Implementing an Antimicrobial Stewardship Program

By Karisma Patel, Pharm.D., BCPPS, BCIDP

Reviewed by Kristen Nichols, Pharm.D., BCPS, BCPPS, BCIDP; and Biljana Lanier, RPh, BCPPS

LEARNING OBJECTIVES

1. Justify the necessity and resources of an antimicrobial stewardship program (ASP) to organizational leadership.
2. Evaluate the resources and processes required to establish and sustain an ASP.
3. Analyze program outcomes to determine the effectiveness of an ASP.
4. Assess barriers to implementing an effective ASP.

ABBREVIATIONS IN THIS CHAPTER

AOM	Acute otitis media
ASP	Antimicrobial stewardship program
AU	Antimicrobial use
CAP	Community-acquired pneumonia
CDI	*Clostridioides difficile* infection
DOT	Days of therapy
EHR	Electronic health record
ESBL	Extended-spectrum β-lactamase
FTE	Full-time equivalent (or employee)
GAS	Group A *Streptococcus*
ID	Infectious diseases
IT	Information technology
MDR	Multidrug resistant
MDRO	Multidrug-resistant organism
NHSN	National Healthcare Safety Network
RDT	Rapid diagnostic testing
SAAR	Standardized antimicrobial administration ratio

Table of other common abbreviations.

INTRODUCTION

Systemic antibiotics are the most commonly prescribed medications in children in the outpatient setting (Chai 2012). Around 60 million antibiotic prescriptions are dispensed each year to outpatients younger than 20 years in the United States at a rate of 650 prescriptions per 1000 individuals (CDC 2019a). An estimated 30% of outpatient antibiotic use is considered inappropriate or unnecessary (Fleming-Dutra 2016). Similarly, around 60% of pediatric inpatients receive at least one antibiotic during their hospitalization (Gerber 2010), 30% of which are likely inappropriate (Tribble 2020b). Antibiotics have revolutionized modern medicine, and although they can cure infections and improve patient outcomes, any antibiotic exposure, regardless of appropriateness, poses a threat of unintended consequences such as antibiotic resistance, *Clostridioides difficile* infections (CDIs), drug-drug interactions, adverse and allergic drug reactions, and autoimmune conditions. To curb these negative effects, unnecessary or inappropriate antibiotic use must be limited.

From a global health perspective, the greatest consequence of antibiotic exposure and a critical patient safety issue is the development of antibiotic resistance. Antibiotic use in children, particularly of broad-spectrum agents, increases the risk of colonization and/or infection with extended-spectrum β-lactamase (ESBL)-producing organisms, carbapenem-resistant Enterobacterales, multidrug-resistant (MDR) *Pseudomonas aeruginosa*, and methicillin-resistant *Staphylococcus aureus* (MRSA) (Cogen 2021; Chiotos 2017; Zerr 2016). Prolonged courses of antibiotic therapy have also been significantly associated with colonization and/or infection with multidrug-resistant organisms (MDROs) (Murray 2019; Tamma 2011). Antibiotics can exert selective pressure on the intestinal microbiota by disrupting antibiotic-susceptible flora and allowing antibiotic-resistant bacteria to survive. Acquired resistance can occur through mutations or, more commonly, horizontal gene transfer (Medernach 2018). Examples of alarming collateral damage potentially caused by these mechanisms include an increased risk of vancomycin-resistant *Enterococcus* infections after third-generation cephalosporin exposure and an increased risk of infection with MRSA, ESBL-producing organisms, and/or carbapenem-resistant Enterobacterales after exposure to fluoroquinolones (Predic 2020; Paterson 2004).

Multidrug-resistant organisms cause around 5%–10% of health care–associated infections in children (Lake 2018). Infections secondary to MDROs can be difficult to treat, contributing to prolonged hospitalizations, increased direct and indirect costs, increased resource use, and higher rates of morbidity and mortality compared with susceptible infections (ARC 2022; Nelson 2021; Serra-Burriel 2020; Chiotos 2018). According to the CDC, an estimated 3 million infections from antibiotic-resistant bacteria occur annually in the United States, leading to 35,000 deaths (CDC 2019b). Rates of MDR infections are rising in pediatric patients (Logan 2017, 2015; Adams 2016). A recent study of pediatric patients admitted to 48 children's hospitals across the United States found a 650% increase in MDR Enterobacterales infections over an 8-year period, which was associated with increased lengths of hospital and ICU stay and mortality. Of note, almost three-fourths of MDR infections originated from the community, despite an expected higher risk of acquiring an MDRO in the traditional health care setting (Meropol 2018). Increased MDR infection rates in children are especially of concern because of the lack of pediatric pharmacokinetic and safety data for new antimicrobials as well as the immature immune systems of neonates, infants, and young children.

C. difficile can cause severe antibiotic-associated diarrhea in children and is associated with prolonged lengths of stay, greater hospital costs, and higher mortality rates (Sammons 2013). Antecedent antibiotic use is a well-established risk factor for CDI in adults and is generally viewed as a risk factor in children as well (Anjewierden 2019). Pediatric studies evaluating the associations of individual antibiotics with CDI risk have implicated fluoroquinolones, clindamycin, and third- and fourth-generation cephalosporins (Adams 2017; De Blank 2013; Sandora 2011). Moreover, there appears to be a shift to a higher CDI burden in the community compared with inpatient facilities (McDonald 2018; Wendt 2014). Beyond CDI, additional harmful effects of unnecessary antibiotic use include adverse events and increased risk of future chronic conditions. Antibiotic-related adverse events such as end-organ toxicities, diarrhea, rash, cytopenias, and allergic reactions account for about 50% of pediatric ED visits for adverse drug events as a result of systemic medications and occur in around 20% of hospitalized pediatric patients receiving antibiotics (Same 2021; Lovegrove 2019). In one study, the likelihood of experiencing an adverse drug reaction increased by 7% with each additional day of antibiotics (Same 2021). Frequent exposure to antibiotics early in life may also affect the intestinal microbiome, possibly leading to the development of autoimmune conditions, including inflammatory bowel disease, asthma, and diabetes (Vangay 2015).

The Society for Healthcare Epidemiology of America (SHEA) and Infectious Diseases Society of America (IDSA) defined antimicrobial stewardship in 1997 as the optimal selection, dose, and duration of antimicrobial therapy to effectively treat an infection, together with control of antibiotic use. This joint project was the first to recommend use of antimicrobial stewardship in hospital settings with a primary goal of preventing and controlling the spread of antimicrobial resistance (Shlaes 1997). An updated definition describes antimicrobial stewardship as "coordinated interventions designed to improve and measure the appropriate use of antimicrobial agents by promoting the selection of the optimal antimicrobial drug regimen including dosing, therapy duration, and route of administration" to maximize patient outcomes while minimizing unintended consequences (Fishman 2012). Antimicrobial stewardship has since become one of the most critical mechanisms to curb the downstream effects associated with antibiotic misuse. Given the slow development of new antimicrobials and the delay in data to guide pediatric use even after adult data are available, preserving and optimizing the use of available antimicrobials has become more important than ever. Pediatric antimicrobial stewardship programs (ASPs) effectively decrease unnecessary antimicrobial use (AU) (MacBrayne 2020; Turner 2017; Hersh 2015;

BASELINE KNOWLEDGE STATEMENTS

Readers of this chapter are presumed to be familiar with the following:

- Definition of antimicrobial stewardship
- Global threat of antimicrobial resistance and its downstream effects

Table of common laboratory reference values

ADDITIONAL READINGS

The following free resources have additional background information on this topic:

- Centers for Disease Control and Prevention (CDC). 2019. Core Elements of Hospital Antibiotic Stewardship Programs.
- Sanchez GV, Fleming-Dutra KE, Roberts RM, et al. Core elements of outpatient antibiotic stewardship. MMWR Recomm Rep 2016;65(RR6):1-12.
- National Quality Forum (NQF). National Quality Partners Playbook: Antibiotic Stewardship in Acute Care.
- Gerber JS, Jackson MA, Tamma PD, et al. Policy statement: antibiotic stewardship in pediatrics. J Pediatric Infect Dis Soc 2021;10:641-9.

Newland 2012; Di Pentima 2011; Metjian 2008), antimicrobial costs (Sick 2013; Agwu 2008; Metjian 2008), and lengths of stay and readmissions (Lee 2017) and prevent the spread of or decrease antimicrobial resistance (Bagga 2021; Stultz 2019; Horikoshi 2017; Di Pentima 2011). This chapter provides an overview of how to successfully implement an ASP in the inpatient or outpatient setting with a focus on pediatric-specific considerations and potential barriers.

IMPLEMENTING AN ASP

Many valuable resources are available to help guide the development of inpatient and outpatient ASPs. The CDC describes a set of Core Elements for antimicrobial stewardship in various health care settings, outlining the necessary components for the program (Box 1). The IDSA and SHEA have published guidelines on implementing ASPs, though they do not address outpatient antimicrobial stewardship (Barlam 2016). In addition, the Pediatric Infectious Diseases Society (PIDS) offers toolkits for both inpatient and outpatient ASPs for organizations seeking pediatric-specific resources (PIDS 2020).

Inpatient Programs

Obtaining Leadership Commitment

The first step to implementing a successful hospital ASP is to engage and secure the support of organizational leadership or the "C-suite" (e.g., chief executive office, chief medical officer) (Table 1). Leadership commitment is critical to recognize and obtain appropriate organization-specific resources, secure buy-in from clinical providers, and accomplish program goals. Pitching a business plan to the C-suite requires a good foundational knowledge of the pressures and demands, decision-making processes, and common terminology of executive leadership. Key components of a business plan are an executive summary; a description of how the initiative aligns with the organization's mission, vision, and values; justification of the business need or rationale; the program objectives (including primary and secondary drivers); and the financial request details (e.g., a precise or clearly defined budget) (Buckel 2020). Justification for ASPs should include targeting current institutional pain points and priorities (Nagel 2014). An example business plan for a pediatric ASP can be found in an online toolkit (PIDS 2020). The primary emphasis of a business plan for an ASP should be on improving patient quality, safety, and outcomes while recognizing regulatory and reimbursement impacts. Most pediatric facilities are members of the Children's Hospitals' Solutions for Patient Safety Network, whose mission is to eliminate serious harm to hospitalized children (SPS 2022). Promoting antimicrobial stewardship efforts is one of the many components of this initiative, which can help drive institutional program goals. The partnership between antimicrobial stewardship and infection prevention programs is critical, and bundled strategies can help achieve parallel overarching goals of preventing the development and spread of antimicrobial resistance in children.

A good way to capture the attention of hospital leadership and obtain staff buy-in is to demonstrate how an ASP can meet regulatory or accreditation requirements and quality indicators. Several U.S. regulatory bodies require implementation of ASPs as part of a global effort to reduce the development of antimicrobial resistance. In July 2016, the Joint Commission (TJC) sanctioned a new medication management standard requiring all accredited hospitals to have an ASP (TJC 2016). At the same time, the Centers for Medicare & Medicaid Services proposed a set of conditions

Box 1. CDC Core Elements of Antimicrobial Stewardship Programs

Hospital Antibiotic Stewardship Programs

- **Leadership commitment:** Dedicate necessary human, financial, and information technology resources
- **Accountability:** Appoint a leader or co-leaders responsible for program management and outcomes. Most hospitals find a physician and pharmacist co-leadership model effective; responsibilities and expectations for each leader should be clear
- **Pharmacy expertise:** Appoint a pharmacist, ideally as the program co-leader, to lead implementation efforts to improve antibiotic use
- **Action:** Implement interventions, such as prospective audit and feedback or preauthorization, to improve antibiotic use
- **Tracking:** Monitor antibiotic prescribing, impact of interventions, and other important outcomes like *C. difficile* infection and resistance patterns
- **Reporting:** Regularly report information on antibiotic use and resistance to prescribers, pharmacists, nurses, and hospital leadership
- **Education:** Educate prescribers, pharmacists, nurses, and patients about adverse reactions from antibiotics, antibiotic resistance, and optimal prescribing

Outpatient Antibiotic Stewardship

- **Commitment:** Demonstrate dedication to and accountability for optimizing antibiotic prescribing and patient safety
- **Action for policy and practice:** Implement at least one policy or practice to improve antibiotic prescribing, assess whether it is working, and modify as needed
- **Tracking and reporting:** Monitor antibiotic prescribing practices and offer regular feedback to clinicians, or have clinicians assess their own antibiotic prescribing practices
- **Education and expertise:** Provide educational resources to clinicians and patients on antibiotic prescribing and ensure access to needed expertise on optimizing antibiotic prescribing

Information from: Centers for Disease Control and Prevention (CDC). 2019. Core Elements of Hospital Antibiotic Stewardship Programs. Available at https://www.cdc.gov/antibiotic-use/core-elements/hospital.html; Sanchez GV, Fleming-Dutra KE, Roberts RM, et al. Core elements of outpatient antibiotic stewardship. MMWR Recomm Rep 2016;65:1-12.

Table 1. Key Steps for Starting an ASP

	Inpatient	Outpatient
Step 1	Obtain leadership commitment	Identify program scope
Step 2	Create an ASP team	Create an ASP team
Step 3	Develop an ASP policy	Assess baseline practice patterns and resistance patterns
Step 4	Determine data targets and tracking methods	Develop program priorities
Step 5	Determine the type of stewardship actions to perform	Develop initiatives and implementation strategy
Step 6	Determine how and to whom data will be reported	Develop and monitor process and outcome measures
Step 7	Develop an education plan	

ASP = antimicrobial stewardship program.

Information from: Pediatric Infectious Diseases Society (PIDS). Pediatric ASP Toolkit. 2020. Available at https://pids.org/pediatric-asp-toolkit/; Klepser ME, Dobson EL, Pogue JM, et al. A call to action for outpatient antibiotic stewardship. J Am Pharm Assoc 2017;57:457-63.

of participation (i.e., reimbursement) requiring U.S. hospitals and critical access hospitals to have active infection prevention and control and ASPs, which was finalized in September 2019 (CMS 2019, 2016). Other third-party payers also offer financial incentives to hospitals with ASPs (Anthem 2017). In addition, health care quality improvement organizations, including the Agency for Healthcare Research and Quality (AHRQ) and the National Quality Forum, have established infectious diseases (ID) quality metrics, which can affect reimbursement or lead to financial penalties.

An institution's national reputation and ranking compared with other hospitals are often influenced by quality metrics, such as patient safety scores, and are a major focus of hospital leadership. The Leapfrog Group is a national nonprofit organization that, among other activities, publicly scores hospitals on their commitment to antibiotic stewardship as outlined by the CDC Core Elements (Leapfrog Group 2021). Similarly, the *U.S. News & World Report* publishes Best Children's Hospitals rankings, which are determined according to patient outcomes (e.g., infections) and the hospital's commitment to patient safety, among other measures. Specific points for antimicrobial stewardship are awarded as part of the survey section on infection prevention, including detailed measures such as amount of full-time equivalent (or employee) (FTE) support and performance of specific stewardship activities. Use of survey results can help health systems improve and promote the quality of pediatric care (Chaulk 2021).

