

# Development of a Multifaceted Antimicrobial Stewardship Curriculum for Undergraduate Medical Education: The Antibiotic Stewardship, Safety, Utilization, Resistance, and Evaluation (ASSURE) Elective

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To address the growing need for dedicated stewardship training in undergraduate medical education, we developed an antimicrobial stewardship curriculum for medical students with the objectives of increasing expertise in antimicrobial prescribing, introducing antimicrobial stewardship fundamentals, and enhancing comfort with engagement in interprofessional antimicrobial stewardship activities.

**Keywords.** antimicrobial stewardship; curriculum; medical education; medical student.

Antimicrobial stewardship programs (ASPs) improve antibiotic use, slowing the rise of antibiotic resistance while contributing to improved patient outcomes. National health care accreditation agencies, public health agencies, and professional societies have called for implementation of ASPs across the care continuum [1]. Despite the expansion and growing recognition of ASPs, most antimicrobial stewardship (AS) teaching efforts are currently directed at the postgraduate level [2, 3]. In contrast, there has been less attention devoted to AS education for medical students [4, 5]. In a survey of fourth-year students,

only one-third of respondents reported feeling comfortable with the principles of antimicrobial prescribing, with 90% expressing a desire for additional instruction [5]. Incorporation of AS education into undergraduate medical education (UME) has enormous potential in influencing future behaviors, as prescribing practices are the most malleable early in training [2, 6]. In addition, given the sociobehavioral drivers of antibiotic prescribing [7], early education regarding key AS topics could promote judicious antimicrobial use by modifying social norms transmitted during training [8]. In this manuscript, we present a novel, immersive curriculum focused on teaching AS concepts at the UME level.

## METHODS

### Design and Setting

To address the growing need for early AS education, the Antibiotic Stewardship, Safety, Utilization, Resistance, and Evaluation (ASSURE) Elective was developed at the Perelman School of Medicine at the University of Pennsylvania. Participants included third- and fourth-year medical students who had completed a year of clinical clerkships. The study was conducted from May 2020 through December 2020 and was granted exempt review status by the University of Pennsylvania Institutional Review Board.

### Curriculum

The 2-week course consisted of learning activities designed to immerse students in multiple facets of AS, with educational materials and a sample student schedule provided in [Supplementary Table 1](#). The first objective was to increase expertise in antimicrobial prescribing by building on knowledge introduced during existing preclinical and clinical courses. Students participated in small-group didactic sessions reviewing the pharmacokinetics and spectra of activity of commonly used antibiotics. During these sessions, they were taught to utilize the “3Ps and 3Ds” AS framework, with consideration of the *place*, *pathogen*, and *patient* to inform decisions about the *drug*, *dose*, and *duration* of antimicrobial therapy ([Table 1](#)), and were provided with clinical cases to practice applying this framework.

The second objective was to introduce the fundamentals of AS through didactics and assigned readings on the components of an ASP, common AS interventions, ethical implications of AS, and sociobehavioral considerations of AS. Sociobehavioral components, or “3Cs,” were added to the AS framework to convey the importance of understanding the *context* of frontline provider decisions to foster effective *communication* and interprofessional *collaboration*. In addition,

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**Table 1. The 3Ps/3Ds/3Cs Framework for Antimicrobial Stewardship**

