

hospital

November 2010
Volume 45 Number 11 Supplement

pharmacy

A practitioner-focused peer reviewed journal for the hospital pharmacist

Supplement

Key Aspects of a Successful Antibiotic Stewardship Program

- Importance and Impact of Antimicrobial Stewardship
- Review of Antibiogram Preparation and Susceptibility Testing Systems
- How to Make Antimicrobial Stewardship Work: Practical Considerations for Hospitals of All Sizes
- Continuing Education Posttest

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Key Aspects of a Successful Antibiotic Stewardship Program

Goal—The goal of this program is to educate pharmacists about the key aspects of a successful antibiotic stewardship program.

Audience—The intended audience for this CE activity is pharmacists.

Learning Objectives—At the completion of this program, the reader will be able to:

1. Describe the potential impact of an antibiotic stewardship program in an acute care setting.
2. List the benefits to patients of antibiotic stewardship.
3. Define the key principles that make up antibiotic stewardship.
4. Explain how to implement the program infrastructure to promote or optimize safe and effective antimicrobial therapy in an acute care setting.
5. Discuss the role of the antibiogram in optimizing antibiotic use within an acute care facility.

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Importance and Impact of Antimicrobial Stewardship

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Abstract

The landscape of health care is rapidly changing. With health care reform on the horizon, institutions are examining many practices to determine the best way to provide optimal care while minimizing economic burden. Antimicrobial stewardship is one method many institutions are implementing to achieve this balance. Antimicrobial stewardship encompasses a wide range of services aimed at improving patient outcomes and minimizing the untoward effects of antimicrobial agents including side effects as well as induction of resistance. These programs have been shown to decrease both the development of resistance as well as expenditures on antimicrobial agents. Recently, computerized decision support software has been implemented at many institutions. This technology has greatly improved the productivity of antimicrobial stewardship programs. Combining available technology with expert knowledge in infectious diseases is necessary to ensure the continued efficacy of current antimicrobial agents.

Key Words—antimicrobial stewardship, antibiotic resistance

Hosp Pharm—2010;45(11 Suppl 1):S1–S5

It is the end of an era. This phrase, made popular in many motion pictures and sporting events, now applies to the world of medicine and health care as we know it. Health care reform is on the forefront of political agendas with implications that are far reaching. In the very near future, hospitals may have to absorb the cost of treating patients with certain avoidable infections. These circumstances have caused health care facilities to turn inward, to examine current practices and evaluate whether they are treating their patients to achieve the best outcomes while allowing for the management of resource utilization. Unfortunately, with antibiotics, the best course of action is not always obvious.

Imagine a patient in the emergency department (ED) complaining of chest pain is diagnosed with an acute myocardial infarction. Most institutions would give the patient a beta-blocker. Whether this institution uses carvedilol or metoprolol or another agent, it does not affect the next patient, or a patient 5 years from now, who comes in with a similar diagnosis. Now imagine a patient in the ED with a diagnosis of community acquired pneumonia (CAP) caused by *Streptococcus pneumoniae* is treated with piperacillin/tazobactam. Will piperacillin/tazobactam cover the

isolated pathogen? Absolutely. Will it affect the next patient, or a patient 5 years down the road, if the ED always treats CAP with piperacillin/tazobactam? Probably. Is it the most appropriate agent for this patient? Probably not. For these reasons, the practice of infectious diseases is not simply about right and wrong. It is a matter of what is best for the patient as well as for patients who will be treated in the facility in the future.

Between 1983 and 1987, 16 new drug entities were approved in the infectious diseases arena, compared to 7 agents from 1998 to 2002 and 5 agents from 2003 to 2007.¹ These numbers indicate that the development of novel antimicrobial agents is coming to a grinding halt. In conjunction with a decline in antimicrobial development, an increase in multidrug-resistant organisms (MDROs) has also occurred. Several studies have indicated that infection with an MDRO is associated with higher rates of morbidity and mortality, longer length of stay, and greater cost of hospitalization.²⁻⁷

In 2009, “Bad Bugs, No Drugs: No ESKAPE,” an article detailing the lack of antimicrobial development occurring worldwide, was published as an update to the prior report “Bad Bugs, No Drugs.”^{1,8} The authors

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concluded that a focus on development of antimicrobial agents for the treatment of ESKAPE pathogens is vital (see Table 1). Later that year, it was recommended that the moniker ESKAPE be changed to the properly spelled ESCAPE pathogens (see Table 1), based on the increasing incidence of *Clostridium difficile* infections as well as the fact that *Escherichia coli* infections outnumber *Klebsiella* spp. and *Enterobacter* spp. infections combined.⁹ The alternative spelling encompasses the majority of current, problematic pathogens, most of which are frequently multidrug resistant. Whatever the nomenclature, the focus on antimicrobial development of agents with novel mechanism of action geared toward these pathogens is critical to the continued practice of infectious diseases.