Sufficient funding for key personnel and necessary resources (e.g., software, equipment) should be requested in the business plan to ensure the ability to effectively implement antimicrobial stewardship practices. According to TJC standards, the inpatient ASP team should be multidisciplinary and at a minimum include an ID physician, a pharmacist, an infection preventionist, and another clinician. A physician leader is a vital member of the team because many interactions through ASPs occur with medical staff. The pharmacist provides broad expertise in ID pharmacotherapy and is often the primary designer and driver of interventions to optimize antibiotic use; the pharmacist should also work with the physician to determine program goals and outcomes. Ideally, both the physician and the pharmacist should be trained in ID and/or antimicrobial stewardship with a pediatric concentration. Currently, only two postgraduate training programs for pharmacists in the United States specialize in pediatric ID and antimicrobial stewardship, limiting the availability of pharmacists trained in both pediatrics and ID. Pediatric pharmacists can gain additional training on antimicrobial stewardship through certificate programs created by national organizations such as the Society of Infectious Diseases Pharmacists or Making-a-Difference in Infectious Diseases. The SHARPS collaborative is another resource open to all medical professionals interested in pediatric antimicrobial stewardship (Newland 2018). Infection preventionists provide valuable contributions to the ASP team, including data on potential program outcome measures including antimicrobial resistance and *C. difficile* trends (CDC 2019c). Finally, inclusion of other pediatric clinicians such as hospitalists, intensivists, or neonatologists is vital to the success of ASP efforts because these clinicians are frequent prescribers of antimicrobial therapy and key drivers of quality improvement. Additional personnel and resources to consider requesting are information technology (IT) support and a data analyst. Enhancing antimicrobial stewardship functionality within the electronic health record (EHR) (e.g., Epic, Cerner) or using add-on clinical decision support systems (e.g., TheraDoc, Sentri7, VigiLanz) can increase the efficiency of program interventions and allow for easier access to data and reports (Forrest 2014). A data analyst is essential to ensure appropriate tracking and reporting of meaningful data to health care team members and leadership. The specific job responsibilities and day-to-day tasks of each requested position should be clearly outlined in a job description and tailored to the needs of the specific health care setting.

Various groups have proposed FTE support according to the institution's size. Currently, the *U.S. News & World Report* survey evaluates hospitals against the most robust recommendation for FTE support, which includes at least 0.5 FTE for a dedicated pharmacist if the hospital has fewer than 250 beds and at least 1 FTE for a dedicated pharmacist if the hospital has 250 beds or more, at least 0.3 FTE for the program's medical director, and at least 0.2 FTE for a dedicated data analyst (Olmsted 2021). In a survey of 29 U.S. children's hospitals belonging to the SHARPS collaborative, 26 (89.7%) reported salary support for a dedicated physician with 0.1–0.8 FTE provided (median 0.3). Eighty-five percent of ASPs (n=22) reported support for pharmacists, with a range of 0.3–1 FTE provided (median 0.5 FTE). However, only five ASPs reported providing financial support for a dedicated data analyst, in the range of 0.2–0.5 FTE (median 0.2 FTE), and none provided support for administrative staff (Zachariah 2016). Benchmarking staffing allocations to other pediatric programs and using the questions from the *U.S. News & World Report* survey may motivate leadership to allocate more resources to the program. For institutions with limited resources, creativity is required; the ASP should consider collaborating with the infection prevention and control program for use of existing infrastructure and data analysis and reporting resources to support the ASP.

Although cost savings should not be conveyed as the primary goal of an ASP, it should be outlined in the business plan. It may be argued that cost savings are unlikely, given the numerically lower doses that smaller pediatric patients require, but newer agents with broader spectra or stability to resistance are typically more expensive. Moreover, limiting unnecessary AU can result in potentially avoidable costs. Many studies have shown cost savings as a result of ASP interventions in the pediatric population (Bagga 2021; Parker 2017; Turner 2017; Lee 2016; Sick 2013; Agwu 2008). The Children's Hospital of Philadelphia ASP showed that interventions performed by a full-time clinical pharmacist were associated with a savings of around $50,000 in drug acquisition costs in 4 months (Metjian 2008). Although most cost analyses focus on antimicrobial expenditures, experts suggest including additional aspects that may indirectly affect costs, such as improved patient flow, reduced variable costs because of process efficiency/improvement, reduced hospital-acquired adverse events, and increased revenue, by enabling more paying hospital admissions (Spellberg 2016). Programs can also aim to reduce readmission rates, which, when high, may be associated with reduced reimbursement from state Medicaid agencies, but also are a focus of many children's hospitals for patient safety purposes (Auger 2019). Projected cost-savings data can also include dose/drug optimization (e.g., renal/hepatic dysfunction adjustment), intravenous-to-oral conversion for antimicrobials, decrease in drug-resistant infections, and potential procedure and laboratory test cost avoidance. However, these data may be more complex to quantify.

Creating a Multidisciplinary Team

The next step in implementing an ASP is to form a multidisciplinary team (see Table 1). Organizing a group of key stakeholders who meet periodically can be helpful in advocating for stewardship efforts and creating opportunities for collaboration with other groups and departments. Hospital ASPs should form a committee led or co-led by the ID physician and/or ID pharmacist. Representatives to consider for the committee include individuals from executive leadership, ID, microbiology, infection prevention and control, pharmacy, pediatric specialties (e.g., hospitalists, intensivists, neonatologists, oncologists, pulmonologists), medical residents/fellows, nursing, IT, regulatory affairs, and quality and patient safety. It is also prudent to delineate the program's reporting structure using a policy or charter (see Table 1). Many institutional ASPs report to a pharmacy and therapeutics committee as the "guards" of medication use; however, it is recommended to report to quality and/or patient safety departments because the goal of ASPs is to optimize clinical outcomes and minimize patient harm by improving antimicrobial prescribing practices (Buckel 2020).

Outpatient Programs

Although early regulatory actions focused on acute care settings, as of January 2020, TJC began requiring ambulatory health care organizations that routinely prescribe antimicrobials to establish antimicrobial stewardship activities (TJC 2019). Outpatient stewardship can be a more challenging endeavor, given the many practice environments, including medical offices, EDs, urgent care centers, dental clinics, retail health clinics, and telehealth. Of note, children seeking medical care in suburban and rural areas have higher rates of prescriptions for viral infections and higher rates of off-guideline, broad-spectrum antibiotic use for conditions that warrant antimicrobial therapy; thus, it is essential to include these practices and outpatient networks when implementing ASP strategies (Wattles 2022; Dantuluri 2020). Recommendations for composition of the outpatient antimicrobial stewardship team are less specific; however, the CDC Core Elements suggest identifying a single leader to oversee antimicrobial stewardship activities (Sanchez 2016). Pharmacists in ambulatory care settings should collaborate with clinic staff members to lead ASP activities. For larger health systems with ambulatory practices, the inpatient ASP committee's responsibilities may extend into the outpatient setting.

ANTIMICROBIAL STEWARDSHIP STRATEGIES

After the ASP team has been formed, an action plan should be developed (see Table 1). Implementing an ASP is not a “one-size-fits-all” approach, given the diversity in the structure and clinical practice of various inpatient and outpatient settings among pediatric organizations. Institutions should identify targeted areas for improvement using baseline data while accounting for available staff, funding, and IT resources. Support from peer pharmacists can be helpful in implementing initiatives that require less ID expertise, such as intravenous-to-oral conversion or dosing optimization, which can allow ASP personnel to focus on ID-specific core and supplemental strategies (Patel 2010). However, even with these efforts, starting small and subsequently expanding may be more practical and successful than trying to launch a comprehensive program from the start. A well-established hospital-based ASP found that evaluating clinical diagnoses and antimicrobials predictive of interventions could help tailor ASP efforts and allow for potential program expansion (Goldman 2015) (Table 2). For hospitals with limited resources, interventions can focus on high-yield targets such as intravenous vancomycin and/or ceftriaxone use and patients with ear, nose, and throat and/or sinopulmonary diagnoses (Klatte 2019; Goldman 2015). Interventions should emphasize engaging frontline clinicians and supplying them with the knowledge and tools needed to optimize their own antimicrobial decision-making.

Several strategies described for inpatient ASPs are impractical in the ambulatory setting because of real-time prescribing and shorter patient interactions. Outpatient stewardship efforts should consider interventions that span various specialties and disciplines to standardize prescribing practices (Poole 2022). Some states have analyzed pediatric Medicaid outpatient pharmacy and medical claims data to assess prescribing patterns and provide a framework for a data-driven approach to outpatient stewardship (Kilgore 2022; Watson 2017). Outpatient interventions should initially focus interventions on high-yield conditions before expanding further (see Table 2).

Special considerations specific to children must be recognized when implementing a pediatric ASP. The common infections, disease processes, antimicrobial resistance patterns, physiologic and psycho/social factors, commonly prescribed antimicrobials, and dosing strategies differ across the spectrum of pediatric development (i.e., premature neonate to adolescent) compared with adults. Prescribers must account for pharmacokinetic and drug metabolism differences in children versus adults to avoid suboptimal dosing or inappropriate use of antimicrobials. These details, in addition to organizational culture and available resources, should be considered when tailoring ASP strategies to fit organizational needs.

Inpatient Stewardship Strategies

Priority ASP Interventions

The two core antimicrobial stewardship interventions supported by evidence and national guidelines are preauthorization and prospective audit and feedback (Barlam 2016; Dellit 2007).

Preauthorization is a “front-end” strategy that requires prescribers to obtain approval before ordering a restricted

Table 2. High-Priority Conditions to Target with Antimicrobial Stewardship Program Interventions

Inpatient	Outpatient
Surgical prophylaxis	Acute otitis media
Community-acquired pneumonia	Group A streptococcal pharyngitis
Ear, nose, and throat infections	Acute bacterial sinusitis
Acute appendicitis	Viral upper respiratory infections (e.g., acute bronchitis, nonspecific upper respiratory infection, or viral pharyngitis)
Cystic fibrosis acute pulmonary exacerbations	Community-acquired pneumonia
Skin and soft tissue infections	Urinary tract infections
	Skin and soft tissue infections

Information from: Poole NM, Frost H. Targets and methods to improve outpatient antibiotic prescribing for pediatric patients. Infect Dis Clin North Am 2022;36:187-202; Klatte JM, Knee A, Szczerba F, et al. Identification of high-yield targets for antimicrobial stewardship program efforts within a non-freestanding children’s hospital. Hosp Pediatr 2019;9:355-64; Goldman JL, Lee BR, Hersh AL, et al. Clinical diagnoses and antimicrobials predictive of pediatric antimicrobial stewardship recommendations: a program evaluation. Infect Control Hosp Epidemiol 2015;36:673-80; Gerber JS, Kronman MP, Ross RK, et al. Identifying targets for antimicrobial stewardship in children’s hospitals. Infect Control Hosp Epidemiol 2013;34:1252-8.

antimicrobial. This approach should be considered for antimicrobials with broad-spectrum activity, high cost, increased risk of adverse events, greater potential for causing resistance, and/or limited supply. Preauthorization leads to immediate and significant reductions in the use and acquisition cost of restricted antimicrobials (Dassner 2018; Horikoshi 2016; Chan 2015; Agwu 2008). Preauthorization also provides the opportunity for direct timely education to the prescriber before initiation of antimicrobial therapy. To ensure successful implementation of preauthorization, certain aspects must be considered. First is the competency of the individual providing the approval. Approvers are typically clinical pharmacists, fellows, and/or attending physicians specialized in ID. Data suggest that antibiotic approvals by a team consisting of an ID-trained clinical pharmacist and an ID physician result in more appropriate recommendations and better clinical outcomes than approvals by ID fellows alone (Gross 2001). Designated approvers should consider performing a direct chart review at the time of evaluation to ensure accuracy of the communicated information by the requesting prescriber and appropriateness of approval. Second, the approver must be available to address requests in real time. Antimicrobial stewardship programs can consider authorizing administration of restricted antimicrobials for a predetermined time (e.g., overnight, initial 18–24 hours) for convenience and to avoid delays in therapy. Use of a second-sign process in the EHR or a web-based tool can also enhance the effectiveness of preauthorization (Dassner 2018; Agwu 2008). Finally, preauthorization may lead to indirect increases in the use of nonrestricted agents, so monitoring antibiotic use patterns is important.

Prospective audit and feedback is the other core strategy commonly implemented to assess the appropriateness of AU. Prospective audit and feedback is a team-based method in which antimicrobial therapy is reviewed after a set amount of time (e.g., 24–96 hours). This approach preserves the autonomy of the ordering provider when choosing antimicrobial therapy and allows the ASP reviewer to have more clinical data to determine appropriateness of therapy, which is not typically available at the time of therapy initiation. When considering which antimicrobials to audit, many institutions choose to target broad-spectrum antimicrobials because their misuse is often more strongly associated with increased antimicrobial resistance. However, according to the results of a recent point prevalence study evaluating antimicrobial prescribing at 32 children's hospitals, 46% of antimicrobial orders considered suboptimal would not have been reviewed by ASPs as part of their routine daily work (Tribble 2020b). This suggests that programs with adequate resources should consider routinely reviewing all antimicrobials. On completion of the review, the ASP team provides the prescriber with recommendations on how to optimize therapy, often by telephone or through electronic methods (e.g., EHR, secure messaging). Face-to-face communication is highly recommended to engage frontline providers in the feedback process and can be achieved using an innovative approach termed *handshake stewardship*. Handshake stewardship has now been incorporated into the TJC ASP standards as well as the CDC Core Elements because of its success in optimizing AU, identifying diagnostic errors, decreasing antimicrobial costs, and increasing the number of ID consultations among hospitalized children (MacBrayne 2020; Searns 2020; Hurst 2019, 2016; Messacar 2017a; Parker 2017). This unique method is characterized by a lack of prior authorization, a shared review of all prescribed antimicrobials by a physician and pharmacist, and a daily, rounding-based, in-person approach to allow for education and interactive discussion (Hurst 2016). Interprofessional collaboration with providers is essential to the success of handshake stewardship. Developing key relationships and educating providers on this process can increase awareness and intentions of the ASP, helping address any fears and input of involved team members. It is also crucial to collaborate with other team members such as nurses, nurse practitioners, physician assistants, and pharmacists from other specialties to improve the efficacy and sustainability of interventions.

Prospective audit and feedback positively affects AU, antimicrobial prescribing errors, and costs (Bagga 2021; Willis 2017; Newland 2012; Di Pentima 2011). Benefits of handshake stewardship specifically include shared decision-making and collaboration, a healthier hospital culture, avoidance of intervention fatigue, a lasting educational impact, and incorporation of diagnostic stewardship (MacBrayne 2020). In institutions with limited resources, modified forms of prospective audit and feedback can be performed. If stewards cannot audit all antimicrobials on a regular basis, prioritizing the review of specific antimicrobials and continued use of preauthorization may be necessary. In addition, effective strategies for smaller ASP teams or non-ID pharmacists include focusing on specific patient care teams (e.g., ICUs, general pediatrics), targeting specific infectious indications (e.g., *S. aureus* infections, candidemia), and limiting the number of rounding-days (Klatte 2018). If in-person rounds are not feasible, virtual methods of communication can be adopted, including virtual meetings, electronic communication, and email (Zembles 2021).

Many institutions use a combination of preauthorization and prospective audit and feedback, adapted to the specific resources, culture, and personnel of the institution (McPherson 2018). Supplemental strategies such as guideline development, use of order sets, or required antimicrobial stop dates can help address suboptimal use of narrow- and broad-spectrum agents in settings with fewer resources.

Supplemental ASP Strategies

Supplemental strategies can be implemented to further enhance an ASP's efficacy and outcomes. Examples include facility-specific treatment guidelines, antibiotic "timeouts," penicillin allergy assessment, intravenous-to-oral conversion, diagnostic stewardship, and education (CDC 2019c; Barlam 2016). Several of these strategies can be particularly useful in settings without dedicated or with limited antimicrobial stewardship support.