<u>Place</u>	<ul style="list-style-type: none"> <li>• What is/are the infection(s) or potential infection(s)?</li> <li>• From what possible places is/are infection(s) coming (eg, skin, gastrointestinal tract, oropharynx, health care environment)?</li> <li>• Are there tests that need to be performed to determine location?</li> </ul>
<u>Pathogen</u>	<ul style="list-style-type: none"> <li>• What organism(s) could be or is/are causing the infection?</li> <li>• If the organism(s) is/are not known yet, which organisms tend to live in the potential locations (eg, skin = <i>Streptococcus</i> and <i>Staphylococcus</i>)?</li> <li>• Are there tests that should be performed to identify the organism(s)?</li> </ul>
<u>Patient</u>	<ul style="list-style-type: none"> <li>• Is the patient sick or not sick?</li> <li>• Are there risks for resistance (eg, health care exposure, recent antibiotics)?</li> <li>• Does the patient have characteristics that affect antibiotic choice (eg, renal insufficiency, prolonged QTc interval, antibiotic allergies)?</li> </ul>
<u>Drug</u>	<ul style="list-style-type: none"> <li>• What antibiotic(s) is/are patient on? What do you want them to be on?</li> <li>• What sort of monitoring is needed for antibiotics (eg, drug levels, labs, electrocardiograms)?</li> <li>• Are there drug characteristics that affect antibiotic choice (eg, cost, efficacy data, drug–drug interactions, spectrum of activity)?</li> </ul>
<u>Dose</u>	<ul style="list-style-type: none"> <li>• What is the dosing frequency of the antibiotic(s)?</li> <li>• Does the dose need to be adjusted for renal function/liver function?</li> <li>• Does the antibiotic need to be dosed by weight? Which weight (ideal body weight, adjusted body weight, actual body weight)?</li> </ul>
<u>Duration</u>	<ul style="list-style-type: none"> <li>• Is there an evidence-based duration for the indication(s) being treated?</li> <li>• Is there an evidence-based duration for the antibiotic(s) being used?</li> <li>• If the duration cannot yet be determined, is there additional testing or follow-up that needs to be done to determine duration?</li> </ul>
<u>Context</u>	<ul style="list-style-type: none"> <li>• What professional or cultural factors may be motivating the provider or team in making antibiotic decisions?</li> <li>• What questions need to be asked to better determine the motivations and context of the provider or team?</li> </ul>
<u>Communication</u>	<ul style="list-style-type: none"> <li>• How should the recommendations be framed to the provider or team considering the context of antibiotic prescribing?</li> <li>• What team member should be contacted to have effective discussion (eg, intern, resident, advanced practice provider, attending, consultant)?</li> </ul>
<u>Collaboration</u>	<ul style="list-style-type: none"> <li>• How can you work together with the provider or team to increase trust and decrease future conflict?</li> <li>• Is follow-up with the team needed?</li> <li>• Should an infectious disease or other consultation be suggested?</li> </ul>

students were assigned to complete eLearning modules 1–2 of the online Infectious Diseases Society of America (IDSA) Core Antimicrobial Stewardship Curriculum for Infectious Disease (ID) Fellows [9], which highlighted key principles in diagnostic and therapeutic stewardship, as well as the sequelae of antimicrobial overuse.

The third objective was to enhance practical knowledge through active engagement in AS activities. As part of the IDSA curriculum, students completed case-based modules reviewing common facets of AS in everyday practice. To supplement this experience, students performed prospective audit-and-feedback activities at the Hospital of the University of Pennsylvania, with daily assignments to review electronic stewardship alerts. Subsequently, they participated in daily AS rounds with ID physicians, pharmacists, and other interprofessional physician, pharmacy, and microbiology trainees, during which they suggested and implemented interventions in real time to frontline providers using the “3Ps, 3Ds, and 3Cs” AS framework. Last, to enhance their confidence with pharmacokinetic principles, students reviewed patients undergoing therapeutic drug monitoring for vancomycin and recommended dosing changes under the supervision of an ID pharmacist. During the 2-week course, ID physicians dedicated 10 hours to leading didactics and case-based sessions, and an ID pharmacist spent approximately 1 hour reviewing pharmacokinetic cases with students.

### Survey Instrument and Analysis

Students completed surveys before and after completion of the course. Each survey consisted of 8 questions about knowledge and comfort with antimicrobial prescribing, AS fundamentals, and AS interventions. All questions were answered on a 5-point Likert scale. Median and interquartile range were recorded for each survey response. For the primary analysis, responses were dichotomized to those of 4–5 (ie, “agree” or “strongly agree”) vs 1–3 (ie, “strongly disagree,” “disagree,” or “neutral”), and changes in paired responses were assessed using the Wilcoxon rank-sum test.

### RESULTS

During the study period, a total of 18 medical students participated in the ASSURE Elective, of which 16 (89%) completed both pre- and postcourse surveys. Paired survey data and statistical analyses are reported in Table 2. Questions 1–3 addressed the first objective of increasing expertise in antimicrobial prescribing. At the time of course enrollment, a minority of students expressed comfort in decisions around antibiotic selection (19%), dosing for agents requiring therapeutic drug monitoring (6%), and adverse effects (19%). By course completion, confidence increased to 100% in each domain ( $P < .001$ ). Questions 4–5 addressed the second objective of introducing students to AS fundamentals. Although students entering the course universally recognized the importance of ASPs, they felt

**Table 2. Survey Responses of Medical Students Before and After Completion of the Antibiotic Stewardship, Safety, Utilization, Resistance, and Evaluation (ASSURE) Elective**

