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Antimicrobial Stewardship (AL Pakyz, Section Editor)

Educational Antimicrobial Stewardship Strategies

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Opinion statement

Educational interventions to improve prescriber and patient knowledge of appropriate antibiotic use are a key component of successful antimicrobial stewardship campaigns in diverse healthcare settings. Provider education may be an impactful strategy for reducing unnecessary prescribing of antibiotics for respiratory tract infections and asymptomatic bacteriuria. Educational interventions designed to improve adherence to prescribing guidelines are more consistently able to impact prescribing of a specific class of medications (e.g., third generation cephalosporins, fluoroquinolones) than overall adherence to a set of specific treatment recommendations. Further research is needed to assess the independent impact of educational programs in bundled stewardship efforts and the duration of their effect on prescribing. Facilitating evidence-based discussions on antimicrobial use between patients and providers has been shown to reduce inappropriate prescribing. However, the impact of these programs on other important metrics in primary care, including duration of physician-patient time, wait times, and number of return office visits, has not been addressed. Educational campaigns in non-clinical settings may be effective ways to educate adults and children on principles of antimicrobial stewardship. Future studies should examine the impact of education outside of the physician's office on future patient behavior.

Introduction

Educational interventions to improve prescriber and patient knowledge of appropriate antibiotic use are a key component of successful antimicrobial stewardship campaigns in diverse healthcare settings [1•, 2•, 3].

Clinician and patient education programs in a variety of formats have consistently been shown to reduce overall and inappropriate antibiotic prescribing alone and in combination with other antimicrobial stewardship program (ASP) strategies, including audit and feedback and decision support systems [1•, 2•]. While no country has mandated continuing medication education specifically on antimicrobial stewardship, government initiatives around the world have developed and promoted education tools [4]. Common programs worldwide include patient-directed resources explaining why antibiotics are not warranted for many illnesses, prescribing guidelines and recommendations, computerized decision aids, mobile applications, and courses for medical students and professionals [4]. Many clinical decision support systems now contain e-learning modules and generate reminder prompts of the best practice advisories during the prescribing process [2•, 5]. Educational ASP information is also increasingly available through a number of infectious disease apps, websites, and social media tools; however, the impact of these resources on antibiotic prescribing is not well documented [5].

Educational programs on prudent antibiotic use incorporate multidisciplinary discussions on topics including bacterial resistance, infection control, indications for antimicrobial therapy, optimal prescribing for empiric and targeted therapies, and communication skills for patient-provider discussions [6•]. While ASP training efforts most commonly target junior physicians [7] and adult patients [6•], the need for education beginning with children and continuing to experienced providers has been discussed [1•, 6•]. This paper will review the latest studies that evaluated the impact of antimicrobial stewardship educational strategies that targeted either providers or patients, or both populations.

Provider education

Traditionally, the majority of the antimicrobial stewardship educational campaigns have targeted medical professionals working in hospitals and primary care [1•]. Educational programs for prescribers have been reported at the national [4], state [8, 9], and health system [1•] level and employ a variety of learning modalities. One literature review of 28 randomized, controlled trials of clinician ASP education strategies reported that the average reduction in rates of overall antibiotic prescribing ranged from 9 % with mailing campaigns to 42 % with guidelines and leaflets and 52 % with small-group education, suggesting that the method of education affects the impact of the intervention [1•].

Despite the documented impact of provider education on antimicrobial stewardship, the availability of such education is lacking. Medical students have repeatedly expressed a desire for more education on the appropriate use of antimicrobials [10, 11]. Additionally, the majority of the hospital pharmacists surveyed in one study were reluctant to make interventions on antimicrobials for UTI on account of a lack of knowledge [12]. Still, educational interventions may be less common components of ASP initiatives compared to other strategies. Two similar surveys of infectious disease physicians and pharmacists at the hospitals in Australia and New Zealand reported that nearly a third of pediatric (29 %) [13] and community hospitals (31 %) [7] do not provide any ASP education to the healthcare practitioners. However, while a lack of education was the most commonly cited barrier to successful ASP among providers at the pediatric hospitals [13], respondents from the community hospitals cited that inadequate pharmacy services (77 %) and competing priorities (71 %), rather than insufficient education (41 %), were the barriers to successful ASP at their hospitals [7]. Thus,

while ASP education is lacking in many facilities, the degree to which a lack of education is perceived to be a barrier to optimal antimicrobial use may differ by setting.