Creation of syndrome-specific guidelines to standardize the approach to patient care is a common supplemental stewardship intervention that improves AU and clinical outcomes (Wakeman 2022; Willis 2018; Rutman 2017; Newman 2012). This type of intervention can be considered for any size of institution, even one with limited resources (Lee 2016). The CDC recommends development of guidelines that target the most common infectious conditions in the hospital such as community-acquired pneumonia (CAP), UTIs, and skin and soft tissue infections (CDC 2019c). An additional indication to consider is perioperative antibiotic prophylaxis because pediatric surgical patients account for greater than 40% of all inpatient antibiotic use (Gerber 2013), around 40% of which is likely inappropriate (Anandalwar 2020). Specific identified priorities for pediatric surgical patients include minimizing the use of broad-spectrum agents for cardiothoracic, neurosurgical, and GI procedures and limiting perioperative antibiotic exposure to recommended durations (Kronman 2015).

Guidelines should describe the likely clinical presentation, appropriate diagnostic testing, empiric treatment choices, de-escalation considerations, and therapy duration (Jenkins 2021). They should be prepared using a structured evidence-based approach with consideration of local microbiologic data and should promote the use of formulary agents. Input should be incorporated from up-to-date published literature, as well as a multidisciplinary group consisting of key stakeholders from relevant pediatric subspecialties (e.g., hospitalists, neonatologists, intensivists, oncologists), pharmacy, nursing, and quality improvement. Guidelines should be disseminated to all health care providers, including pharmacists, and appropriate concomitant education should be provided to ensure understanding and encourage guideline uptake. Antimicrobial stewardship programs should ensure guidelines are easily accessible to providers at the point of prescribing, such as by embedding links in the EHR, posting on the institution's intranet site, or including in a pocket handbook. In addition, for institutions with EHRs, use of corresponding order sets and/or order sentences can help reinforce guideline-based prescribing decisions, optimize antibiotic dosing, and monitor adherence to guideline recommendations (Lanata 2021).

Antibiotic timeouts can increase clinician engagement and consistency in the antibiotic decision-making process. Use of the AHRQ's "Four Moments of Antibiotic Decision Making" framework can prompt clinicians to consider specific questions at appropriate time points in patient care. The moments are (1) assessing the patient for an infection in which antibiotics are required; (2) ensuring appropriate cultures are ordered before antibiotics are initiated and initiating appropriate empiric antimicrobials; (3) reassessing whether antibiotics can be discontinued, narrowed, or stepped down from intravenous to oral; and (4) determining an adequate therapy duration once an infection has been diagnosed (AHRQ 2019). The optimal timing (i.e., 24 hours, 48 hours, 72 hours) for antibiotic timeouts is unknown, but performing daily reviews is suggested until a definitive diagnosis and treatment duration are finalized. Timeouts have been implemented in varying ways in several pediatric hospital settings and have improved and reduced antibiotic use and improved documentation of the timeout components (Stang 2021; Wirtz 2020; Adams 2019; Thom 2019). Although the CDC recommends that reviews be the responsibility of the frontline prescriber rather than the ASP team (CDC 2019c), this intervention can also successfully be implemented by decentralized pharmacists (Stang 2021; Wirtz 2020). Timeouts should not be used as a substitute for prospective audit and feedback (CDC 2019c). For one established pediatric ASP using a prospective audit and feedback model, implementation of a peer pharmacist-driven 48-hour timeout process did not decrease ASP intervention rates, but augmented ASP efforts (Wirtz 2020).

Pharmacists can play a major role in implementing pharmacy-driven strategies such as intravenous-to-oral conversions, dose optimization and adjustments, prevention or avoidance of duplicative therapy, documentation of indication and duration for antimicrobial orders, and detection and prevention of antibiotic-related drug-drug interactions. According to the 2015 Pediatric Health Information System data from 48 freestanding children's hospitals, only 36% of antibiotics with 80% or greater oral bioavailability were administered orally, demonstrating the need for intravenous-to-oral conversion programs in pediatric patients (Smith 2019). Both the hospital and the patient can benefit from this intervention because use of oral rather than intravenous antimicrobials leads to decreased antimicrobial expenditure costs, shorter hospital stays, and decreased risks of complications related to intravenous catheter placement (McMullan 2021; Murphy 2016; Elemraid 2014). Therapeutic drug monitoring and dose optimization, including use of optimized pharmacokinetic/pharmacodynamic dosing strategies such as extended infusions for β-lactams or extended intervals for aminoglycosides, can help ensure optimal therapeutic dosing, minimize the development of resistance, avoid antibiotic-associated harm, and decrease the use of alternative broader-spectrum agents. A prospective study showed that dosing guidelines and a pharmacokinetic consult service as part of a pediatric ASP helped achieve safe, rapid, and sustained target vancomycin concentrations compared with a control group (Kreitmeyr 2021).

Another strategy that pharmacists can take the lead on is assessing children with documented penicillin allergies for potential de-labeling, because most children who report a penicillin allergy are able to tolerate penicillins (Norton 2018a). A reported penicillin allergy can limit the use of several narrow-spectrum β-lactam antibiotics exposing the patient to unnecessarily broad, less effective, more expensive antimicrobial agents, which can lead to higher health care costs, increased antibiotic resistance, risk of suboptimal treatment, and higher rates of CDIs (Vyles 2020; Joint Task Force 2010). There are several effective approaches to assess penicillin allergies. Historically, patients with suspected antibiotic allergies were referred to allergy and immunology specialists to undergo consultation for skin testing or oral drug challenges to confirm the presence of a true drug allergy. However, recent data suggest that skin testing or challenge doses can often be avoided using alternative approaches such as risk-assessment questionnaires and/or clinical pathways to safely and effectively de-label low-risk hospitalized pediatric patients (Rischin 2022; Bauer 2021). A risk-based approach created in collaboration with pediatric allergists, pharmacists, and nursing can help determine whether patients can be de-labeled or require further evaluation. Such assessment tools can effectively be championed by frontline pediatric clinical pharmacists (Louden 2021). Pharmacists are also well positioned to be involved in performing penicillin skin testing and direct oral graded challenges in inpatient settings, though published data are limited on this in the pediatric population. Resources are available to help pharmacists successfully implement penicillin skin testing (Bland 2019; Jones 2017).

Rapid diagnostic testing (RDT) has expanded the role of microbiology laboratories beyond antibiogram development, antibiotic susceptibility cascade reporting, and specimen testing guidance. Use of rapid, sensitive diagnostic testing informs prescribing practices through early pathogen identification and, in some cases, detection of certain antibiotic resistance genes (Avdic 2014). The primary focus on the use of RDTs has been in the setting of bloodstream infections, though they can also be used in respiratory, CNS, and GI infections. Rapid diagnostic testing can facilitate optimization of antimicrobial therapy through timely de-escalation; broadening, if necessary; or discontinuation. However, RDTs should be used together with antimicrobial stewardship for the most benefit (Timbrook 2017); diagnostic stewardship is also key (Messacar 2017b). Diagnostic stewardship refers to selection of the appropriate test for a specific patient that will provide accurate, clinically relevant results at the right time. In the pediatric population, several published studies describe the impact of RDT used together with antimicrobial stewardship, specifically in the setting of bacteremia. The primary effect described to date is decreased time to optimal therapy, though reduced vancomycin use and decreased duration of bacteremia have also been described (Tribble 2020a; Welch 2020; Reuter 2019). Antimicrobial stewardship programs should specifically plan for RDT implementation, including how results will be communicated and acted on at various times of the day, before use of a new test. A guidance document and/or education provided by the ASP, or incorporated into the EHR, can help prescribers with appropriate test ordering (if necessary), interpreting test results, and deciding when ID consultation may be beneficial. Protocol-driven processes can also be considered to allow clinical pharmacists to independently make changes on the basis of RDT results. Although RDT can affect clinical outcomes, use is generally limited to a few patients (i.e., those with bacteremia). In addition, RDTs can be costly and occasionally resource-intensive from a clinical microbiology laboratory perspective.

Education is also an essential component of antimicrobial stewardship. However, education should not be a stand-alone strategy. Education should be incorporated into the implementation of other core and supplemental strategies. Everyone involved in patient care, including physicians, nurse practitioners, physician assistants, pharmacists, nurses, trainees, patients, and caregivers, should be included in educational initiatives. Educating providers on relevant new evidence and useful guidelines can help drive behavioral and practice changes. There are many methods of disseminating education, including during prospective audit and feedback or using formal and informal didactic presentations; posters, flyers, or pocket cards; guides; brochures and newsletters; and emails (Barlam 2016).

Special Populations

Established pediatric ASPs should consider expanding their efforts to include subpopulations that account for smaller percentages of the overall pediatric population but receive a disproportionately higher percentage of antibiotics. High-risk pediatric patients such as neonates or patients who are critically ill, are immunocompromised, or have underlying complex conditions bring unique challenges and barriers to antimicrobial stewardship. These patients are more likely to receive broad-spectrum antimicrobials for longer durations and are at higher risk of developing infections with MDROs or *C. difficile*. Medical providers are often hesitant to follow ASP recommendations to de-escalate or discontinue antimicrobial therapy in these populations because of factors such as fear of adverse outcomes and limited evidence regarding appropriate treatment durations. However, following ASP recommendations in these special populations has not been associated with poor clinical outcomes (Kennedy 2022; Lanata 2021; Goldman 2019; Horikoshi 2018; Cantey 2016). A multidisciplinary approach including pediatric physicians and pharmacists from the respective subspecialty, pediatric ID physicians and pharmacists, and quality improvement specialists should be considered when discussing the implementation of specific ASP strategies for these subpopulations. It is also helpful to provide data to key stakeholders to further support recommended changes.

Patients with cystic fibrosis are one such pediatric population with a high level of antibiotic use (Gerber 2013). Patients with cystic fibrosis can be challenging to treat because they are typically colonized with many bacteria that are often multidrug resistant and are highly prone to the negative effects of AU, including toxicities and antibiotic resistance. Antimicrobial stewardship opportunities in this patient population include determining which patients might benefit from intravenous versus oral versus aerosolized antibiotic courses, examining the optimal duration of antibiotics, and reevaluating the number of antibiotics necessary for the treatment of pulmonary exacerbations and/or chronic suppression (Cogen 2020). A quality improvement initiative targeted at pediatric patients with cystic fibrosis included the development of an empiric antibiotic algorithm by a multidisciplinary team of pulmonologists, ID physicians, and pharmacists; adherence to the algorithm increased over time, and piperacillin/tazobactam use decreased, without an increase in treatment failure (i.e., requiring greater than 14 days of therapy [DOT] or readmission for pulmonary exacerbation within 30 days) (Kennedy 2022).

Children with cancer and/or undergoing stem cell transplantation are at increased risk of infection-related morbidity and mortality and thus receive frequent, prolonged courses of broad-spectrum antimicrobial therapy (Wolf 2016). General goals of antimicrobial stewardship in oncology patients include avoiding initiation of or expedited cessation or de-escalation of unnecessary antimicrobials. Common strategies used by pediatric ASPs caring for immunocompromised patients include locally adapted clinical practice guidelines, dose optimization, prospective audit and feedback, clinician education, and formulary restriction (Wattier 2017; Wolf 2016). It also important to establish trust, emphasize mutual interests and shared goals, and keep communication regular among oncology provider groups.

Patients in the ICU are an additional resource-intensive population. Several ASP strategies have been used successfully in this population. Use of a timeout process 48–72 hours after antimicrobial initiation was associated with a reduction in broad-spectrum use in a pediatric ICU (Adams 2019). Another area of interest is the usefulness of procalcitonin in reducing antibiotic use in pediatric ICU patients. Although studies have found no significant benefit on duration of antibiotic therapy, use of a procalcitonin testing and treatment algorithm combined with ASP guidance may be beneficial for antibiotic de-escalation (Katz 2021b; Downes 2020). As with other special populations, obtaining buy-in from frontline critical care providers is essential to the success of ASP interventions in the pediatric ICU. In addition to using core strategies, development of clear and concise recommendations combined with clinical education and use of order sets can reduce targeted AU.

Neonates present unique challenges that lead to antibiotic use, including nonspecific clinical symptoms and maternal risk factors (i.e., chorioamnionitis, infection before/during delivery) (Gkentzi 2019; Cantey 2014). Empiric therapy is often initiated for suspected infections with a perception that benefits outweigh risks of antibiotic exposure; however, only a few neonates have positive cultures (Cantey 2019). In addition, longer durations of therapy are often chosen because of the lack of data to support shorter courses in this population. Several of the common core and supplemental ASP strategies can be safely and effectively implemented in the neonatal ICU, particularly prospective audit and feedback, guideline development, and diagnostic stewardship. Antimicrobial stewardship programs should consider targeting high-priority indications in neonates such as sepsis, necrotizing enterocolitis, and perioperative prophylaxis (Katz 2021a). Participation in an internet-based national quality improvement collaborative called Choosing Wisely can provide further feedback on specific opportunities to address in the neonatal ICU (Dukhovny 2019). As with any intervention, multidisciplinary collaboration is critical (Katz 2021a).

Outpatient Stewardship Strategies

The approach to antimicrobial stewardship in pediatric outpatients, as in inpatients, requires consideration of pediatric-specific indications and factors. Several potential actions have been described.

Clinical practice guidelines can help outpatient providers use evidence-based diagnostic criteria and treatment recommendations (i.e., drug, dose, route, and duration) to mitigate antibiotic misuse (Sanchez 2016). Antimicrobial stewardship program leaders should focus guideline development on high-priority conditions (see Table 2). Organization-specific guidelines should be created using national guidelines that have been customized to local epidemiology and antibiotic availability. Free resources available for institutions with limited ability to create internal guidelines include the SHARPS outpatient collaborative and online pathways from other pediatric institutions (CHC 2022; Seattle Children's Hospital 2022; El Feghaly 2021).

It is particularly important that local guidelines include recommendations for the shortest effective antimicrobial duration. Although several national guidelines recommend broad ranges for therapy duration, more recent evidence supports the use of shorter antibiotic durations (e.g., 5–7 days) compared with longer durations for several common pediatric indications, including UTIs and CAP (Pernica 2021; Afolabi 2020; Fox 2020). Although some guidelines include recommendations for short courses, such as for acute otitis media (AOM) and skin and soft tissue infections, longer courses are commonly prescribed for such indications in clinical practice (Frost 2020a; Jaggi 2018). Bundled interventions including individualized audit and feedback, education, and/or EHR changes can improve the prescribing of guideline-concordant durations.

Specific EHR strategies to consider as guideline supplements include order sets and/or addition of guideline hyperlinks, "help" text describing dose and duration, and/or "quick" buttons for dose and duration of commonly used antibiotics (Frost 2022a; Zahlanie 2020). Building order sentences into the electronic medical record for use at the time of prescribing can provide real-time dosing guidance for antimicrobials with different dosing strategies depending on the diagnosis, such as thrice-daily dosing of amoxicillin in CAP compared with twice-daily dosing in AOM (Monsees 2021). Another method to ensure safe and effective antibiotic administration in children is provision of an antibiotic handbook that outlines the appropriate antibiotic, dosing, duration, and formulation for the most common pediatric infections in outpatient settings (Monsees 2021).

For indications such as acute uncomplicated sinusitis or mild AOM that generally self-resolve but may require treatment if the patient does not improve, delayed prescribing or watchful waiting can be used to safely decrease antibiotic use (Frost 2021). In delayed prescribing, clinicians provide caregivers/patients a postdated "safety-net" prescription to fill at a later time, if necessary, or advise them to call or return to collect a prescription if symptoms worsen or do not improve (Sanchez 2016). This strategy engages families with the plan and can maintain patient satisfaction while avoiding potentially unnecessary early initiation of antibiotics.