ANTIMICROBIAL STEWARDSHIP GUIDELINES

Current efforts to thwart the siege of MDROs and to address the lack of development of antimicrobial agents center on antimicrobial stewardship. In 2007, The Infectious Diseases Society of America (IDSA) published guidelines in conjunction with the Society for Healthcare Epidemiology of America to outline antimicrobial stewardship practices.¹⁰ These guidelines focus on collaborative practice with infectious diseases physicians and infectious diseases–trained pharmacists. In addition, support from microbiologists, infection preventionists, informatics personnel, and hospital leadership is key to the success of these programs. The primary goal of antimicrobial stewardship is “to optimize clinical outcomes while minimizing unintended consequences of antimicrobial use, including toxicity, the selection of pathogenic organisms (such as *C. difficile*), and the emergence of resistance.”^{10(p159)}

These guidelines outline the necessary components of an antimicrobial stewardship program (see the box titled, “Recommendations From the Infectious Diseases Society of America for Components of Antimicrobial Stewardship Programs”). The first core strategy for the provision of antimicrobial stewardship is a prospective audit with intervention and feedback.

This approach is labor intensive and requires a dedicated person to prospectively evaluate patients receiving antimicrobial therapy, identify possible interventions, and address the issues with the medical staff in a timely fashion. Multiple studies have shown that a prospective audit with immediate feedback can decrease the utilization of broad spectrum antimicrobials as well as decrease the length of therapy.^{11–14} Clinical Decision Support Software (CDSS), to be discussed later in this review, can aid the pharmacist in the identification of patients in an expedited manner.

The second core strategy in the provision of antimicrobial stewardship is formulary restriction with the development of preauthorization requirements. This front-end approach may be more feasible for smaller hospitals without a dedicated antimicrobial stewardship team. Formulary restriction may be conducted by the pharmacy and therapeutics (P&T) committee, by the antibiotic subcommittee of the P&T committee, or at the pharmacy level. By decreasing the number of available agents on formulary, the institution is able to control the overuse of certain medications. In addition to formulary restriction, there can also be the assignment of criteria for approval for certain antibiotics. For example, consider the carbapenem class. Some institutions have created criteria similar to the following for carbapenem use: (a) isolation of a pathogen that is resistant to multiple agents, or (b) documented extended-spectrum β -lactamase (ESBL)–producing organism. If these criteria are not met, physicians may still obtain a carbapenem with the approval of an infectious diseases physician or pharmacist. Implementing restrictions and criteria for approval can aid in the preservation of broad-spectrum antimicrobial agents for use in severe infections caused by MDROs.

The establishment of antibiotic stewardship programs has benefited institutions both microbiologically and financially.^{15–18} A reduction in the number of infections caused by MDROs is the primary goal of most programs. Although microbiologic impact may take longer to observe, the implications are great.

Table 1. ESKAPE pathogens and the proposed changes for ESCAPE pathogens

E	<i>Enterococcus faecium</i>	E	<i>Enterococcus faecium</i>
S	<i>Staphylococcus aureus</i>	S	<i>Staphylococcus aureus</i>
K	<i>Klebsiella pneumoniae</i>	C	<i>Clostridium difficile</i>
A	<i>Acinetobacter baumannii</i>	A	<i>Acinetobacter baumannii</i>
P	<i>Pseudomonas aeruginosa</i>	P	<i>Pseudomonas aeruginosa</i>
E	<i>Enterobacter</i> spp.	E	<i>Enterobacteriaceae</i>

Recommendations From the Infections Diseases Society of America for Components of Antimicrobial Stewardship Programs

Prospective audit with intervention and feedback

Formulary restriction and preauthorization requirements for specific agents

Provision of education

Development of guidelines and clinical pathways

Identification of combination therapy for the prevention of resistance versus redundant antimicrobial coverage

Identification of a process for streamlining and de-escalation of therapy

Dose optimization

Conversion of parenteral therapy to oral therapy

Financial incentives are usually characterized early in the program's inception but are hard to sustain over a prolonged period of time. The following sections will describe the microbiologic and financial benefits of antimicrobial stewardship.