Interventions to reduce prescribing for potentially inappropriate indications

A number of educational interventions aim to limit prescribing of antibiotics for acute uncomplicated respiratory tract infections (RTIs) given the limited benefit of antibiotics among patient populations [14]. The use of role-playing and communication scripts for physicians in speaking with patients with infectious complications can also be a useful way to curb antibiotic use. A randomized controlled trial among European physicians reported that those who had received internet-based training in point-of-care C-reactive protein testing or advanced communication scripts were 46 and 31 %, less likely to prescribe antibiotics for RTIs, respectively, after controlling for patient presentation. Physicians who received both types of training were 64 % less likely to prescribe antibiotics. Furthermore, clinical measures of symptom improvement or worsening were similar between groups; though, patients treated by physicians who received advanced communication training reported symptom resolution in a median of 6 days, compared to 5 days among control patients [15].

In response to a high level of inappropriate prescribing for respiratory tract infections, one health system implemented a bundled intervention among outpatient prescribers, combining didactic teaching, monthly meetings, provider report cards, and clinical decision support tools. The intervention significantly reduced antibiotic prescribing for RTIs and led to increased treatment guideline adherence (91.3 vs. 25.0 %, p=0.003), though the independent impact of the educational component of the bundled intervention could not be assessed [16]. On-site educational programs for long-term care providers, nurses, residents, and family members at nursing homes were similarly associated with decreased prescribing of antibiotics for RTIs (IRR 0.71; 95 % CI 0.56–0.90) [17]. Finally, two studies report that fewer antibiotics for RTIs were prescribed by French general practitioners, and this effect was sustained as far out as 30 [18] and 54 months [19] after their attendance at an educational seminar. However, the clinical significance of the prescribing differences between physicians who did and did not attend the seminar may be limited [18, 19]. Similarly, a combination of clinician education and audit and feedback did not produce lasting prescribing changes for RTIs when audit and feedback was terminated [20]. Collectively, these results suggest that provider education may be an impactful strategy for reducing unnecessary prescribing of antibiotics for respiratory tract infections. However, further studies are needed to assess the long-term impact of educational session and the potential need for regular continuing education on the topic.

As with respiratory tract infections, current practice guidelines recommend against antibiotic treatment for the majority of patients with asymptomatic bacteriuria (ABU) [21], and a number of educational interventions have focused on reducing inappropriate antibiotic

prescribing for ABU. One health system implemented educational sessions for medical residents in addition to sending microbiology lab messages listing the indications for antibiotic treatment of ABU at only one of its two hospitals. When compared to patients at the control hospital, ABU patients at the intervention hospital were significantly less likely to be inappropriately treated with antibiotics (OR 0.1, 0.02–0.5) [22]. A pre-post study of a similar hospital-based intervention that combined educational presentations, both print and electronic notifications of ABU treatment algorithms, and daily audits also reported significant reductions in inappropriate antibiotic treatment of ABU (OR 0.24, 0.13–0.43) [23]. Because recent studies of educational interventions on ABU have examined the impact of provider education only when bundled with electronic interventions, the independent role of education on the reported reductions in inappropriate prescribing cannot be determined.

Interventions improve adherence to evidence-based guidelines

Health systems often develop and circulate internal guidelines for antibiotic use based on best practices established by national-level organizations [1•]. However, the degree to which these guidelines impact clinical prescribing patterns can vary [24]. Many institutions have thus implemented interventions to improve adherence to guideline recommendations for antimicrobial prescribing.

Given that surgical site infections are common causes of nosocomial infections, the degree of adherence to surgical prophylaxis guidelines has garnered significant attention from antimicrobial stewardship teams. One hospital in India hosted an educational presentation on surgical prophylaxis attended by all staff in the Department of Surgery. Post-interventional analysis showed a shift in prescribing from predominately ceftriaxone (67.5 %) to cefazolin (56.3 %) and cefuroxime (37.5 %). The intervention was also associated with a reduction in the duration of antimicrobial prophylaxis, though a majority of patients (53.8 %) still received more than one dose [25]. A similar educational intervention targeting surgeons and anesthesiologists in Egypt reduced the duration of postoperative surgical antimicrobial prophylaxis [26]. The timing of the first prophylactic antibiotic dose remained problematic for the hospital; however, suggesting in combination with the previous study that educational efforts to improve prescribing habits for surgical prophylaxis may be effective for some, but not all, aspects of prophylactic antibiotic use.