Several methods can be used to ensure appropriate use of diagnostic tests in the outpatient setting. Use of clinical decision rules outlining criteria for appropriate use can be considered to focus RDT on patients with a higher pretest probability. Requiring clinicians to select an indication before ordering the test may limit overuse of tests. Benchmarking diagnostic test ordering by individual providers compared with that of peers can also be used to curb overuse. Combining these approaches with provider-specific education and feedback approaches is essential. Indications for which to consider the clinical usefulness of diagnostic tests include acute pharyngitis, AOM, UTI, and acute sinusitis (Gerber 2021). Appropriate use of group A *Streptococcus* (GAS) testing is of particular interest because of overdiagnosis and overtreatment of GAS pharyngitis (Dooling 2014). Investigators conducted a quality improvement project with the goal of improving the testing and treatment of GAS pharyngitis in a large outpatient pediatric practice. Many interventions were used, including webinars to educate providers and staff, elimination of a nursing standing order for rapid testing before provider evaluation, communication skills training, and patient education. The greatest decrease in inappropriate testing was seen specifically in patients younger than 3 years and in patients with two or more viral symptoms, though no changes were observed in antibiotic prescribing. The authors suggest greater efforts are needed to reduce inappropriate GAS testing to witness an improvement in antibiotic use (Norton 2018b). As another example, standardizing uncomplicated UTI diagnostic testing using a guideline approach can improve the appropriate diagnosis and treatment of UTIs (Walters 2019).

Engagement of frontline providers is critical to the success of ambulatory stewardship efforts. Personalized audit and feedback can positively affect antibiotic prescribing (Diaz 2020). This approach should be combined with other ASP interventions such as education or periodically sharing data with key stakeholders for optimal effect and sustainability (Katz 2022; Taylor 2021; Gerber 2014, 2013). According to available IT and data resources, alternative methods of feedback to consider are use of less-frequent reporting, point prevalence evaluation, and automated reports (El Feghaly 2021; Frost 2022b, 2020b; Tribble 2020b).

Inpatient ASPs can extend their reach into the outpatient space in several ways. Institutions with ID-trained pharmacists and/or providers can offer their expertise to outpatient practices as a consultative service. Another approach to consider is reviewing discharge antimicrobial prescriptions for appropriateness, which can also be delegated to decentralized pharmacists. Investigators proposed a checklist framework for evaluating discharge antibiotic appropriateness termed the *4 D's for discharge stewardship*: diagnosis, drug (i.e., choice, route, dose, frequency, cost), duration, and designated clinician (Hersh 2016). In addition, if feasible, automatic interventions to subtract inpatient DOT from the intended total duration for discharge prescriptions could increase adherence to recommended therapy durations (Olson 2019). Finally, pediatric ID expert evaluation of the specific route of discharge prescriptions can limit the use of outpatient parenteral antibiotic therapy (OPAT) to conditions for which oral therapy is suboptimal. Active ASP intervention on OPAT reduces OPAT use, leading to direct and indirect benefits, which may include cost savings for central line placement, avoidance of central line complications, and cost and time savings associated with OPAT administration (Hersh 2018).

As vaccine technology continues to grow, promoting the uptake of vaccines is another antimicrobial stewardship opportunity that can target the prevention of antibiotic-resistant infections as the root of antibiotic use/misuse during transitions of care (Hersh 2017).

OPTIMIZING RECOMMENDATION ACCEPTANCE

The overall impact of an ASP on antimicrobial prescribing practices relies partly on behavioral changes of the individuals involved in prescribing, dispensing, administering, and receiving antimicrobial therapy. With respect to providers, prescribing behavior can be subject to a certain "prescribing etiquette," which places importance on factors such as medical hierarchy (i.e., following practices set by senior colleagues) and professional relationships (i.e., hesitancy to change antimicrobial therapy plans made by prior colleagues) (Charani 2011). Existing evidence highlights the influence of social norms, attitudes, and beliefs on antimicrobial prescribing practices, but limited data are available on using these factors in the design and assessment of ASP interventions (Charani 2011). The success of ASP interactions relies on stewards' and prescribers' perceptions of being on the "same team" with aligning goals compared with an "us-versus-them" mentality (Szymczak 2021). Antimicrobial stewardship programs should focus efforts on building relationships and gaining the trust of providers to help produce a sustainable change in prescribing behavior.

Effective interpersonal communication skills are critical to improving antibiotic use and preventing antibiotic-associated harm. Suggested communication strategies to help develop lasting relationships with providers include "moderating language to minimize defensive recommendations when delivering stewardship recommendations, aligning the goals of stewardship with the goals of the clinical team, communicating with prescribers about things other than stewardship, compromising for the sake of future interactions, and engaging in strategic face-to-face interactions" (Szymczak 2021). According to experience with the handshake stewardship model, face-to-face communication is quite effective in enhancing the acceptance rate of ASP recommendations (Hurst 2019). An additional consideration is to tailor the language and timing of interventions to social norms, type of provider (i.e., intern vs. attending), and motivations of physicians from various specialties (i.e., medical vs. surgical team) (Charani 2019; Szymczak 2019). For established ASPs, eliciting feedback from frontline prescribers can engage them in further enhancing program impact (Szymczak 2019).

Motivational interviewing is an evidence-based communication style used to drive behavioral change by empowering people to draw out their own meaning, importance, and capacity for change in a collaborative manner (Miller 2013). In the context of antimicrobial stewardship, an example of motivational interviewing in an interaction with a prescriber includes asking about the patient's condition, affirming the information received, asking permission to fill in any blanks, communicating the ASP recommendations, asking for thoughts about the recommendations provided, and affirming the decision. Conveying recommendations to primary teams using this technique facilitates face-to-face communication in a nonconfrontational manner (Goff 2016). These interactions should ideally occur in the presence of the entire primary medical or surgical team caring for the patients to allow for extensive discussion with bidirectional feedback, development of rapport with providers, and provision of real-time education, maximizing teachable moments (Foral 2016).

In the pediatric outpatient setting, greater emphasis is placed on the relationship between provider and parent/patient in delivering high-quality care. Effective communication between providers and parents improves antibiotic prescribing and increases parent satisfaction (Mangione-Smith 2015). Shared decision-making is a team approach that allows for exchange of information between the clinician and the patient to lead to an informed joint decision. The AHRQ developed the SHARE approach to describe the essential steps of shared decision-making (Table 3). Use of this approach should be considered with patients and parents/caregivers who are requesting antibiotic treatment for a likely viral infection or are unsure whether an antimicrobial is necessary for their condition. Pediatric providers can enforce their commitment to appropriate antibiotic use by reviewing physical examination findings using a "no-problem" commentary (i.e., using language to address parental concern and reassure parents that symptoms are not of concern), delivering a clear diagnosis, using a two-part negative/positive treatment recommendation, and providing a specific contingency plan (Poole 2018). Communication skills training can also help clarify the provider's intent to use antibiotics only when clinically appropriate and support the fully informed contribution of parents and children in decisions about antibiotics (Cals 2013). It is also essential to create educational materials for patients and families with relevant information to support reduction in antibiotic use. In addition, use of office educational materials such as commitment posters addressing the practice's goals for evidence-based care, especially regarding antibiotic use, is recommended (Poole 2022). As medication experts and frontline providers, pharmacists can also play a key role in the shared decision-making process and education of patients and families regarding appropriate antibiotic use.

Table 3. SHARE Approach: Five Essential Steps of Shared Decision-Making

Step 1	**S**eek your patient's participation	Communicate that a choice/decision point exists, and invite your patient to be involved in decisions
Step 2	**H**elp your patient explore and compare treatment options	Discuss the benefits and harms of each option
Step 3	**A**ssess your patient's values and preferences	Consider what matters most to your patient
Step 4	**R**each a decision with your patient	Decide together on the best option and arrange for a follow-up appointment
Step 5	**E**valuate your patient's decision	Plan to revisit decision and monitor its implementation

Information from: Agency for Healthcare Research and Quality (AHRQ). SHARE Approach Workshop Curriculum. Available at https://www.ahrq.gov/health-literacy/professional-training/shared-decision/workshop/mod1-guide.html.

Educating providers on the importance of antimicrobial stewardship can strengthen their commitment to prescribing antibiotics only when necessary and prepare them for discussions with parents who expect antibiotics. Physicians, nursing staff, midlevel providers, and trainees (medical students, residents, fellows), including both pediatric and non–pediatric-specific providers, can benefit from evidence-based education efforts provided in an instructional and conversational manner rather than didactic lecture–based methods. An interesting outpatient learning collaborative between American Academy of Pediatrics members and staff, CDC antimicrobial stewardship experts, pediatricians, and representatives from a health insurer showed the usefulness of virtual education and multidisciplinary collaboration in improving outpatient prescribing practices for AOM (Norlin 2021).

DATA TRACKING AND REPORTING

Evaluation of data is important both before and after implementing an ASP. Analysis of baseline data before program implementation can help identify targeted areas for improvement and prioritize interventions. Availability of baseline data also allows ASPs to measure the impact of implemented strategies. The effectiveness of all quality improvement initiatives should be measured to assess outcomes, including efficacy at achieving desired goals; learn from successes and failures; and identify continued areas for improvement. Antimicrobial stewardship is no different, and tracking outcomes is critical, as indicated by the inclusion of standards for tracking within CDC and TJC guidance. Antimicrobial stewardship metrics often aim to demonstrate improved patient outcomes, optimized hospital processes, and reduced health care costs. Periodic analysis of metrics also helps ensure the sustained effectiveness and viability of established ASPs (Kronman 2018). Tracking the outcomes from ASP strategies and interventions demonstrates the program's value and can allow early identification of any unintended consequences.

Three general categories of metrics can and should be evaluated in antimicrobial stewardship: AU measures (e.g., DOT) to assess the quantity of antibiotic use; other process measures (e.g., length of therapy, cost data) to determine the quality of antibiotic use; and outcome measures (e.g., CDI rates, MDRO infection rates, antibiogram changes, lengths of hospitalization, readmission rates) to evaluate the financial, microbial, and patient impacts from health care processes and interventions (CDC 2019c). When selecting the metrics to implement, many factors should be considered, including institutional and hospital leadership pain points and priorities, specific program or initiative goals and balancing measures, and resource availability (i.e., what data/metrics are readily available). Many possible metrics can be used, but some are used more commonly than others. A stepwise approach (Table 4) allows institutions to focus on high-value targets before expanding to more advanced metrics.

Table 4. Stepwise Approach for Implementing Stewardship Metrics

Measures	Basic	Intermediate	Advanced
Antibiotic use	Antibiotics used (total number of grams) Length of therapy	DOT/1000 patient-days, days-present, or admissions on the basis of unit/service, indication, and/or antimicrobial class	DOT/1000 patient-days, days-present, or admissions depending on prescriber SAAR
Process	Accurate allergy/adverse reaction documentation Adherence to specified interventions Types of ASP recommendations Acceptance of ASP recommendations	Performance of antibiotic timeouts Adherence to documentation policies	Adherence to facility-specific pathways or clinical guidelines Assessment of timeliness of therapy and adherence to timeliness initiatives
Outcome	30-day readmission rates for pneumonia and *C. difficile* *C. difficile* infection rates Direct antimicrobial expenditures	Antibiotic resistance patterns Antibiogram changes Prevention of hospital-acquired infections Type and frequency of antibiotic-associated adverse events	Infection-related mortality Infection-related length of stay Cost of care Societal cost

ASP = antimicrobial stewardship program; DOT = days of therapy; SAAR = standardized antimicrobial administration ratio.

Information from: National Quality Forum (NQF). National Quality Partners Playbook: Antibiotic Stewardship in Acute Care. Available at www.qualityforum.org/NQP/Antibiotic_Stewardship_Playbook.aspx; Centers for Disease Control and Prevention (CDC). Core Elements of Hospital Antibiotic Stewardship Programs. CDC, 2019. Available at https://www.cdc.gov/antibiotic-use/core-elements/hospital.html.

Box 2. Sample Calculation for DOT

A patient is prescribed ceftriaxone 500 mg IV once daily × 7 days and metronidazole 100 mg IV every 8 hr × 7 days

Ceftriaxone DOT = 1 DOT × 7 days = 7 DOT

Metronidazole DOT = 1 DOT × 7 days = 7 DOT

Total DOT = 14 DOT

DOT = day(s) of therapy; IV = intravenous(ly).

Antimicrobial use should be monitored by the ASP. The two most common measures are defined daily dose and DOT. Days of therapy is the most accurate and preferred measure, particularly in the pediatric population, because it is independent of age- and weight-related differences in doses (CDC 2019c; Barlam 2016). Days of therapy represents the total number of unique antibiotics administered per hospital-day (Box 2). Antimicrobial stewardship programs have the option to report AU data to the National Healthcare Safety Network (NHSN) AU Option. Electronic reporting to the NHSN AU Option is currently voluntary and available to hospitals that can export electronic medication administration records and/or bar-coding medication administration records. The NHSN AU Option provides antibiotic use rates expressed as DOT per 1000 days-present for almost all antibiotics at the patient, unit, and hospital levels. Days-present is calculated as the number of patients who were present for any portion of a day during a calendar month at a specific location (NHSN 2022). If institutions cannot report to NHSN, antibiotic use data can be collected from pharmacy record systems or the electronic medical record. Purchasing data are a last-line option if other antibiotic use metrics are unavailable, given that they may not accurately assess antibiotic exposure because they do not account for factors such as drug waste, missed/lost doses, and outdating (Parker 2017; Barlam 2016). A limitation to measuring antibiotic use as DOT is that it favors the use of broad-spectrum monotherapy (i.e., meropenem) over the use of narrow-spectrum combination therapy (i.e., ceftriaxone and metronidazole). The DOT approach is also unable to reflect overall patient exposure for patients receiving a dosing interval greater than 24 hours, such as in the setting of renal dysfunction, and does not account for the appropriateness of therapy received.

As a standardized measure, DOT can be normalized to patient-days to benchmark on a larger scale for intra- and

Patient Care Scenario

The new antimicrobial stewardship pharmacist at a 450-bed pediatric academic institution is responsible for performing a prospective audit and feedback on all patients receiving antibiotic therapy for at least 48 hours. After completing 6 months of reviews, data analysis shows an increase in the number of interventions in managing UTIs; specifically, the most common interventions include discontinuing unnecessary therapy and shortening duration of therapy, with a 35% rejection rate. What strategies would best improve antibiotic use for UTIs at this institution?

ANSWER

UTIs are common infections requiring antimicrobial therapy when diagnosed appropriately. Key opportunities to improve antibiotic use in this case are to consider implementing diagnostic criteria for ordering urine cultures to prevent having to discern whether positive urine cultures indicate infection versus colonization. Reflexing orders for urine cultures in the setting of positive urinalyses have successfully reduced rates of urine culture obtainment and use of unnecessary antibiotic therapy, though reflex urine cultures are controversial in pediatric patients because of the lack of standardized criteria that best predict a true UTI. A better approach may be to focus testing on patients with UTI-specific symptoms and discourage "pan-culturing." Facility-specific treatment guidelines are also important in enhancing the effectiveness of prospective audit and feedback. Evidence-based guidelines on managing UTIs can establish clear recommendations on diagnostic approaches, antibiotic selection for both empiric and targeted therapy, and therapy duration. Recommendations should consider locally observed pathogens, susceptibilities, formulary options, and patient mix and aim to optimize diagnosis and management. Providers from groups that commonly treat UTIs at the institution should be included when designing the guidelines, and the stewardship team should try to understand and address the reasons for unnecessary therapy and prolonged durations. Adherence to guidelines can be improved by including treatment recommendations, including minimally effective durations, in electronic order sets. To supplement guideline dissemination and implementation, provider education is important to increase awareness and uptake of the guideline. Periodic reeducation may be necessary to sustain the effects of guideline implementation.

1. Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program; guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Clin Infect Dis 2016;62:e51-77.
2. Centers for Disease Control and Prevention (CDC). 2019. Core Elements of Hospital Antibiotic Stewardship Programs. Available at https://www.cdc.gov/antibiotic-use/core-elements/hospital.html.
3. Fakih M, Advani S, Vaughn VM. Diagnosis of urinary tract infection: need for a reflective rather than reflexive approach. Infect Control Hosp Epidemiol 2019;40:834-5.

interhospital comparison. Patient-days quantifies the number of patients present in the facility at the same time on each day combined for the month (NHSN 2022). Interhospital comparison of AU can help define standards and identify areas in which to improve clinical care. Comparative data can be obtained from sources such as the Pediatric Health Information System, a database with clinical and resource use data for inpatient, ambulatory surgery, ED, and observation unit encounters for greater than 50 freestanding children's hospitals (CHA 2022). A limitation to using comparative data from such databases is that these data do not account for differences in composition of diagnoses and procedures among hospitals. Data should be risk-adjusted on the basis of case mix, severity of illness, and other factors to minimize the effect of confounding variables when comparing institutional data (Ibrahim 2012). Investigators evaluated an indirect standardization method to adjust inpatient pediatric AU data for differences in case mix. Data from the Pediatric Health Information System were used to adjust DOT through calculating an observed/expected (O/E) ratio on the basis of clinical strata and compared with unadjusted DOT per 1000 patient-days. Use of the O/E ratio to adjust DOT reduced interhospital variation and could lead to the development of more informed ASP interventions (Wattier 2021). The AU Option also facilitates risk-adjusted benchmarking within and across institutions using the standardized antimicrobial administration ratio (SAAR). The SAAR compares observed antibiotic use with predicted use, where use is predicted on the basis of risk-adjusted models of data submitted to the NHSN AU Option (NHSN 2022). Use of the Pediatric Health Information System and NHSN databases requires specialized knowledge and training, whereas a more accessible benchmarking resource is through the SHARPS collaborative. The SHARPS national antimicrobial stewardship collaborative focuses on sharing data reports and benchmarking AU in both the inpatient and outpatient settings to improve antimicrobial prescribing in children (Newland 2018). Access to the SHARPS collaborative is free and not limited to freestanding children's hospitals. Additional research is needed to determine the true benefits of benchmarking.

In the outpatient setting, both quantitative and qualitative metrics are important and can be performed at the clinician or facility level. A benchmarking subgroup of a national pediatric stewardship collaborative has proposed metrics to allow for benchmarking in pediatric outpatient settings (Poole 2021). Identified metrics focus on high-priority conditions (see Table 2), with consideration of clinical impact and feasibility of tracking. Valuable quantitative metrics for outpatient pediatric AU are the total number of antibiotics prescribed per patient population or the percentage of visits with an antibiotic prescribed per defined period. These metrics can further be broken down to quantify AU by diagnosis, such as the percentage of acute respiratory tract infection visits prescribed antibiotics. Furthermore, the percentage of visits for specific diagnoses that receive antibiotics can greatly help in evaluating conditions in which antibiotics are typically recommended (e.g., streptococcal pharyngitis, UTI), where antibiotics may be appropriate (e.g., CAP, AOM), and where antibiotics are not appropriate (e.g., viral upper respiratory infections). Although measuring quantity is informative, measuring the quality of antibiotic use can better describe prescribing practices by incorporating indication, antibiotic spectrum, and therapy duration into the metric. Examples include a B/N ratio (ratio of broad-spectrum to narrow-spectrum antibiotics), an amoxicillin index (proportion of amoxicillin prescribed compared with all antibiotics prescribed), proportion of first-line concordant antibiotic prescriptions or the proportion of prescriptions not indicated, and median therapy duration (Poole 2021).

Specific process measures will depend on the interventions implemented at each individual institution. According to use of the core strategies recommended by national guidance, priority process measures include tracking the types and acceptance of recommendations from prospective audit and feedback interventions, monitoring preauthorization interventions including any potential delay in therapy, and monitoring adherence to facility-specific treatment guidelines (CDC 2019c). Other potential process measures include compliance with required components of antimicrobial medication orders (e.g., appropriate drug, dose, indication, and duration for the diagnosis) and adherence to antibiotic timeouts. Adherence to intravenous-to-oral changes and rates of unnecessary duplicate therapy can be followed in any setting but may be particularly feasible metrics in smaller or critical access hospitals. Disease- or drug-specific or other AU process initiatives should be evaluated as appropriate depending on the aims and design of the specific interventions. Process metrics can also be used when providing feedback to prescribers, departments, or administrators to improve the quality of prescribing and ensure appropriate AU in both the inpatient and outpatient settings (Hamilton 2015).

Clinical outcome measures to consider include changes in antibiotic resistance, CDI rates, and type and frequency of antibiotic-associated adverse events. Antibiotic resistance is an outcome that must be measured over time. Evaluating changes in the institutional antibiogram annually can provide information on the effects of prescribing practices but may be affected by many factors. Annual rates of infections caused by MDROs (e.g., vancomycin-resistant *Enterococcus*; ESBL-producing, carbapenem-resistant Enterobacterales) can specifically be evaluated in collaboration with infection prevention professionals. The impact of ASP on CDI in children can be more difficult to demonstrate because the incidence of CDI is lower in children (Lessa 2015). *C. difficile* is often a colonizer versus a true pathogen in young children, so tests in patients younger than 2 years may need to be excluded (Gerber 2021). Antibiotic resistance and health care–associated infection rates can also be reported to NSHN, allowing standardization of the classification and reporting of both metrics for benchmarking purposes. Outcomes such as hospital length of stay and readmission rates are easier data points to collect but are typically less helpful for ASPs because they are affected by many non-stewardship factors, making changes difficult to attribute directly to stewardship activities. Death is relatively rare in children, so mortality rates are difficult to associate with ASP interventions. It is not recommended to use mortality as a primary outcome in either children or adults (Gerber 2021). Because many of these outcomes are affected by confounding variables, an expert panel suggests use of risk adjustment for severity of illness, patient case type, and infection control activities (Moehring 2017). Even if a stewardship intervention is not expected to improve clinical outcomes, these metrics can be used as "balancing measures" to confirm the absence of unintended harm (Nagel 2014).

Costs are generally of significant interest to hospital and pharmacy administrations. Direct antimicrobial expenditures are a common cost metric that is easily reportable using pharmacy purchasing data. However, purchasing data have many limitations, including fluctuating prices because of shortages and other reasons (Parker 2017; Barlam 2016). Therefore, the CDC recommends that antibiotic cost data be estimated according to prescription or administration of antibiotics to distill previously mentioned confounders to such metrics. Additional drivers of cost savings may include reductions in length of stay, CDI rates, and readmissions. However, costs related to length of stay are complex, and correlating these drivers with actual numbers can be difficult.

Data transparency is essential for ASPs. Data should be reported to organizational and pharmacy leadership on a routine basis to demonstrate ASP successes and identify future areas of improvement. The CDC recommends tracking antibiotic prescribing at the individual clinician level and providing targeted feedback with peer comparison, when possible (Sanchez 2016). Provider-specific report cards are a way to provide feedback and compare prescribing habits among peer providers. Peer comparison of AU positively influences prescribing practices (Clegg 2019). The feasibility of peer comparison may be greater for outpatient providers and hospitalists because of ease of data extraction, whereas teaching hospitals may have more difficulty because of the variety and layering of inpatient providers (e.g., residents, fellows, interns). Prescribers may also benefit from facility-specific medication use evaluations and summaries of issues that arise during prospective audit and feedback reviews and preauthorization requests.

BARRIERS

When implementing a new process, it is important to anticipate, assess, and prepare for potential barriers that may arise. Barriers may differ depending on the institution's size and location, as well as the availability of preexisting resources. Table 5 describes potential barriers and possible solutions when implementing specific ASP strategies.

A significant barrier when starting an ASP is ensuring buy-in from both administration and health care providers. Historically, a lack of awareness by hospital administration about the value of ASPs was commonly reported as a barrier to implementing ASP among pediatric institutions (Hersh 2009). However, more recent regulatory requirements and reported successes of pediatric antimicrobial stewardship nationally may have improved awareness. Antimicrobial stewardship programs may receive pushback from pediatric providers for recommendations such as discontinuing therapy or de-escalating or streamlining therapy because of diagnostic uncertainty, lack of pediatric-specific data and trials, and fear of poor clinical outcomes in children. In addition, prescribers may perceive a loss of autonomy, which can lead to resistance against ASPs and affect program development and outcomes. It can be challenging to gain trust and convince providers to change how they approach the care of their patients. Significant time and investment in effective, continuous educational strategies are needed to change practice, prescribing patterns, and learned behaviors of health care providers.

Another major barrier identified is a lack of time and financial support, especially when starting new programs (Hersh 2009). Although hospital or pharmacy leadership may suggest using existing personnel to develop an ASP, lack of ID- and ASP-trained physicians and pharmacists can hinder the ability to implement certain stewardship strategies and may not achieve the same degree of outcomes as trained personnel. From a time resource perspective, ASPs may feel overwhelmed on where to start with implementing and identifying the highest-impact targets and most effective methods with the allocated resources.

Lack of IT support in the form of personnel and electronic tools is an additional barrier, especially to smaller ASPs and underserved areas. Lack of access to user-friendly reporting functionality can prevent ASPs from adequately monitoring, tracking, and analyzing antibiotic use across a wide range of settings. With respect to benchmarking, it can be difficult to find similar hospitals with a similar case-mix index to compare, as well as to determine which metrics to compare. Optimal metric tracking and reporting is complex and may involve the navigation of complex databases, which may require additional training and time to use effectively. Alternatively, an institution can have an overwhelming amount of data that are difficult to organize and interpret as meaningful information.

Outpatient antimicrobial stewardship is a quickly growing area of practice and research, but many barriers remain, including a frequent lack of the infrastructure typical to inpatient programs. Outpatient-specific barriers were recently assessed in a survey of pediatric ASPs across the United States. Surveyors found that lack of time was the most commonly reported barrier, followed by lack of financial support,

Table 5. Antimicrobial Stewardship Strategies with Associated Barriers and Potential Solutions

Strategy	Barriers	Potential Solutions
Prospective audit and feedback	Lack of human resources	Complete periodic reviews (i.e., 2 or 3 × weekly vs. daily) Target reviews for specific antimicrobials, units, and/or indications
	Lack of resources needed to identify patients receiving suboptimal therapy in a timely manner	Use clinical decision support tools to identify patients requiring intervention
	Difficulty communicating recommendations	Establish relationships with key stakeholders Use motivational interviewing techniques Keep conversations open-ended and nonconfrontational Use primary literature to support recommendations
	Determination of optimal feedback delivery methods	Use face-to-face communication, when possible Incorporate handshake stewardship into daily ASP activities Engage providers and solicit input on feedback delivery methods
	Provider pushback	Build relationships Compromise as needed and appropriate
	Concerns regarding legal implications of documenting recommendations in the medical record	Create nonpermanent forms for written communication in the EHR
Prior authorization	Loss of prescriber autonomy	Consider granting initial approvals for 24–72 hr
	Integration of restriction policies into workflow	Create an approved policy outlining procedures Incorporate functionality into EHR to prevent delays in authorization (e.g., second-sign process)
	Lack of human resources to manage requests	Use ID pharmacists if ID physicians/fellows are unavailable Use telemedicine
Clinical practice guidelines	Poor knowledge of and adherence to guidelines	Disseminate guidelines in the form of printed handbooks, integrate information into order sets, and ensure easy accessibility Use primary literature to support recommendations
	Lack of time in developing and updating guidelines	Involve key stakeholders when developing guidelines Use national guidelines Adapt guidelines from peer institutions Review guidelines periodically on a set schedule
	Inability to monitor adherence	Use electronic order sets Develop automated reports
Antibiotic timeouts	Lack of engagement, compliance, and knowledge of frontline clinicians	Integrate into EHR to prompt providers Use automatic stop orders
Intravenous-to-oral conversion	Identification of eligible patients	Develop clear criteria to determine eligibility; integrate into EHR to rapidly identify qualifying patients Integrate into daily activities of frontline clinical pharmacists
De-escalation, streamlining, minimizing therapy duration	Unwillingness of providers	Use primary literature to support recommendations Provide hospital-specific data, if available Track balancing measures

(*continued*)

(*continued*)

Table 5. Antimicrobial Stewardship Strategies with Associated Barriers and Potential Solutions

Strategy	Barriers	Potential Solutions
Education	Lack of provider knowledge about the role of ASPs	Include education as part of new clinical staff orientation
		Disseminate annual education to providers about ASP initiatives and include hospital-specific data
		Participate in CDC's Antibiotic Awareness Week
	Lack of patient knowledge	Promote CDC modules (training on antimicrobial resistance and available resources), offer rotations to medical/pharmacy residents
		Display posters, educational materials, and videos that can educate the public on why antibiotics may be unnecessary
		Use prescription pads that recommend symptomatic relief rather than antibiotics
		Provide communication skills training for providers regarding inappropriate antibiotic prescribing

ASP = antimicrobial stewardship program; EHR = electronic health record; ID = infectious diseases.

Information from: Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program; guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Clin Infect Dis 2016;62:e51-77; Drew RH, White R, MacDougall C, et al. Insights from the Society of Infectious Diseases Pharmacists on antimicrobial stewardship guidelines from the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Pharmacotherapy 2009;29:593-607.

development of meaningful reports, and hospital administrative support (El Feghaly 2021). Antimicrobial stewardship programs can optimize time and resources by choosing practical interventions for high-priority indications (see Table 2).

CONCLUSION

Antimicrobial stewardship is essential to minimize unintended consequences of antimicrobials, such as antibiotic-related adverse events and the development of antibiotic resistance, which is currently affecting pediatric patients across the globe. Implementation of ASPs in the inpatient and outpatient settings involves obtaining leadership support, dedicating a physician and/or pharmacist to lead the program, determining appropriate actions feasible for the specific health care setting, tracking and reporting meaningful data, and educating providers, patients, and families on the importance of judicious antibiotic use. Justification for pediatric ASPs should emphasize potential improvement in patient care and quality metrics, in addition to program value through a cost-benefit analysis. Regardless of the institution's size and available resources, antimicrobial stewardship activities can be incorporated into the daily practices of available staff (including pharmacists, physicians, infection preventionists, and nurses) with a focus on the unique needs of pediatric patients. Organizations should collaborate with local communities, including other hospitals and outpatient health care facilities within the city or state, as well as national organizations to advance pediatric stewardship practices and mitigate the threat of antimicrobial misuse and resistance in children.

REFERENCES

Adams DJ, Eberly MD, Goudie A, et al. Rising vancomycin-resistant *Enterococcus* infections in hospitalized children in the United States. Hosp Pediatr 2016;6:404-11.

Adams DJ, Eberly MD, Rajnik M, et al. Risk factors for community-associated *Clostridium difficile* infection in children. J Pediatr 2017;186:105-9.

Adams SM, Ngo L, Morphew T, et al. Does an antimicrobial time-out impact the duration of therapy of antimicrobials in the PICU? Pediatr Crit Care Med 2019;20:560-7.

Afolabi TM, Goodlet KJ, Fairman KA. Association of antibiotic treatment duration with recurrence of uncomplicated urinary tract infection in pediatric patients. Ann Pharmacother 2020;54:757-66.

Agency for Healthcare Research and Quality (AHRQ). 2019. Four Moments of Antibiotic Decision Making. Available at https://www.ahrq.gov/antibiotic-use/acute-care/four-moments/index.html.