MICROBIOLOGICAL IMPACT

In 1998, an academic medical center in Kentucky established a formal antimicrobial stewardship team (AST). After a 5-year period, an evaluation of current practice was undertaken.¹⁵ A number of interventions were made by the AST during the 5-year study period including restriction of antimicrobial agents to criteria-based approval, institution of a 72-hour automatic stop order for vancomycin, and removal of ceftazidime, cefotaxime, and ciprofloxacin from the formulary. Evaluation of data from 1998 to 2002 showed stability of *Pseudomonas aeruginosa* susceptibility over the study period. Methicillin-resistant *Staphylococcus aureus* (MRSA) incidence peaked at 40% in 1999 but decreased an average of 3% per year through 2002. *Klebsiella pneumoniae* resistance to ceftazidime decreased rapidly and drastically after its removal from the formulary (11% vs <2%).

Another academic medical facility initiated a comprehensive infection control bundle to control an outbreak of *C. difficile*.¹⁶ Included in this bundle were a number of infection-control measures as well as targeted antimicrobial restriction, including clindamycin, ceftriaxone, and levofloxacin. *C. difficile* infections peaked in 2000 at 10.4 infections per 1000 patient days. By 2006, a decrease to 3 infections per 1000 patient days was observed – a 71% reduction ($P < .001$). Although a number of interventions occurred with the initiation of this program, the decline in antimicrobial consumption may have contributed to the success of the bundle.

Even in the setting of antimicrobial stewardship, microbiological outcomes are sometimes difficult to

elucidate. One study at a tertiary medical center demonstrated remarkable reductions in antibiotic consumption (measured in defined daily dose per 1000 patient days) but failed to show any significant changes in their antibiogram after the first 6 quarters of implementation of an AST.¹⁷ In fact, rates of MRSA increased in non-intensive care unit (non-ICU) areas but they decreased in the ICU setting. The rate decrease in the ICU was attributed to infection prevention measures implemented during the study period.

The microbiological impact of antimicrobial stewardship is not easily visible during the first few years of program development. Changes in resistance patterns and antibiograms are not typically evident until some time has passed. It is important to monitor antibiograms (discussed in the following article) on a unit-specific as well as a hospital level to assess changes in susceptibility for key organisms.

FINANCIAL IMPACT

As previously iterated in the IDSA guidelines for antimicrobial stewardship, the primary goal of antimicrobial stewardship is “to optimize clinical outcomes while minimizing unintended consequences of antimicrobial use.” In addition, there are financial incentives to providing optimized antimicrobial therapy. It is important for clinicians and administrators to distinguish between microbiological and financial goals at the outset of program development. Even though the majority of antimicrobial stewardship programs are financially self-sustaining, it is important to remember that programs will not save money forever, nor should that be the goal. A focus on prevention of resistance and appropriate de-escalation of therapy will allow for sustained cost avoidance at a minimum, while optimizing patient care.

There are data detailing the financial benefits of antimicrobial stewardship. A 5-year analysis of the above-mentioned AST in Kentucky was conducted.¹⁵

Between 1998 and 2002, the AST showed a decrease in antimicrobial expenditures by 25%, or \$1,401,146. In addition, antimicrobial cost per inpatient day decreased from \$21.14 in 1998 to \$16.24 in 2002. Financial victories, coupled with the resistance outcomes as discussed earlier, demonstrate the financial and clinical stability and utility of antimicrobial stewardship programs.

Institutions lacking an official AST may still achieve financial benefits with the development of simple protocols to be carried out by all pharmacy staff. One example of this is an intravenous to oral conversion (IV to PO) protocol. In a private teaching hospital in Connecticut, a guideline was developed to allow for automatic IV to PO conversion for levofloxacin by the pharmacy staff.¹⁸ After implementation of the protocol, a cost minimization analysis of level 1, level 2, and level 3 costs was undertaken. Level 1, 2, and 3 costs were defined as cost of drug acquisition only, acquisition cost of drug plus all costs related to drug administration, and acquisition cost plus costs related to drug administration plus cost of hospital stay, respectively. Costs were reduced across all levels after the implementation of the protocol. Level 3 costs were reduced by approximately \$3,300 per patient receiving levofloxacin, although this number was not statistically significant. Level 1 and level 2 costs were statistically lower after the implementation of the IV to PO protocol.