Interventions targeting prescribing patterns for skin and soft tissue infections (SSTI) with the goal of improving adherence to Infectious Diseases Society of America (IDSA) guidelines have also shown variable success. Following a voluntary, online, non-interactive educational presentation that garnered a low participation rate (37.5 %), the majority of prescriptions for associated methicillin-resistant *Staphylococcus aureus* remained out of compliance with IDSA guidelines (57 %) [27].

However, the proportion of patients with uncomplicated SSTIs who were discharged with the IDSA-recommended short course of antibiotics

increased following another institution's multifaceted intervention (23 vs. 74 %; *p* value/95 % CI not provided). The impact on that intervention, which included educational sessions for attending and resident physicians, informational lanyard cards, and modification of electronic order sets, was sustained over the 6-month follow-up period [28]. The variability in the impact of interventions targeting prescribing for SSTIs may reflect a need for multifaceted, mandatory-type educational interventions over limited, voluntary ones.

Several educational interventions have targeted reductions in institutional fluoroquinolone (FQ) use. A teaching hospital in Ontario, Canada, assessed the impact of guideline-based educational tools and meetings on prescribing patterns for intra-abdominal infections.

The hospital reported a reduction in ciprofloxacin use by 58 % and a corresponding >600 % increase in ceftriaxone use, changes that were sustained during the 2-year follow-up period [29]. Similarly, an antibiogram-based educational intervention on the selection of empiric therapy for health care-associated pneumonia reduced average length of FQ use and empirical dual anti-*Pseudomonas* coverage [30]. In part due to concerns over increasing rates of fluoroquinolone-resistant *Escherichia coli*, the IDSA recommends reserving FQs for only complicated urinary tract infections including pyelonephritis [31]. Accordingly, one hospital investigated the impact of education on local antimicrobial resistance rates and urinary tract infection (UTI) practice guidelines on prescribing patterns for UTIs in its emergency department (ED) [32]. The intervention significantly increased the selection of recommendation-based empiric therapy for UTIs (44.8 to 83 %; difference 38.2; 95 % CI 33–43 %), largely due to decreased FQ use for cystitis (12.8 vs. 33 %) and increased use of FQ for pyelonephritis (47 to 70.4 %) [32].

Taken together, the results of these studies suggest that educational interventions designed to improve adherence to guidelines were more consistently able to impact prescribing of a specific class of medications (e.g., third generation cephalosporins and fluoroquinolones) than overall adherence to a set of drug, dose, and duration recommendations.

Non-physician provider education

While ASP educational efforts most commonly target prescribers alone or in combination with their care teams, a number of interventions have focused exclusively on the education of hospital pharmacists or nurses. These providers are often in a position to influence antibiotic management, and those who participate in the educational stewardship programs may be more likely to impact stewardship efforts in clinical practice. This was the case among nurses at the Australian hospitals, who were much more likely to raise questions to the treating team about antimicrobial orders after participating in small group and one-on-one tutorials on infection control [33].

One large, community hospital enrolled pharmacists in a mandatory, intensive educational program consisting of 2 h of live sessions, self-learning e-mail reviews, a "game show" quiz session, and weekly question, and answer meetings over the course of 4 months. Mean

pharmacist scores on a competency assessment were significantly higher following the program (79.2 vs. 49.7 %; mean difference 29.6 %; 95 % CI 23.1–36.03 %) [34]. Pharmacists showed similar improvements in knowledge regarding antimicrobial treatment of UTIs (77 vs. 56 %, $p<0.005$) following a 1-h live or recorded continuing education session [12]. Participants in both studies provided positive feedback on the programs [12, 34]. However, a substantial number of pharmacists did not achieve the commonly used competency or passage score of 70 % on the post-test, suggesting that ongoing education may be needed to gain or maintain competence [34].

Patient and caregiver education

Antibiotic prescribing occurs within the larger context of modern healthcare, in which prescribers must navigate the complexities of the physician-patient relationship as well as increasing demands on their time and concern for patient satisfaction. Providers thus face significant challenges in providing meaningful education on antimicrobial stewardship to patients who often hold established perceptions of and expectations for antibiotics. Several studies have focused on assessing the impact of educational interventions on patients' awareness of antimicrobial resistance and understanding of appropriate antibiotic use.