Agwu AL, Lee CK, Jain SK, et al. A World Wide Web-based antimicrobial stewardship program improves efficiency, communication, and user satisfaction and reduces cost in a tertiary care pediatric medical center. Clin Infect Dis 2008;47:747-53.

Anandalwar SP, Milliren C, Graham DA, et al. Trends in the use of surgical antibiotic prophylaxis in general pediatric surgery: are we missing the mark for both stewardship and infection prevention? J Pediatr Surg 2020;55:75-9.

Anjewierden S, Han Z, Foster CB, et al. Risk factors for *Clostridium difficile* infection in pediatric inpatients: a

Practice Points

- Antimicrobial stewardship is recommended to improve antibiotic prescribing and prevent the downstream effects of inappropriate antibiotic use.
- Business plans for ASPs should emphasize national regulatory or legal standards and the importance of judicious antibiotic use, address costs and revenue, specify job responsibilities for key personnel, and describe planned interventions of the program.
- Pediatric ASPs should be led by physicians and pharmacists with pediatric expertise, including knowledge of ID and/or antimicrobial stewardship.
- Core interventions for inpatient ASPs include prospective audit and feedback using a handshake stewardship approach and formulary restriction/preauthorization.
- Supplemental strategies for inpatient ASPs include use of clinical practice guidelines, antibiotic timeouts, penicillin allergy assessment, intravenous-to-oral conversion, and incorporation of RDT.
- Selection of stewardship activities should consider aspects such as available personnel, required time commitment, identified areas of improvement, and IT support.
- Inpatient and outpatient ASPs should focus on high-priority conditions, such as upper and lower respiratory tract infections; ear, nose, and throat infections; and UTIs.
- Pediatric ASPs should expand to pediatric subpopulations with high antibiotic use when possible, such as patients with cystic fibrosis, neonates, critically ill patients, and immunocompromised patients (e.g., oncology, solid organ transplant).
- ASPs should focus efforts on behavioral change to drive long-term changes in prescribing practice.
- Good communication and relationship building are imperative.
- Metrics to evaluate the effectiveness of ASPs should include AU, process and outcome measures, and costs.
- Program outcomes and data should be openly shared with leadership, prescribers, and pharmacy to share successes and identify areas for improvement.
- Because there are several potential barriers to implementing antimicrobial stewardship, innovative approaches may be necessary.
- The most common barriers include lack of awareness of the importance of antimicrobial stewardship, diagnostic uncertainty and fear of poor clinical outcomes, and lack of necessary resources/funding.

meta-analysis and systematic review. Infect Control Hosp Epidemiol 2019;40:420-6.

Anthem. 2017. Anthem Blue Cross and Blue Shield in Ohio Joint Commission Align Quality Recognition Criteria for Antibiotic Stewardship, Palliative Care Programs. Available at https://www.anthem.com/press/ohio/anthem-joint-commission-align-quality-recognition-criteria/.

Antimicrobial Resistance Collaborators (ARC). Global burden of bacterial antimicrobial resistance in 2019: a systematic analysis. Lancet 2022;399:629-55.

Auger KA, Harris JM, Gay JC, et al. Progress (?) toward reducing pediatric readmissions. J Hosp Med 2019;14:618-21.

Avdic E, Carroll KC. The role of the microbiology laboratory in antimicrobial stewardship programs. Infect Dis Clin North Am 2014;28:215-35.

Bagga B, Stultz J, Arnold S, et al. A culture change: impact of a pediatric antimicrobial stewardship program based on guideline implementation and prospective audit with feedback. Antibiotics 2021;10:1307.

Barlam TF, Cosgrove SE, Abbo LM, et al. Implementing an antibiotic stewardship program; guidelines by the Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America. Clin Infect Dis 2016;62:e51-77.

Bauer ME, MacBrayne C, Stein A, et al. A multidisciplinary quality improvement initiative to facilitate penicillin allergy delabeling among hospitalized pediatric patients. Hosp Pediatr 2021;11:427-34.

Bland CM, Bookstaver PB, Griffith NC, et al. A practical guide for pharmacist to successfully implement penicillin allergy testing. Am J Health Syst Pharm 2019;76:136-47.

Buckel WR, Kaye KS, Patel PK. Collaborative antimicrobial stewardship: working with hospital and health system administration. Infect Dis Clin North Am 2020;34:1-15.

Cals JW, deBock L, Beckers PJ, et al. Enhanced communication skills and C-reactive protein point-of-care testing for respiratory tract infection: 3.5-year follow-up of a cluster randomized trial. Ann Fam Med 2013;11:157-64.

Cantey JB, Hersh AL. Antibiotic stewardship in the neonatal intensive care unit: lessons from oxygen. Pediatrics 2019;143:e20183902.

Cantey JB, Patel SJ. Antimicrobial stewardship in the NICU. Infect Dis Clin North Am 2014;28:247-61.

Cantey JB, Wozniak PS, Pruszynski JE, et al. Reducing unnecessary antibiotic use in the neonatal intensive care unit (SCOUT): a prospective interrupted time-series study. Lancet Infect Dis 2016;16:1178-84.

Centers for Disease Control and Prevention (CDC). 2019a. Outpatient Antibiotic Prescriptions – United States, 2019. Available at https://www.cdc.gov/antibiotic-use/pdfs/Annual-Report-2019-H.pdf.

Centers for Disease Control and Prevention (CDC). 2019b. Antibiotic Resistance Threats in the United States, 2019. Available at https://www.cdc.gov/drugresistance/pdf/threats-report/2019-ar-threats-report-508.pdf.

Centers for Disease Control and Prevention (CDC). 2019c. Core Elements of Hospital Antibiotic Stewardship Programs. Available at https://www.cdc.gov/antibiotic-use/core-elements/hospital.html.

Centers for Medicare & Medicaid Services (CMS). 2019. Medicare and Medicaid Programs; Regulatory Provisions to Promote Program Efficiency, Transparency, and Burden Reduction; Fire Safety Requirements for Certain

Dialysis Facilities; Hospital and Critical Access Hospital (CAH) Changes to Promote Innovation, Flexibility, and Improvement in Patient Care. Available at https://www.federalregister.gov/d/2019-20736.

Centers for Medicare & Medicaid Services (CMS). 2016. Medicare and Medicaid Programs; Hospital and Critical Access Hospital (CAH) Changes to Promote Innovation, Flexibility, and Improvement in Patient Care. Available at https://www.federalregister.gov/d/2016-13925.

Chai G, Governale L, McMahon AW, et al. Trends of outpatient prescription drug utilization in US children, 2002-2010. Pediatrics 2012;130:23-31.

Chan S, Hossain J, Di Pentima MC. Implications and impact of prior authorization policy on vancomycin use at a tertiary pediatric teaching hospital. Pediatr Infect Dis J 2015;34:506-8.

Charani E, Ahmad R, Rawson TM, et al. The differences in antibiotic decision-making between acute surgical and acute medical teams: an ethnographic study of culture and team dynamics. Clin Infect Dis 2019;69:12-20.

Charani E, Edwards R, Sevdalis N, et al. Behavior change strategies to influence antimicrobial prescribing in acute care: a systematic review. Clin Infect Dis 2011;53:651-62.

Chaulk D, Tran T, Neeley A, et al. Children's hospital quality ratings: where are we and can we do better? Hosp Pract (1995) 2021;49:405-12.

Children's Hospital Association (CHA). 2022. Leverage Clinical and Resource Utilization Data. Available at https://www.childrenshospitals.org/content/analytics/product-program/pediatric-health-information-system.

Chiotos K, Tamma PD, Flett KB, et al. Multicenter study of the risk factors for colonization or infection with carbapenem-resistant Enterobacteriaceae in children. Antimicrob Agents Chemother 2017;61:e01440-17.

Chiotos K, Tamma P, Flett KB, et al. Increased 30-day mortality associated with carbapenem-resistant Enterobacteriaceae in children. Open Forum Infect Dis 2018;5:ofy222.

Clegg HW, Bean RA, Ezzo SJ, et al. Impact of education and peer comparison on antibiotic prescribing for pediatric respiratory tract infections. Pediatr Qual Saf 2019;4:e195.

Cogen JD, Kahl BC, Maples HM, et al. Finding the relevance of antimicrobial stewardship for cystic fibrosis. J Cyst Fibros 2020;19:511-20.

Cogen JD, Onchiri FM, Hamblett NM, et al. Association of intensity of antipseudomonal antibiotic therapy with risk of treatment-emergent organisms in children with cystic fibrosis and newly acquired *Pseudomonas aeruginosa*. Clin Infect Dis 2021;73:987-93.

Dantuluri KL, Bruce J, Edwards KM, et al. Rurality of residence and inappropriate antibiotic use for acute respiratory infections among young Tennessee children. Open Forum Infect Dis 2020;8:ofaa587.

Dassner AM, Girotto JE. Evaluation of a second-sign process for antimicrobial prior authorization. J Pediatric Infect Dis Soc 2018;7:113-8.

De Blank P, Zaoutis T, Fisher B, et al. Trends in *Clostridium difficile* infection and risk factors for hospital acquisition of *Clostridium difficile* among children with cancer. J Pediatr 2013;163:699-705 e691.

Dellit TH, Owens RC, McGowan JE, 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;44:159-77.

Diaz MCG, Handy LK, Crutchfield JH, et al. Impact of a personalized audit and feedback intervention on antibiotic prescribing practices for outpatient pediatric community-acquired pneumonia. Clin Pediatr 2020;59:988-94.

Di Pentima MC, Chan S, Hossain J. Benefits of a pediatric antimicrobial stewardship program at a children's hospital. Pediatrics 2011;128:1062-70.

Dooling KL, Shapiro DJ, Van Beneden C, et al. Overprescribing and inappropriate antibiotic selection for children with pharyngitis in the United States, 1997-2010. JAMA Pediatr 2014;168:1073-4.

Downes KJ, Fitzgerald JC, Weiss SL. Utility of procalcitonin as a biomarker for sepsis in children. J Clin Microbiol 2020;58:e01851-19.

Dukhovny D, Buus-Frank ME, Edwards EM, et al. A collaborative multicenter QI initiative to improve antibiotic stewardship in newborns. Pediatrics 2019;144:e20190589.

Elemraid MA, Rushton SP, Thomas MF, et al. Changing clinical practice: management of paediatric community-acquired pneumonia. J Eval Clin Pract 2014;20:94-9.

El Feghaly RE, Monsees EA, Burns A, et al. Outpatient antimicrobial stewardship programs in pediatric institutions in 2020: status, needs, barriers. Infect Control Hosp Epidemiol 2021;1-7.

Fishman N. Policy statement on antimicrobial stewardship by the Society for Healthcare Epidemiology of America (SHEA), the Infectious Diseases Society of America (IDSA), and the Pediatric Diseases Society (PIDS). Infect Control Hosp Epidemiol 2012;33:322-7.

Fleming-Dutra KE, Hersh AL, Shapiro DJ, et al. Prevalence of inappropriate antibiotic prescriptions among US ambulatory care visits, 2010-2011. JAMA 2016;315:1864-73.

Foral PA, Anthone JM, Destache CJ, et al. Education and communication in an interprofessional antimicrobial stewardship program. J Am Osteopath Assoc 2016;116:588-93.

Forrest GN, Van Schooneveld TC, Kullar R, et al. Use of electronic health records and clinical decision support systems for antimicrobial stewardship. Clin Infect Dis 2014;59:S122-33.

Fox MT, Amoah J, Hsu AJ, et al. Comparative effectiveness of antibiotic treatment duration in children with pyelonephritis. JAMA Netw Open 2020;3:e203951.

Frost HM, Becker LF, Knepper BC, et al. Antibiotic prescribing patterns for acute otitis media for children 2 years and older. J Pediatr 2020a;220:109-15.e1.

Frost HM, Knepper BC, Shihadeh KC, et al. A novel approach to evaluate antibiotic utilization across the spectrum of inpatient and ambulatory care and implications for prioritization of antibiotic stewardship efforts. Clin Infect Dis 2020b;70:1675-82.

Frost HM, Lou Y, Keith A, et al. Increasing guideline-concordant durations of antibiotic therapy for acute otitis media. J Pediatr 2022a;240:221-7.e9.

Frost HM, Monti JD, Andersen LM, et al. Improving delayed antibiotic prescribing for acute otitis media. Pediatrics 2021;147:e2020026062.

Frost HM, Munsiff SS, Lou Y, et al. Simplifying outpatient antibiotic stewardship. Infect Control Hosp Epidemiol 2022b;43:260-1.

Gerber JS, Jackson MA, Tamma PD, et al. Antimicrobial stewardship in pediatrics. Pediatrics 2021;147: e2020040295.

Gerber JS, Kronman MP, Ross RK, et al. Identifying targets for antimicrobial stewardship in children's hospitals. Infect Control Hosp Epidemiol 2013;34:1252-8.

Gerber JS, Newland JG, Coffin SE, et al. Variability in antibiotic use at children's hospitals. Pediatrics 2010;126:1067-73.

Gerber JS, Prasad PA, Fiks AG, et al. Durability of benefits of an outpatient antimicrobial stewardship intervention after discontinuation of audit and feedback. JAMA 2014;312:2569-70.

Gkentzi D, Dimitriou G. Antimicrobial stewardship in the neonatal intensive care unit: an update. Curr Pediatr Rev 2019;15:47-52.

Goff D, Reeve W, Naumovski S, et al. Approaches to modifying the behavior of clinicians who are noncompliant with antimicrobial stewardship program guidelines. Clin Infect Dis 2016;63:532-8.

Goldman JL, Lee BR, Hersh AL, et al. Clinical diagnoses and antimicrobials predictive of pediatric antimicrobial stewardship recommendations: a program evaluation. Infect Control Hosp Epidemiol 2015;36:673-80.

Goldman JL, Newland JG, Price M, et al. Clinical impact of an antimicrobial stewardship program on high-risk pediatric patients. Infect Control Hosp Epidemiol 2019;40:968-73.

Gross R, Morgan AS, Kinky DE, et al. Impact of a hospital-based antimicrobial management program on clinical and economic outcomes. Clin Infect Dis 2001;33:289-95.

Hamilton KW, Gerber JS, Moehring R, et al. Point-of-prescription interventions to improve antimicrobial stewardship. Clin Infect Dis 2015;60:1252-8.

Hersh AL, Beekmann SE, Polgreen PM, et al. Antimicrobial stewardship programs in pediatrics. Infect Control Hosp Epidemiol 2009;30:1211-7.

Hersh AL, De Lurgio SA, Thurm C, et al. Antimicrobial stewardship programs in freestanding children's hospitals. Pediatrics 2015;135:33-9.

Hersh AL, Fleming-Dutra KE. Vaccines and outpatient antibiotic stewardship. Pediatrics 2017;140:e20171695.

Hersh AL, Newland JG, Gerber JS. Pediatric antimicrobial discharge stewardship: an unmet need. JAMA Pediatr 2016;170:191-2.

Hersh AL, Olson J, Stockmann C, et al. Impact of antimicrobial stewardship for pediatric outpatient parenteral antibiotic therapy. J Pediatric Infect Dis Soc 2018;7:e34-e36.

Horikoshi Y, Higuchi H, Suwa J, et al. Impact of computerized pre-authorization of broad spectrum antibiotics in *Pseudomonas aeruginosa* at a children's hospital in Japan. J Infect Chemother 2016;22:532-5.

Horikoshi Y, Kaneko T, Morikawa Y, et al. The north wind and the sun: pediatric antimicrobial stewardship program combining restrictive and persuasive approaches in hematology-oncology ward and hematopoietic stem cell transplant unit. Pediatr Infect Dis J 2018;37:164-8.