As previously stated, financial outcomes will never be 100% sustainable. This is the main impetus for evaluation of antimicrobial stewardship programs for other outcomes as well, including microbiologic trends, adherence to published/approved guidelines and pathways, and treatment outcomes. At times, it may be in the interest of antimicrobial stewardship to broaden coverage or add agents for combination therapy. Although this may increase the consumption of antimicrobials and negatively affect pharmacy budgets, the best interest of the patient is still being served; thereby, antimicrobial stewardship has occurred.

INCORPORATING TECHNOLOGY

The technology of health care is expanding, creating new and exciting modalities to deliver and monitor safe and effective treatment for patients. CDSS is recently making its mark in the provision of antimicrobial stewardship. Systems are capable of identifying a number of clinical interventions including, but not limited to, IV to PO conversions, drug-bug mismatch, duplicate therapy, drug-lab problems, and un-

necessary double coverage of pathogens. In addition, most CDSS programs allow for documentation of interventions directly in the system, which permits easy analysis of the impact of the AST. The systems also provide infection prevention professionals with a variety of information regarding MDROs, allowing for rapid identification of patients who are infected and/or colonized for isolation purposes. Whether home-grown or commercially available, CDSS programs have greatly increased the productivity and documentation of many stewardship activities.

CDSS can come in 2 varieties: passive or active. Passive systems require the user to query the database for possible interventions, whereas active systems push the information to the user. Imagine that a patient on the medical ICU is receiving vancomycin empirically for bacteremia. The culture returns positive for methicillin-sensitive *Staphylococcus aureus* (MSSA). Utilizing a passive system, the user would be able to log into the system, pull up patient information, look at cultures, examine current antimicrobial therapy, and make changes as necessary. If the clinician does not look for that information, however, the intervention may be missed. Now, take the same patient and a clinician who is using an active system. The clinician would log into the CDSS system and immediately receive a notification that there was a drug-bug mismatch. The system could then recommend discontinuation of vancomycin and initiation of nafcillin. The clinician had information pushed to him/her in a timely fashion, which allowed for a more rapid initiation of the de-escalation process.

Recently, a number of articles have been published discussing the utility of CDSS in the performance of antimicrobial stewardship activities. One study demonstrated a 22.8% reduction in antimicrobial expenditures over 3 months when utilizing a CDSS as compared to standard of care for their institution.¹⁹ A reduction in time was also noted with the assistance of the CDSS. Time spent on interventions was 4.1 person-hours/day compared to 3.2 person-hours/day in the control versus CDSS arms, respectively. In addition, a trend toward reduction in diarrhea and *C. difficile* was noted in patients with interventions secondary to the CDSS recommendations, although these were not statistically significant. No changes in mortality or length of stay were observed between the 2 study arms.

Another study evaluated the incidence of redundant antimicrobial therapy identified through the use of CDSS.²⁰ Formulary antibiotics were entered into the CDSS, with certain combinations flagged as

potentially redundant. Utilizing this built-in rule, 431 patients were identified as receiving potentially redundant therapy in the study period (23 non-consecutive days evaluated over a 3-month period). Of those patients, 192 patients met criteria for evaluation. It was determined that 71% of evaluated patients were receiving redundant therapy. Intervention and subsequent discontinuation of redundant therapy resulted in annualized savings of \$60,000 and approximately 3,500 antibiotic days. Combined with the time the pharmacist spent performing interventions, the estimated net annualized cost savings was closer to \$48,000.

CONCLUSIONS

Antimicrobial stewardship programs are becoming a mainstay in the fight against MDROs. The microbiologic and financial incentives for antimicrobial stewardship have been widely publicized in the literature. Financial benefits should not be the goal of antimicrobial stewardship but rather a pleasant by-product. Drug development efforts coupled with discriminate use of antimicrobial agents that are aimed at delaying antimicrobial resistance are key to the survival of available agents for the treatment of infectious diseases.