Waiting room posters and pamphlets are low-resource-intensive interventions commonly used to disseminate educational information. A primary care clinic in Surrey, UK, conducted a multifaceted educational campaign for both patients and staff consisting of patient-oriented posters in the waiting and exam rooms; patient fact sheets saved on every clinic computer for easy printing during patient encounters; and staff information sheets with evidence-based information to use when communicating with patients [35]. At the same time, the clinic encouraged its providers to practice "delayed antibiotic prescribing", as an average of 70 % of delayed prescriptions written by UK providers are never filled. Compared with pre-intervention prescribing rates, overall antibiotic prescribing following the educational campaign decreased for both patients presenting with cough (37.7 vs. 54.5 %) and upper respiratory infections (19.7 vs. 32.6 %). However, the clinic reported that the intervention required significant clinician buy-in and frequent reinforcement of stewardship goals [35]. Additionally, the independent effect of the three components was not known, and the impact of the program on several other metrics in primary care, including duration of physician-patient time, wait times, and number of return office visits, was not assessed.

The effectiveness of an interactive booklet "When Should I Worry?" aimed at increasing parent understanding of appropriate antibiotic use has been evaluated [36]. Francis et al. aimed to examine clinician use of the booklet in clinical practice and its effect on provider-patient interactions [37]. While the majority of the 13 physicians surveyed felt that the booklet effectively addresses knowledge gaps through clear and consistent messaging, some reported difficulties incorporating the booklet into their consultations. Most parents who received the booklets from their

child's physician reported improved confidence in symptom management and the identification of worsening symptoms that may necessitate a return physician visit [37]. Though small, this qualitative study provides insight into the general acceptability of the written educational materials among both patients and providers and suggests that clinician difficulty in incorporating these materials into the established flow of patient visits may present a barrier to more widespread use of such materials.

Opportunities for patient-focused educational interventions in antimicrobial stewardship extend beyond the medical clinic setting. Lecky et al. created a series of interactive science shows based on the established UK classroom education tool, e-Bug, for use at a family holiday resort [38]. These shows cover several key areas such as a discussion and visualization of the microbes, hand hygiene, microbes on food, how microbes are spread through a sneeze and the importance of completing a course of antibiotics. Prior to the 40-min show, the vast majority of adults (94.7 %) and approximately one-half of the children (47.0 %) correctly identified that overuse of antibiotics can reduce their effectiveness, but both adults (47.6 %) and children (69.1 %) incorrectly believed that antibiotics kill viruses. Following the interactive intervention, significantly more adults and children demonstrated an improvement in their knowledge that antibiotics kill bacteria but not viruses, and the children's overall understanding of microbes and antimicrobials improved significantly [38]. In a similarly interactive intervention, individuals in gyms, malls, and the supermarket scored significantly higher on a survey of antimicrobial knowledge following a 10-min discussion with a pharmacist [39]. While both of these studies suggest that educational campaigns in non-clinical settings may be effective ways to educate adults and children on the principles of antimicrobial stewardship, the long-term effects of the educational sessions on patient knowledge and future antibiotic use were not studied.

Overall, a variety of patient educational initiatives have been shown to effectively improve patient knowledge of appropriate antibiotic use. Further studies are needed in the area of patient antimicrobial stewardship education to assess clinician buy-in and long-term use of informational materials during clinic visits and to determine the impact of education outside of the physician's office on future patient behavior.

Conclusion

Provider education in antimicrobial stewardship is an impactful strategy for reducing unnecessary prescribing of antibiotics and increasing adherence to prescribing guidelines. Based on the available evidence, it is clear that education is only one piece in a multifaceted approach to ensuring appropriate antimicrobial use. Oftentimes, evaluation and feedback through an audit system are needed to solidify and reinforce the knowledge gained from these educational interventions. Additionally, patient-directed educational programs have been shown to increase patient knowledge of appropriate antibiotic use. Future research is needed to

assess the independent impact of both provider and patient education on long-term prescribing and use patterns as well as to determine the most effective methods of presenting educational information on antimicrobial stewardship.

Compliance with ethical standards

Conflict of interest
Drs Gravatt, Patterson and Franzese declare no conflict of interest.

Human and animal rights and informed consent
This article does not contain any studies with human or animal subjects performed by the authors.

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