Horikoshi Y, Suwa J, Higuchi H, et al. Sustained pediatric antimicrobial stewardship program with consultation to infectious diseases reduced carbapenem resistance and infection-related mortality. Int J Infect Dis 2017;64:69-73.

Hurst AL, Child J, Parker SK. Intervention and acceptance rates support handshake-stewardship strategy. J Pediatr Infect Dis Soc 2019;8:162-5.

Hurst AL, Child J, Pearce K, et al. Handshake stewardship: a highly effective rounding-based antimicrobial optimization service. Pediatr Infect Dis J 2016;35:1104-10.

Ibrahim OM, Polk RE. Benchmarking antimicrobial drug use in hospitals. Expert Rev Anti Infect Ther 2012;10:445-57.

Jaggi P, Wang L, Gleeson S, et al. Outpatient antimicrobial stewardship targets for treatment of skin and soft-tissue infections. Infect Control Hosp Epidemiol 2018;39:936-40.

Jenkins T, Tamma PD. Thinking beyond the "core" antimicrobial stewardship interventions: shifting the onus for appropriate antibiotic use from stewardship teams to prescribing clinicians. Clin Infect Dis 2021;72:1457-62.

(The) Joint Commission (TJC). 2016. Approved: New Antimicrobial Stewardship Standard. Available at https://www.jointcommission.org/assets/1/6/New_Antimicrobial_Stewardship_Standard.pdf.

(The) Joint Commission (TJC). 2019. Antimicrobial Stewardship in Ambulatory Health Care. R3 Report 2019. Available at https://www.jointcommission.org/-/media/tjc/documents/standards/r3-reports/r3_23_antimicrobial_stewardship_amb_6_14_19_final2.pdf.

Joint Task Force on Practice Parameters representing the American Academy of Allergy, Asthma and Immunology; American College of Allergy, Asthma and Immunology; Joint Council of Allergy, Asthma and Immunology. Drug allergy: an updated practice parameter. Ann Allergy Asthma Immunol 2010;105:259-73.

Jones BM, Bland CM. Penicillin skin testing as an antimicrobial stewardship initiative. Am J Health Syst Pharm 2017;74:232-37.

Katz SE, Banerjee R, Schwenk H. Antibiotic stewardship for the neonatologist and perinatologist. Clin Perinatol 2021a;48:379-91.

Katz SE, Crook J, Gillon J, et al. Use of a procalcitonin-guided antibiotic treatment algorithm in the pediatric intensive care unit. Pediatr Infect Dis J 2021b;40:333-7.

Katz SE, Spencer P, Cates J, et al. Improvements in appropriate ambulatory antibiotic prescribing using a bundled antibiotic stewardship intervention in general pediatrics practices. Infect Control Hosp Epidemiol 2022:1-7.

Kennedy C, Greenberg I, Perez GF, et al. Measuring the impact of an empiric antibiotic algorithm for pulmonary exacerbation in children and young adults with cystic fibrosis. Pediatr Pulmonol 2022;57:965-75.

Kilgore JT, Lanata MM, Willis JM, et al. Utilization of West Virginia pediatric Medicaid claims data to guide outpatient antimicrobial stewardship interventions. J Pediatric Infect Dis Soc 2022;11:172-6.

Klatte JM, Knee A, Szczerba F, et al. Identification of high-yield targets for antimicrobial stewardship program efforts within a non-freestanding children's hospital. Hosp Pediatr 2019;9:355-64.

Klatte JM, Kopcza K, Knee A, et al. Implementation and impact of an antimicrobial stewardship program at a non-freestanding children's hospital. J Pediatr Pharmacol Ther 2018;23:84-91.

Kreitmeyr K, Pecar A, Mikolajczyk R, et al. Pediatric antimicrobial stewardship: optimization of vancomycin therapy based on individual pharmacokinetics. Pediatr Infect Dis J 2021;40:556-62.

Kronman MP, Banerjee R, Duchon J, et al. Expanding existing antimicrobial stewardship programs in pediatrics: what comes next. J Pediatric Infect Dis Soc 2018;7:241-8.

Kronman MP, Hersh AL, Gerber JS, et al. Identifying antimicrobial stewardship targets for pediatric surgical patients. J Pediatric Infect Dis Soc 2015;4:e100-8.

Lake JG, Weiner LM, Milstone AM, et al. Pathogen distribution and antimicrobial resistance among pediatric healthcare-associated infections reported to the National Healthcare Safety Network, 2011-2014. Infect Control Hosp Epidemiol 2018;39:1-11.

Lanata MM, Diaz A, Hecht SM, et al. Empiric vancomycin reduction in a pediatric intensive care unit. Pediatrics 2021;148:e2020009142.

Leapfrog Group. Leapfrog Hospital Safety Grade. 2021. Available at https://www.hospitalsafetygrade.org/.

Lee BR, Goldman JL, Yu D, et al. Clinical impact of an antibiotic stewardship program at a children's hospital. Infect Dis Ther 2017;6:103-13.

Lee KR, Bagga B, Arnold SR. Reduction of broad-spectrum antimicrobial use in a tertiary children's hospital post antimicrobial stewardship program guideline implementation. Pediatr Crit Care Med 2016;17:187-93.

Lessa FC, Mu Y, Bamberg WM, et al. Burden of *Clostridium difficile* infection in the United States. N Engl J Med 2015;372:825-34.

Logan LK, Gandra S, Mandal S, et al. Multidrug- and carbapenem-resistant *Pseudomonas aeruginosa* in children, United States, 1999-2012. J Pediatric Infect Dis Soc 2017;6:352-9.

Logan LK, Renschler JP, Gandra S, et al. Carbapenem-resistant Enterobacteriaceae in children, United States, 1999-2012. Emerg Infect Dis 2015;21:2014-21.

Louden NJ, Hansen LA, Rimal A, et al. Implementation of a pharmacist-driven penicillin and cephalosporin allergy assessment tool: a pilot evaluation. J Pediatr Pharmacol Ther 2021;26:696-701.

Lovegrove MC, Geller AI, Fleming-Dutra KE, et al. US emergency department visits for adverse drug events from antibiotics in children, 2011-2015. J Pediatric Infect Dis Soc 2019;8:384-91.

MacBrayne CE, Williams MC, Levek C, et al. Sustainability of handshake stewardship: extending a hand is effective years later. Clin Infect Dis 2020;70:2325-32.

Mangione-Smith R, Zhou C, Robinson JD, et al. Communication practices and antibiotic use for acute respiratory tract infections in children. Ann Fam Med 2015;13:221-7.

McDonald LC, Gerding DN, Johnson S, et al. Clinical practice guidelines for *Clostridium difficile* infection in adults and children: 2017 updated by the Infectious Diseases Society of America (IDSA) and Society for Healthcare Epidemiology of America (SHEA). Clin Infect Dis 2018;66:e1-e48.

McMullan BJ, Mahony M, Java L, et al. Improving intravenous-to-oral antibiotic switch in children: a team-based audit and implementation approach. BMJ Open Qual 2021;10:e001120.

McPherson C, Lee BR, Terrill C, et al. Characteristics of pediatric antimicrobial stewardship programs: current status of the Sharing Antimicrobial Reports for Pediatric Stewardship (SHARPS) collaborative. Antibiotics 2018;7:4.

Medernach RL, Logan LK. The growing threat of antibiotic resistance in children. Infect Dis Clin North Am 2018;32:1-17.

Meropol SB, Haupt AA, Debanne SM. Incidence and outcomes of infections caused by multidrug-resistant Enterobacteriaceae in children, 2007-2015. J Pediatric Infect Dis Soc 2018;7:36-45.

Messacar K, Campbell K, Pearce K, et al. A handshake from antimicrobial stewardship opens doors for infectious disease consultations. Clin Infect Dis 2017a;64:1449-52.

Messacar K, Hurst AL, Child J, et al. Clinical impact and provider acceptability of real-time antimicrobial stewardship decision support for rapid diagnostics in children with positive blood culture results. J Pediatric Infect Dis Soc 2017b;6:267-74.

Metjian TA, Prasad PA, Kogon A, et al. Evaluation of an antimicrobial stewardship program at a pediatric teaching hospital. Pediatr Infect Dis J 2008;27:106-11.

Miller WR, Rollnick S. Motivational Interviewing: Helping People to Change, 3rd ed. Guilford Press, 2013.

Moehring RW, Anderson DJ, Cochran RL, et al. Expert consensus on metrics to assess the impact of patient-level antimicrobial stewardship interventions in acute-care settings. Clin Infect Dis 2017;64:377-83.

Monsees EA, Burns AN, Lee BR, et al. Considerations for implementation: pediatric outpatient antimicrobial stewardship program. Am J Infect Control 2021;49:1543-6.

Murphy JL, Fenn N, Pyle L, et al. Adverse events in pediatric patients receiving long-term oral and intravenous antibiotics. Hosp Pediatr 2016;6:330-8.

Murray MT, Beauchemin MP, Neu N, et al. Prior antibiotic use and acquisition of multidrug-resistant organisms in hospitalized children: a systematic review. Infect Control Hosp Epidemiol 2019;40:1107-15.

Nagel JL, Stevenson JG, Eiland EH, et al. Demonstrating the value of antimicrobial stewardship programs to hospital administrators. Clin Infect Dis 2014;59(suppl 3):S146-S153.

National Healthcare Safety Network (NHSN). 2022. Antimicrobial Use and Resistance Module. Available at https://www.cdc.gov/nhsn/pdfs/pscmanual/11pscaurcurrent.pdf.

Nelson RE, Hatfield KM, Wolford H, et al. National estimates of healthcare costs associated with multidrug resistant bacterial infections among hospitalized patients in the United States. Clin Infect Dis 2021;72(suppl 1):S17-26.

Newland JG, Gerber JS, Kronman MP, et al. Sharing Antimicrobial Reports for Pediatric Stewardship (SHARPS): a quality improvement collaborative. J Pediatric Infect Dis Soc 2018;7:124-8.

Newland JG, Stach LM, De Lurgio SA, et al. Impact of a prospective-audit-with-feedback antimicrobial stewardship program at a children's hospital. J Pediatric Infect Dis Soc 2012;1:179-86.

Newman RE, Hedican EB, Herigon JC, et al. Impact of a guideline on management of children hospitalized with community-acquired pneumonia. Pediatrics 2012;129:e597-604.

Norlin C, Fleming-Dutra K, Mapp J, et al. A learning collaborative to improve antibiotic prescribing in primary care pediatric practices. Clin Pediatr 2021;60:230-40.

Norton AE, Konvinse K, Phillips EJ, et al. Antibiotic allergy in pediatrics. Pediatrics 2018a;141:e20172497.

Norton LE, Lee BR, Harte L, et al. Improving guideline-based streptococcal pharyngitis testing: a quality improvement initiative. Pediatrics 2018b;142:e20172033.

Olmsted MG, Powell R, Murphy J, et al. 2021. Methodology: *U.S. News & World Report* Best Children's Hospitals 2021-22. Available at https://health.usnews.com/media/best-hospitals/BCH_Methodology_2021-22.pdf.

Olson J, Thorell EA, Hersh AL. Evaluation of discharge antibiotic prescribing at a freestanding children's hospital: opportunities for stewardship. J Pediatric Infect Dis Soc 2019;8:563-6.

Parker SK, Hurst AL, Thurm C, et al. Anti-infective acquisition costs for a stewardship program: getting to the bottom line. Clin Infect Dis 2017;65:1632-7.

Patel D, MacDougall C. How to make antimicrobial stewardship work: practical considerations for hospitals of all sizes. Hosp Pharm 2010;45(suppl 11):S10-S18.

Paterson DL. "Collateral damage" from cephalosporin or quinolone antibiotic therapy. Clin Infect Dis 2004;38:S341-5.

Pediatric Infectious Diseases Society (PIDS). 2020. Pediatric ASP Toolkit. Available at https://pids.org/pediatric-asp-toolkit/.

Pernica JM, Harman S, Kam AJ, et al. Short-course antimicrobial therapy for pediatric community-acquired pneumonia: the SAFER randomized clinical trial. JAMA Pediatr 2021;175:475-82.

Poole NM. Judicious antibiotic prescribing in ambulatory pediatrics: communication is key. Curr Probl Pediatr Adolesc Health Care 2018;48:306-17.

Poole NM, Frost H. Targets and methods to improve outpatient antibiotic prescribing for pediatric patients. Infect Dis Clin North Am 2022;36:187-202.

Poole NM, Wattles BM, El Feghaly RE, et al. Proposed metrics to benchmark antibiotic prescribing in pediatric outpatient settings. Am J Infect Control 2021;49:1547-550.

Predic M, Delano JP, Tremblay E, et al. Evaluation of patient risk factors for infection with carbapenem-resistant Enterobacteriaceae. Am J Infect Control 2020;48:1028-31.

Reuter CH, Palac HL, Kociolek LK, et al. Ideal and actual impact of rapid diagnostic testing and antibiotic stewardship on antibiotic prescribing and clinical outcomes in children with positive blood cultures. Pediatr Infect Dis J 2019;38:131-7.

Rischin KJ, Mostaghim M, Rao A, et al. ESCAPE-Allergy: evaluating screening for children and adolescents with penicillin allergy. J Pediatr Child Health 2022;58:83-9.

Rutman L, Wright DR, O'Callaghan J, et al. A comprehensive approach to pediatric pneumonia: relationship between standardization, antimicrobial stewardship, clinical testing, and cost. J Healthc Qual 2017;39:e59-69.

Same RG, Hsu AJ, Cosgrove SE, et al. Antibiotic-associated adverse events in hospitalized children. J Pediatric Infect Dis Soc 2021;10:622-8.

Sammons JS, Localio R, Xiao R, et al. *Clostridium difficile* infection is associated with increased risk of death and prolonged hospitalization in children. Clin Infect Dis 2013;57:1-8.

Sanchez GV, Fleming-Dutra KE, Roberts RM, et al. Core elements of outpatient antibiotic stewardship. MMWR Recomm Rep 2016;65(RR6):1-12.

Sandora TJ, Fung M, Flaherty K, et al. Epidemiology and risk factors for *Clostridium difficile* infection in children. Pediatr Infect Dis J 2011;30:580-4.

Searns JB, Williams MC, MacBrayne CE, et al. Handshake antimicrobial stewardship as a model to recognize and prevent diagnostic errors. Diagnosis (Berl) 2020;8:347-52.

Seattle Children's Hospital. 2022. Clinical Standard Work Pathways and Tools. Available at https://www.seattlechildrens.org/healthcare-professionals/gateway/clinical-resources/pathways/.

Serra-Burriel M, Keys M, Campillo-Artero C, et al. Impact of multi-drug resistant bacteria on economic and clinical outcomes of healthcare-associated infections in adults: systematic review and meta-analysis. PLoS One 2020;15:e0227139.

Shlaes DM, Gerding DN, John JF, et al. Society for Healthcare Epidemiology of America and Infectious Diseases Society of America Joint Committee on the Prevention of Antimicrobial Resistance: guidelines for the prevention of antimicrobial resistance in hospitals. Infect Control Hosp Epidemiol 1997;18:275-91.

Sick AC, Lehmann CU, Tamma PD, et al. Sustained savings from a longitudinal cost analysis of an internet-based preapproval antimicrobial stewardship program. Infect Control Hosp Epidemiol 2013;34:573-80.

Smith MJ, Thurm C, Shah S, et al. Route of administration for antibiotics with high oral bioavailability. Infect Control Hosp Epidemiol 2019;40:248-9.