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Review of Antibiogram Preparation and Susceptibility Testing Systems

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Abstract

The overall rate of antibiotic resistance within health care institutions is dependent on data accumulated from antimicrobial testing performed on individual isolates. The type of testing method may vary depending on the bacterial species. A consensus document entitled “Analysis and Presentation of Cumulative Antimicrobial Susceptibility Test Data, M39-A2,” produced by the Clinical and Laboratory Standards Institute, presents a guideline for clinical laboratories when preparing a cumulative antibiogram. This document includes detailed recommendations for the collection, storage, analysis, and presentation of data. The antibiogram should also state the methods used to measure antibiotic resistance, the number of isolates tested in the analysis period, and the time period of analysis. Thus this cumulative report assists the health care institution by identifying trends or unusual patterns in microorganisms.

Key Words—antibiogram, antibiotics, susceptibility methods

Hosp Pharm—2010;45(11 Suppl 1):S6-S9

The primary use of a cumulative antibiogram is for the selection of appropriate empiric therapy.¹ These cumulative data are generated from the individual results of clinical isolates that are tested against a battery of antimicrobial agents. The development and presentation of an antibiogram are generally initiated by the clinical microbiology laboratory with collaboration from physicians, pharmacists, and infection control personnel.

In 2006, the Clinical and Laboratory Standards Institute (CLSI) published a document titled “Analysis and Presentation of Cumulative Antimicrobial Susceptibility Test Data: Approved Guideline.”¹ This document provides recommendations for the analysis and presentation of cumulative antibiogram data. It defines a cumulative antibiogram as “the report generated by analysis of isolates from a particular institution(s) during a defined period of time that reflects the percentage of first isolates per patient of a given species that is susceptible to each of the antimicrobial agents routinely tested.”

The challenge for the microbiology laboratory is to produce a concise antibiogram on an annual basis. This

document should display current, accurate, and clinically useful data in an organized fashion. The development of sophisticated computer programs and improvements in laboratory information systems aid in this process. The Joint Commission recognizes the antibiogram document as a quality-assurance measure for clinical laboratories, thus fulfilling JCAHO Standard IM.8. This standard falls under the Management Information Section concerning Aggregate Data and Information and is defined as follows: “The hospital collects and aggregates data and information to support care and service delivery and operations.” Despite this, antibiograms are not produced by all hospitals, especially those with fewer than 50 beds, and distribution policies vary widely among institutions at which cumulative antibiograms are available.²⁻⁴

ANTIBIOTIC SUSCEPTIBILITY TESTING METHODS

Clinical laboratories use a variety of antimicrobial susceptibility testing methods to determine the effectiveness of antimicrobial agents against clinical bacterial isolates. These testing methods have been standardized to provide reproducible, qualitative and/

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or quantitative results. Qualitative results are expressed as susceptible (S), intermediate (I), or resistant (R). Quantitative results are expressed as minimal inhibitory concentration (MIC, $\mu\text{g/mL}$) values accompanied by an S, I, or R on the laboratory report.

Annual guidelines are published by CLSI for performance and interpretation of disk diffusion and MIC tests.⁵ Clinical laboratories should use one of the CLSI reference methods or a commercial test system that has been cleared by the US Food and Drug Administration (FDA) for testing clinical isolates. FDA clearance indicates that results obtained from the commercial test system have been shown to be comparable to those generated by a CLSI reference method. All commercial systems for susceptibility testing require a manual set-up or inoculation step with either a manual or an automated reading and interpretation.

Automated antimicrobial susceptibility systems simplify and eliminate the subjectivity associated with reading, interpretation, and reporting of results. With semi-automated systems, the initial set-up and incubation is done outside of the instrument and the panel is placed in the instrument for the reading and interpretations functions. However, with fully automated systems, panels are inoculated and then placed in an automated incubator/reader. When the incubation is complete, the instrument automatically generates a report from the system's computer program. All clinical susceptibility instruments used for clinical testing require rigorous evaluation and approval from the FDA before they are used for testing bacterial isolates from patients. Currently there are 4 fully automated antimicrobial susceptibility instruments (ie, *VITEK Legacy*, *VITEK 2*, *MicroScan WalkAway*, and *BD Phoenix*) on the US market. The automated susceptibility systems generally use the same principle as the broth dilution system discussed later. The instrument uses various measures of automation, such as inoculation of premade panels, optical analysis of test panels for detecting bacterial growth, computerization of results, interpretation, and reporting. Many times the computers with these instruments can be interfaced with laboratory or hospital information systems. However, this interface should be verified periodically to detect potential problems with data transfer.