Question	Precourse Survey		Postcourse Survey		P Value <sup>a</sup>
	Median (IQR)	"Agree" or "Strongly Agree"	Median (IQR)	"Agree" or "Strongly Agree"	
1. How would you rate your comfort level with selecting antibiotics for bacterial infections?	3 (2–3)	19%	5 (4–5)	100%	<.001
2. How would you rate your comfort level with dosing of intravenous vancomycin?	1 (1-1)	6%	4 (4–5)	100%	<.001
3. How would you rate your comfort with evaluating the adverse effects of antibiotics when making antibiotic prescribing decisions?	3 (2–3)	19%	4 (4–5)	100%	<.001
4. How would you rate the importance of AS programs?	5 (5-5)	100%	5 (5-5)	100%	1.0
5. How would you rate your comfort with explaining the function of AS programs?	4 (3–4)	63%	5 (5-5)	100%	.03
6. How would you rate your comfort with communicating to other medical providers in reference to antibiotics?	2 (2–3)	13%	5 (4–5)	100%	<.001
7. How would you rate your comfort with explaining the ways collaboration with the microbiology department can improve antibiotic use?	3 (2–4)	38%	5 (5-5)	100%	.002
8. How would you rate your comfort in working with an interprofessional team (eg pharmacists and physicians) to improve antibiotic prescribing?	3 (3–4)	44%	5 (5-5)	100%	.004

Abbreviations: AS, antibiotic stewardship; IQR, interquartile range.

<sup>a</sup>Statistical analysis was conducted based on dichotomized paired survey results.

less comfortable describing its functions, though this ability improved after course completion (63% to 100%;  $P = .03$ ). Questions 6–8 addressed the third objective of enhancing practical knowledge through engagement in AS activities. At course onset, a minority of students expressed comfort in communicating with frontline providers (13%), functioning within an interprofessional AS team (44%), and collaborating with AS support services such as microbiology (38%). Again, confidence in each domain improved to 100% following course completion ( $P \leq .004$ ). Invited, open-ended comments were highly favorable, with themes highlighted in [Supplementary Table 2](#).

## DISCUSSION

In this manuscript, we describe a novel, multifaceted AS curriculum for medical students that was developed to address the growing need for dedicated stewardship training in UME. Prior studies have noted a lack of evidence-based approaches to AS education for medical students and called for evaluation data to assess the impact of these curricula [8, 10]. Through comparison of pre- and postcourse survey data, we demonstrated our course's effectiveness in improving confidence regarding antimicrobial prescribing, knowledge about AS fundamentals, and comfort with engaging in AS activities as part of an interprofessional team.

One innovative component of our curriculum was the incorporation of trainees into prospective audit and feedback activities. While prior AS curricula have consisted of interactive workshops among trainees [8, 11], ours is the first to our knowledge that actively engages medical students in hospital-based stewardship activities. This approach intentionally immerses students within an interdisciplinary team of providers and other

trainees to perform AS activities and gain insight into AS team functions, while also fulfilling a mandate for interprofessional educational experiences by medical school accrediting agencies [12]. In addition, the incorporation of medical students in AS serves a practical benefit for ASPs, as it allows students to share in prospective audit and other frontline stewardship responsibilities under supervision. Furthermore, these activities can be conducted in-person or virtually, providing students with additional flexibility to engage in remote learning when necessary.

Another unique aspect of the course was the integration of the IDSA Core Fellow AS Curriculum for medical student education. The inclusion of this curriculum reflects prior guidance recommending the incorporation of preexisting AS modules into new courses, when feasible [10]. While this curriculum was developed for ID fellows [3, 9], our study demonstrated that its content can be appropriate for use in UME as a part of a dedicated AS course, suggesting its broader applicability to AS education at different levels of training.

Our study has several limitations. First, because the curriculum was developed and implemented at a single academic institution, it is possible that it may not have broad applicability to other centers, though it should be feasible to implement at any medical school affiliated with a hospital that contains an active prospective audit-and-feedback program. Second, selection bias may have influenced our findings, as the survey was taken by a small group of medical students who demonstrated interest in AS prior to taking the course, and the results of this study may thus not be generalizable to all students. Third, while the pre- and postcourse surveys demonstrated significant improvement in confidence regarding each of the course objectives, this survey was not validated. Nevertheless, we do not feel that the lack of validation of the survey instrument abrogates its substantial findings. Fourth,

the time commitment required from ID physicians may serve as a practical limitation for the course, though this could be overcome by conducting more sessions in an asynchronous manner through use of prerecorded material. Finally, enrollment in the elective was limited due to its immersive format. The course's content could be adapted and incorporated into the core medical school curriculum to reach a broader audience.

In conclusion, we describe a novel AS curriculum for medical students that increased confidence in antibiotic prescribing and knowledge of AS principles, adding to the limited published studies surrounding AS education in UME. This course's objectives and structure could serve as an example to guide the development of similar curricula at other institutions.

### Supplementary Data

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

### Notes

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