Solutions for Patient Safety (SPS). 2022. Available at https://www.solutionsforpatientsafety.org/.

Spellberg B, Bartlett JG, Gilbert DN. How to pitch an antimicrobial stewardship program to the hospital C-suite. Open Form Infect Dis 2016;3:ofw210.

Stang CRT, Jaggi P, Tansmore J, et al. Implementation of a pharmacist-led antimicrobial time-out for medical-surgery services in an academic pediatric hospital. J Pediatr Pharmacol Ther 2021;26:284-90.

Stultz JS, Arnold SR, Shelton CM, et al. Antimicrobial stewardship impact on *Pseudomonas aeruginosa* susceptibility to meropenem at a tertiary pediatric institution. Am J Infect Control 2019;47:1513-5.

Szymczak J, Kitt E, Hayes M, et al. Threatened efficiency not autonomy: prescriber perceptions of an established pediatric antimicrobial stewardship program. Infect Control Hosp Epidemiol 2019;40:522-7.

Szymczak J, Muller B, Shakamuri N, et al. The impact of social role identity on communication in hospital-based antimicrobial stewardship. Antimicrob Steward Healthc Epidemiol 2021;1:s14.

Tamma PD, Turnbull AE, Milstone AM, et al. Ventilatory-associated tracheitis in children: does antibiotic duration matter? Clin Infect Dis 2011;52:1324-31.

Taylor M, Liechti S, Palazzi D. Intermittent education and audit and feedback reduce inappropriate prescribing of oral third-generation cephalosporins for pediatric upper respiratory tract infections. Jt Comm J Qual Patient Saf 2021;47:250-7.

Thom KA, Tamma PD, Harris AD, et al. Impact of a prescriber-driven antibiotic time-out on antibiotic use in hospitalized patients. Clin Infect Dis 2019;68:1581-4.

Timbrook TT, Morton JB, McConeghy KW, et al. The effect of molecular rapid diagnostic testing on clinical outcomes in bloodstream infections: a systematic review and meta-analysis. Clin Infect Dis 2017;64:15-23.

Tribble AC, Lee BR, Flett KB, et al. Appropriateness of antibiotic prescribing in United States children's hospitals: a national point prevalence survey. Clin Infect Dis 2020b;71:e226-34.

Tribble AC, Gerber JS, Bilker WB, et al. Impact of rapid diagnostics with antimicrobial stewardship support for children with positive blood cultures: a quasi-experimental study with time trend analysis. Infect Control Hosp Epidemiol 2020a;41:883-90.

Turner RB, Valcarlos E, Loeffler AM, et al. Impact of an antimicrobial stewardship program on antibiotic use at a nonfreestanding children's hospital. J Pediatric Infect Dis 2017;6:e36-e40.

Vangay P, Ward T, Gerber JS et al. Antibiotics, pediatric dysbiosis, and disease. Cell Host Microbe 2015;17:553-64.

Vyles D, Antoon JW, Norton A, et al. Children with reported penicillin allergy: public health impact and safety of delabeling. Ann Allergy Asthma Immunol 2020;124:558-65.

Wakeman D, Livingston MH, Levatino E, et al. Reduction of surgical site infections in pediatric patients with complicated appendicitis: utilization of antibiotic stewardship principles and quality improvement methodology. J Pediatr Surg 2022;57:63-73.

Walters EM, D'Auria J, Jackson C, et al. An ambulatory antimicrobial stewardship initiative to improve diagnosis and treatment of urinary tract infections in children. Jt Comm J Qual Patient Saf 2019;45:829-37.

Watson JR, Wang L, Klima J, et al. Healthcare claims data: an underutilized tool for pediatric outpatient antimicrobial stewardship. Clin Infect Dis 2017;64:1479-85.

Wattier RL, Levy ER, Sabnis AJ, et al. Reducing second gram-negative antibiotic therapy on pediatric oncology and hematopoietic stem cell transplantation services. Infect Control Hosp Epidemiol 2017;38:1039-47.

Wattier RL, Thurm CW, Parker SK, et al. Indirect standardization as a case mix adjustment method to improve comparison of children's hospitals' antimicrobial use. Clin Infect Dis 2021;73:925-32.

Wattles BA, Vidwan NK, Feygin Y, et al. Antibiotic prescribing to Kentucky Medicaid children, 2012-2017: prescribing is higher in rural areas. J Rural Health 2022;38:427-32.

Welch S, Patel R, Morris L, et al. Impact of antimicrobial stewardship and rapid diagnostics in children with *Staphylococcus aureus* bacteremia. J Am Coll Clin Pharm 2020;3:1304-11.

Wendt JM, Cohen JA, Mu Y, et al. *Clostridium difficile* infection among children across diverse UA geographic locations. Pediatrics 2014;133:651-8.

Willis ZI, Duggan EM, Gillon J, et al. Improvements in antimicrobial prescribing and outcomes in pediatric complicated appendicitis. Pediatr Infect Dis J 2018;37:429-35.

Willis ZI, Gillon J, Xu M, et al. Reducing antimicrobial use in an academic pediatric institution: evaluation of the effectiveness of a prospective audit with real-time feedback. J Pediatric Infect Dis Soc 2017;6:339-45.

Wirtz AL, Burns AN, Lee BR, et al. Effectiveness and safety of mandatory antimicrobial indications and durations and a pharmacist-driven 48-hour time-out in a pediatric hospital. Am J Health Syst Pharm 2020;77:614-21.

Wolf J, Sun Y, Tang L, et al. Antimicrobial stewardship barriers and goals in pediatric oncology and bone marrow transplantation: a survey of antimicrobial stewardship practitioners. Infect Control Hosp Epidemiol 2016;37:343-7.

Zachariah P, Newland JG, Gerber JS, et al. Costs of antimicrobial stewardship programs at U.S. children's hospitals. Infect Control Hosp Epidemiol 2016;37:852-4.

Zahlanie Y, Mang NS, Lin K, et al. Improved antibiotic prescribing practices for respiratory infections through use of computerized order sets and educational sessions in pediatric clinics. Open Forum Infect Dis 2020;8:ofaa601.

Zembles TN, MacBrayne CE, Mitchell ML, et al. Lessons learned from virtual handshake stewardship during a pandemic. Jt Comm J Qual Patient Saf 2021;47:198-200.

Zerr DM, Miles-Jay A, Kronman MP, et al. Previous antibiotic exposure increases risk of infection with extended-spectrum-β-lactamase-and AmpC-producing *Escherichia coli* and *Klebsiella pneumoniae* in pediatric patients. Antimicrob Agents Chemother 2016;60:4237-43.

Self-Assessment Questions

1. Which one of the following best describes how to explain the role of cost savings in antimicrobial stewardship to the executive leadership of a pediatric institution?
   A. Cost savings should be a primary goal for antimicrobial stewardship programs (ASP).
   B. Cost assessment of initiatives should incorporate total cost of care and personnel costs.
   C. Antimicrobial acquisition costs are the best measure for evaluating cost savings.
   D. Cost savings are closely tied to improved patient safety.
2. A clinical pharmacist at a non-freestanding children's hospital has been allocated 0.5 full-time equivalent to support antimicrobial stewardship activities. Because of the hospital's size and location, direct access to infectious diseases (ID) physicians is limited. Which one of the following is best to consider as a program co-leader?
   A. Medical resident with a microbiology background
   B. Pediatric hospital medicine director
   C. Infection prevention coordinator
   D. Chair of the pharmacy and therapeutics committee

Questions 3-5 pertain to the following case.

The ASP at a large academic pediatric institution ("Mainland Health") has implemented prospective audit and feedback over the past year. When reviewing a detailed analysis of prospective audit and feedback interventions for the hospitalist and general pediatrics services, the ASP pharmacist notices more interventions by the ASP team for de-escalating therapy from ceftriaxone to ampicillin and shortening the therapy duration for community acquired pneumonia (CAP) compared with other interventions.

3. Which one of the following is the best supplemental strategy to increase the appropriate use of antibiotics for this indication at Mainland Health?
   A. Add automatic stop dates to ceftriaxone orders for CAP.
   B. Educate residents and hospitalists on the PIDS/IDSA pediatric CAP guidelines.
   C. Develop a clinical practice guideline for the treatment of pediatric CAP.
   D. Require ID preauthorization for the use of ceftriaxone for CAP.
4. Which one of the following metrics is best to collect to assess the impact of ASP interventions targeting CAP at Mainland Health?
   A. Length of hospitalization
   B. CAP-related readmissions
   C. Days of therapy (DOT) for ampicillin and ceftriaxone
   D. *Clostridioides difficile* infection rates
5. Which one of the following strategies is most likely to enhance the acceptance of the ASP recommendations made to prescribers using prospective audit and feedback at Mainland Health?
   A. Comparison with peer prescribing
   B. Handshake antimicrobial stewardship
   C. SHARE decision-making approach
   D. Education on the audit and feedback process

Questions 6 and 7 pertain to the following case.

The ASP pharmacist is collecting baseline data before initiation of antimicrobial stewardship activities at a large academic pediatric institution ("Pediatric Services"). To help tailor the ASP's intervention strategies, the ASP pharmacist benchmarks the institution's antimicrobial use (AU) data to other institutions. On review, the pharmacist notes that the institution has high overall AU compared with other institutions.

6. Which one of the following stewardship interventions is most likely to have a sustained impact on total antibiotic consumption as measured by DOT at Pediatric Services?
   A. Indication-specific clinical practice guidelines
   B. Pharmacy-to-dose protocol for vancomycin and aminoglycosides
   C. Antimicrobial restriction with preauthorization of broad-spectrum agents
   D. Prospective audit and feedback for patients receiving antimicrobial therapy
7. When risk-adjusted for differences among the compared institutions, which one of the following variables best increases the validity of benchmarked AU data at Pediatric Services?
   A. Institutional size
   C. Institutional location
   B. Case-mix index
   D. Infectious diagnosis
8. The pharmacist co-leader of an established ASP at a freestanding children's hospital is looking to expand ASP efforts across the institution. Currently, most of the ASP pharmacist's time is dedicated to performing prospective audit and feedback using the handshake stewardship approach. Which one of the following strategies is best to consider for delegating to peer pharmacists to supplement prospective audit and feedback?
   A. Antibiotic timeouts after 48 hours of therapy
   B. Penicillin allergy assessments on admission
   C. Daily positive culture result reviews

D. Weekly educational sessions to providers

9. Which one of the following best describes the National Healthcare Safety Network (NHSN) AU Option?
   A. Is a mandatory electronic reporting tool to quantify an institution's AU.
   B. Provides rates of antibiotic use as DOT/1000 days-present.
   C. Uses antimicrobial purchasing data to quantify antibiotic use metrics.
   D. Facilitates risk-adjusted benchmarking using the standardized antimicrobial administration ratio (SAAR).

Questions 10 and 11 pertain to the following case.

N.S., a 6-year-old boy with no significant medical history, presents to the ED with signs and symptoms consistent with urosepsis. A blood and urine culture are obtained before initiation of empiric therapy with vancomycin and ceftriaxone. He is admitted to the pediatric ICU for further care. Vancomycin is discontinued after 48 hours when urine and blood cultures identify an ESBL-producing organism. On admission day 4, he is transitioned to ertapenem. On further clinical improvement, he is transitioned to oral ciprofloxacin on day 7 to complete a planned 10-day course. The medication administration record is as follows:

Medication	1/1	1/2	1/3	1/4	1/5	1/6	1/7
Ceftriaxone 75 mg/kg/dose IV q24hr	Given at 12:05 p.m.	Given at 11:59 a.m.	Given at 12:14 p.m.	Given at noon			
Vancomycin 15 mg/kg/dose IV q6hr	Given at 1:21 p.m., 6:59 p.m.	Given at 1:09 a.m., 6:58 a.m., 1:15 p.m., 7:08 p.m.	Given at 1:24 a.m., 7:12 a.m.				
Ertapenem 15 mg/kg/dose IV q12hr				Given at 3:34 p.m.	Given at 3:23 a.m., 3:15 p.m.	Given at 3:07 a.m., 3:08 p.m.	Given at 3:15 a.m.
Ciprofloxacin 15 mg/kg/dose PO q12hr							Given at 3:00 p.m.

IV = intravenous(ly); PO = oral(ly); q = every.

10. Which one of the following best represents N.S.'s total DOT?
    A. 7
    B. 10
    C. 12
    D. 19

11. On further review, the ASP pharmacist notices that effective therapy with ertapenem was not initiated until hospital day 4. Which one of the following strategies could best help decrease time to appropriate therapy for N.S.?
    A. Design an order set with preset durations of therapy.
    B. Educate providers on how to interpret susceptibility results.
    C. Require ID approval for the use of ertapenem.
    D. Encourage providers to perform an antibiotic timeout.

12. Which one of the following components would most likely hinder the implementation of prospective audit and feedback at a pediatric institution?
    A. Loss of prescriber autonomy
    B. Difficulty identifying patients to review
    C. Poor adherence to facility-specific guidelines
    D. Lack of dedicated ID physician support

Questions 13–15 pertain to the following case.

L.M. is a 4-year-old girl presenting to her primary care physician (PCP) with the chief concern of sore throat and cough. She has no reports of fever or any specific group A *Streptococcus* (GAS) pharyngitis examination finding; however, on physical examination, she has conjunctivitis and a rash on her torso. The PCP orders a rapid antigen test for GAS, which returns positive. She is prescribed a 10-day course of amoxicillin.

13. When performing audit and feedback on L.M.'s visit, the ASP team assesses that the positive culture likely represents colonization because of the presence of several viral symptoms and that antibiotics were unnecessary. Which one of the following outpatient antimicrobial stewardship strategies could best help in the appropriate use of antibiotics for future, similar scenarios like L.M.'s?
    A. Promote delayed prescribing.
    B. Develop a clinical practice guideline.
    C. Post a commitment poster in each examination room.
    D. Provide communication skills training to providers.

14. When performing audit and feedback on all patients diagnosed with GAS pharyngitis over the past 3 months, the pharmacist finds that triage nurses are performing throat swabs on all patients presenting with a sore throat to

evaluate for GAS pharyngitis. Which one of the following strategies could best help provide guidance on appropriate testing for GAS pharyngitis in L.M.?

A. Use a clinical decision support tool.
B. Educate staff on appropriate testing of GAS.
C. Require documentation of indication for testing.
D. Provide benchmarked data on penicillin DOT.

15. Which one of the following data measures would be most appropriate to track and report for this outpatient ASP in L.M.?

A. Adherence to facility-specific guidelines
B. Rates of antibiotic-related adverse drug events
C. Percentage of visits with an antibiotic prescribed
D. SAAR

Learner Chapter Evaluation: Implementing an Antimicrobial Stewardship Program

As you take the posttest for this chapter, also evaluate the material's quality and usefulness, as well as the achievement of learning objectives. Rate each item using this 5-point scale:

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

1. The content of the chapter met my educational needs.
2. The content of the chapter satisfied my expectations.
3. The author presented the chapter content effectively.
4. The content of the chapter was relevant to my practice and presented at the appropriate depth and scope.
5. The content of the chapter was objective and balanced.
6. The content of the chapter is free of bias, promotion, and advertisement of commercial products.
7. The content of the chapter was useful to me.
8. The teaching and learning methods used in the chapter were effective.
9. The active learning methods used in the chapter were effective.
10. The learning assessment activities used in the chapter were effective.
11. The chapter was effective overall.
12. The activity met the stated learning objectives.
13. If any objectives were not met, please list them here.

OTHER COMMENTS

14. Please provide any specific comments related to any perceptions of bias, promotion, or advertisement of commercial products.
15. Please expand on any of your above responses, and/or provide any additional comments regarding this chapter: