One year antibiotic cost savings of $69,424 (46% cost reduction). Significant decrease in use of moxifloxacin, but no difference in antibiotic use overall. Also significant decrease in *C. difficile* infection rates.
Yeo et al[17]	Academic medical center (hematology/ oncology patients)	ID fellow	Prospective audit with intervention and feedback; dose optimization; streamlining/de-escalation of therapy; IV to PO conversion	ID Fellow plus ID pharmacist-run AS program instead of ID attending plus ID pharmacist-run program	During year of fellow-led AS program: 14.8% fewer AS recommendations made, 14.4% lower recommendation acceptance rate, and higher use of all IV antibiotics, including carbapenems, third and fourth generation cephalosporins, piperacillin/ tazobactam, and vancomycin
Rimawi et al[18]	Academic medical center (medical ICU)	ID fellow	Prospective audit with intervention and feedback; education; streamlining/de-escalation of therapy; IV to PO conversion	ID fellow reviewed charts of all MICU patients receiving antimicrobials daily. ID attending was available for discussion of complex cases. ID fellow met with MICU attending, critical-care fellow, and critical-care pharmacist to discuss recommendations.	In 3-mo intervention period, there were: significant reductions in the use of piperacillin-tazobactam carbapenems, vancomycin, linezolid, and metronidazole, a 25% increase in compliance with national guidelines, decrease in antibiotic costs ($22,486), and significant decreases in days of mechanical ventilation and MICU length of stay.

Note. AS, antimicrobial stewardship; ID, infectious diseases; APPE, advanced pharmacy practice experience; IV, intravenous; PO, enteral route; ICU, intensive care unit; MICU, medical intensive care unit
[a]Academic medical center, community hospital, long-term care, etc.
[b]Student, resident, fellow.

Table 2. Publications about Pharmacy Trainees' Involvement in AS Efforts[22-25]

Study	Setting[a]	Level of Trainee[b]	AS Strategy/ Strategies Employed	AS-Related Intervention Details	Outcomes (If Applicable)
Benson[22]	Long-term acute-care hospital	APPE student	Prospective audit with intervention and feedback; dose optimization; streamlining/de-escalation of therapy	Students collected data on patients with an infection-related problem. Focus was on dose optimization, appropriate duration of therapy, drug allergy assessment, efficacy and toxicity monitoring, and adjustment of empirical therapy. Daily meetings with pharmacist, weekly meetings with ID physician.	Antimicrobial daily expense decreased 14.9%, a cost savings of $261,630 for the 2-y period after implementation of the AS program.
Laible et al[23]	Community teaching hospital (medical/ surgical ward)	PGY2 critical-care resident, PGY1 pharmacy resident, APPE student	Prospective audit with intervention and feedback; dose optimization; streamlining/de-escalation of therapy	Trainees collected data on all patients receiving antimicrobials. Focus was on dose optimization, drug changes, and discontinuation of therapy. Met 3 times per week with clinical pharmacist and ID physician.	554 recommendations were made; 68.4% were accepted in 2-y period.
Smith et al[24]	Academic medical center	PGY2 residents (critical care, oncology, pediatrics), PGY1 resident	Dose optimization; education	Call schedule was once every 14 days, including overnight, on weekends, and on holidays for 24-h periods starting at 0800 each day. Focus was on pharmacokinetic monitoring of aminoglycosides and vancomycin, drug information consultation, assessing adverse drug events, screening for drug–drug interactions, and taking medication histories for HIV patients. Multiple clinical pharmacists were available for consultation by residents if needed.	863 activities were completed by the on-call residents with an average of 6.5 activities per day in a 6-mo period.
Siegfried et al[25]	Academic medical center	PGY2 residents (infectious diseases and critical care)	Prospective audit with intervention and feedback; formulary restriction and preauthorization; dose optimization	Residents provided weekend coverage of AS program. Focus was on approval of restricted antimicrobial orders, prospectively auditing patients on restricted and broad-spectrum antibiotics at 72 h after treatment initiation, providing medication reconciliation for patients on antiretrovirals, advising on dosing of aminoglycosides and vancomycin, and reviewing all gram-positive bacteria blood cultures. ID-trained pharmacist available if needed.	1,443 documented interventions in 1-y period. Compared to year before program implementation, antibiotic utilization decreased by 58.6 days of therapy/1,000 patient days, including decreases in the use of carbapenems, MRSA-active agents, and broad-spectrum antibiotics with antipseudomonal coverage. There was also a decrease in the *Clostridium difficile* infection rate.

Note. AS, antimicrobial stewardship; APPE, advanced pharmacy practice experience; ID, infectious diseases; PGY, postgraduate year.
[a]Academic medical center, community hospital, long-term care, etc.
[b]Student, resident, fellow.

The review identified few published articles for both medical and pharmacy trainee involvement in AS. There are likely more activities that medical and pharmacy trainees perform in AS that have yet to be published. For example, the review did not show any publications that described medical and pharmacy trainees being involved in the more administrative tasks of AS, such as facility-specific guideline and clinical pathway development and/or review, despite this being a recommended component of AS programs in the guidelines[1,3] and an objective for PGY2 infectious diseases pharmacy residencies.[34] The lack of publication of the more administrative tasks is likely related to the difficulty in measuring process-based and clinical outcomes. Additionally, all of the publications identified in the search were conducted in acute-care or long-term acute-care settings, with none coming from outpatient AS. The authors encourage more published accounts of the extent of the AS activities of trainees in all health disciplines in all healthcare settings.

An unanswered question related to this topic includes the impact of AS training programs by tracking the AS impact of graduates at their future places of employment. Also, a unique question is to what degree changes in didactic trainee AS education versus "hands on" AS training (as described in this article) successfully prepare trainees to participate in AS in their careers.

Given the worldwide threat of antimicrobial resistance, the importance of effective AS programs has become paramount. To enact such AS programs, training programs in medicine, pharmacy, and other health professions need to incorporate both AS education and AS activities to ensure that AS principles are followed beyond graduation. Additional documentation of these activities and impact of trainees' involvement in AS in the published literature is also greatly needed to serve as exemplars for other training programs.

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References

1. Dellit TH, Owens RC, McGowan JE Jr, *et al.* Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. *Clin Infect Dis* 2007;44:159–177.
2. Joint Commission on Hospital Accreditation. APPROVED: new antimicrobial stewardship standard. *Jt Comm Perspect* 2016;36:1, 3–4, 8.
3. Barlam TF, Cosgrove SE, Abbo LM, *et al.* Implementing an antimicrobial stewardship program: Guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. *Clin Infect Dis* 2016;62:351–377.
4. Carling P, Fung T, Killion A, *et al.* Favorable impact of a multidisciplinary antibiotic management program conducted during 7 years. *Infect Control Hosp Epidemiol* 2003;24:699–706.
5. Sanders J, Pallotta A, Bauer S, *et al.* Antimicrobial stewardship program to reduce antiretroviral medication errors in hospitalized patients with human immunodeficiency virus infection. *Infect Control Hosp Epidemiol* 2014;35:272–277.
6. Liew YX, Lee W, Tay D, *et al.* Prospective audit and feedback in antimicrobial stewardship: Is there value in early reviewing within 48 h of antibiotic prescription? *Int J Antimicrob Agents* 2015;45:168–173.
7. Kelley D, Aaronson P, Poon E, *et al.* Evaluation of an antimicrobial stewardship approach to minimize overuse of antibiotics in patients with asymptomatic bacteriuria. *Infect Control Hosp Epidemiol* 2014;35:193–195.
8. The Match: Fellowship Match Summary, 2018 Appointments. National Resident Matching Program website. http://www.nrmp.org/wp-content/uploads/2018/02/Results-and-Data-SMS-2018.pdf. Published 2018. Accessed May 3, 2018.
9. Chandrasekar PH. Bad news to worse news: 2015 infectious diseases fellowship match results. *Clin Infect Dis* 2015;60:1438.
10. Chandrasekar P, Havlichek D, Johnson LB. Infectious diseases subspecialty: declining demand challenges and opportunities. *Clin Infect Dis* 2014;59:1593–1598.
11. Bonura EM, Lee ES, Ramsey K, Armstrong WS. Factors influencing internal medicine resident choice of infectious diseases or other specialties: a national cross-sectional study. *Clin Infect Dis* 2016;63:155–163.
12. Gauthier TP, Worley M, Laboy V, *et al.* Clinical infectious diseases pharmacists in the United States: a problem of both supply and demand. *Clin Infect Dis* 2015;60:826–827.
13. Applying to ID Fellowships. Stanford Medicine website. http://med.stanford.edu/id/programs/apply.html. Accessed May 20, 2018.
14. American Society of Hospital Pharmacists. Definitions of pharmacy residencies and fellowships. *Am J Hosp Pharm* 1987;44:1142–1144.
15. Foral PA, Anthone JM, Destache CJ, *et al.* Education and communication in an interprofessional antimicrobial stewardship program. *J Am Osteopath Assoc* 2016;116:588–593.
16. Lee TC, Frenette C, Jayaraman D, *et al.* Trainee-led structured antibiotic time-outs to improve antimicrobial use. *Ann Int Med* 2014;161:S53–S58.
17. Yeo CL, Wu JE, Chung GW-T, *et al.* Specialist trainees on rotation cannot replace dedicated consultant clinicians for antimicrobial stewardship of specialty disciplines. *Antimicrob Resist Infect Control* 2012;1:36.
18. Rimawi RH, Mazer MA, Siraj DS, *et al.* Impact of regular collaboration between infectious diseases and critical care practitioners on antimicrobial utilization and patient outcome. *Crit Care Med* 2013;41:2099–2107.
19. Graber CJ, Jones MM, Chou AF, *et al.* Association of inpatient antimicrobial utilization measures with antimicrobial stewardship activities and facility characteristics of Veterans Affairs Medical Centers. *J Hosp Med* 2017;12:301–309.
20. Chou AF, Graber CJ, Jones MM, *et al.* Characteristics of antimicrobial stewardship programs at Veterans Affairs hospitals: results of a nationwide survey. *Infect Control Hosp Epidemiol* 2016;37:647–654.
21. Chahine EB, El-Lababidi RM, Sourial M. Engaging pharmacy students, residents, and fellows in antimicrobial stewardship. *J Pharm Pract* 2015;28:585–591.
22. Benson JM. Incorporating pharmacy student activities into an antimicrobial stewardship program in a long-term acute-care hospital. *Am J Health Syst Pharm* 2014;71:227–230.
23. Laible BR, Nazir J, Assimacopoulos AP, Schut J. Implementation of a pharmacist-led antimicrobial management team in a community teaching hospital: use of pharmacy residents and pharmacy students in a prospective audit and feedback approach. *J Pharm Pract* 2010;23:531–535.
24. Smith KM, Hecht KA, Armitstead JA, Davis GA. Evolution and operation of a pharmacy residency on-call program. *Am J Health Syst Pharm* 2003;60:2236–2241.
25. Siegfried J, Merchan C, Scipione MR, *et al.* Role of postgraduate year 2 pharmacy residents in providing weekend antimicrobial stewardship coverage in an academic medical center. *Am J Health Syst Pharm* 2017;74:417–423.
26. Abbo LM, Cosgrove SE, Pottinger PS, *et al.* Medical students' perceptions and knowledge about antimicrobial stewardship: how are we educating our future prescribers? *Clin Infect Dis* 2013;57:631–638.
27. Justo JA, Gauthier TP, Scheetz MH, *et al.* Knowledge and attitudes of doctor of pharmacy students regarding the appropriate use of antimicrobials. *Clin Infect Dis* 2014;59 Suppl 3:S162–S169.
28. Kufel WD, Jeffres MN, MacDougall C, *et al.* Antimicrobial stewardship education in US colleges and schools of pharmacy. *J Antimicrob Chemother* 2018;73:2252–2258.
29. Yang K, Wu D, Tan F, *et al.* Attitudes and perceptions regarding antimicrobial use and resistance among medical students in Central China. *Springerplus* 2016;5:1779.
30. Chuenchom N, Thamlikitkul V, Chaiwarith R, *et al.* Perception, attitude, and knowledge regarding antimicrobial resistance, appropriate antimicrobial use,

https://doi.org/10.1017/ice.2018.332 Published online by Cambridge University Press

and infection control among future medical practitioners: a multicenter study. *Infect Control Hosp Epidemiol* 2016;37:603–605.
31. Inacio J, Barnes LM, Jeffs S, *et al*. Master of Pharmacy students' knowledge and awareness of antibiotic use, resistance and stewardship. *Curr Pharm Teach Learn* 2017;9:551–559.
32. Dyar OJ, Pulcini C, Howard P, *et al*. European medical students: a first multicentre study of knowledge, attitudes and perceptions of antibiotic prescribing and antibiotic resistance. *J Antimicrob Chemother* 2014; 69:842–846.
33. Luther VP, Shnekendorf R, Abbo LM, *et al*. Antimicrobial stewardship training for infectious diseases fellows: program directors identify a curriculum need. *Clin Infect Dis* 2018;67:1285–1287.
34. Required competency areas, goals, and objectives for postgraduate year two (PGY2) infectious diseases pharmacy residencies. American Society of Health-System Pharmacists website. https://www.ashp.org/-/media/assets/professional-development/residencies/docs/pgy2-infectious-diseases-pharmacy-residency-competency-areas-goals-objectives-2017.ashx?la=en&hash=5A6C02C187B9D8384FD2C30C7BF91A1B94137BB9. Published 2017. Accessed May 25, 2018.

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