Disk diffusion testing is the most common non-automated system used to determine susceptibility of a bacterial isolate. One advantage of the disk diffusion method is flexibility in choosing the antimicrobial agents that are tested against each isolate. Addition-

ally, newly released antimicrobial agents are typically available in disk form before they are available in commercial MIC test systems.

Generally, up to 12 disks can be tested on a 150-mm diameter agar plate. The zone diameter of growth inhibition is measured and recorded in millimeters. The zone size of each agent is related to the ability of the drug to diffuse through the agar medium, the concentration of the drug in the disk, the number of bacteria applied to the agar plate, and the susceptibility of the bacterial isolate to the antimicrobial agent. Devices are available to capture and measure inhibition zones produced following disk diffusion testing. Zone measurements are transmitted to a computer containing software that interprets and stores data, which facilitates reporting.

An additional method is the manual MIC testing system that uses either broth or agar dilution. Normally, a 6- to 8-well series of 2-fold dilutions of each antimicrobial agent is prepared in liquid media in a 96-well broth microdilution panel. In general, up to 12 antimicrobial agents can be tested per panel along with a positive broth control that contains the bacteria but no antimicrobial agent and a negative control well that contains broth alone. The MIC of an agent is defined as the lowest concentration of drug that inhibits the visible growth of a bacterium. Broth microdilution panels can be purchased from commercial sources. Manual MIC testing can also be performed in test tubes where 1- to 2-mL volumes of bacteria/antimicrobial solution are tested. This broth macrodilution method is rarely used in clinical laboratories.

A unique manual method for evaluating the MIC of a clinical isolate is the *Etest*. This assay consists of a plastic strip with various concentrations of a single antibiotic. The antibiotic concentrations are shown on the top of the strip allowing the reader to interpret the inhibitory antibiotic concentration. The *Etest* is placed on the surface of an inoculated agar plate and incubated overnight. The highest concentrations of antibiotic are at the top of the strip. An elliptical zone of bacterial inhibition is wider at the top of the strip, where the higher concentrations of antibiotic are located, and gradually narrows as the antibiotic concentrations fail to inhibit bacterial growth. The MIC is read as the concentration of antibiotic that intersects with the growth of the bacteria. Several different antibiotic *Etest* strips can be tested concurrently on the same plate.

The methods used in microbiology laboratories for susceptibility testing vary depending on the

laboratory and the bacteria being tested. For example, *Streptococcus pneumoniae* may be tested with a method that detects the MIC when determining the susceptibility to penicillin. However, for *Escherichia coli*, automated commercial systems are used frequently. Some bacterial strains, such as *Haemophilus influenzae*, are tested only for the production of β -lactamase using a rapid method. Additionally, some well-characterized antibiotic resistance is detected by molecular methods, such as the *mecA* gene in *Staphylococcus aureus* for detecting methicillin resistance and the *vanA/B* genes in *Enterococcus faecium* for detecting vancomycin resistance. The use of these molecular methods can more quickly identify these antibiotic-resistant pathogens and can lead to more appropriate therapy.

ANTIBIOGRAM PREPARATION

Antibiogram data are based on the cumulative data from all different methods. These data should be organized into separate tables for gram-positive and gram-negative bacteria so that the user can easily find the data. The total numbers of isolates for each bacterial species should be listed, and susceptibility data are presented as the percent of strains that were susceptible to each drug. Bacteria that are “intermediate” should not be included as susceptible.¹

In general, antibiograms that include larger numbers of isolates for a particular bacterial species provide a more accurate assessment of antibiotic susceptibility because the impact of unusual isolates is minimized. For this reason, a cumulative antibiogram is generated on a yearly basis.

The inclusion of multiple isolates from the same patient during an analysis period can significantly skew susceptibility data reported on the antibiogram. Failure to eliminate duplicates can lead to inaccurate susceptible values. Duplicate isolates are defined by CLSI as “two isolates that are the same based on defined phenotypic or genotypic characteristics.”¹ Various methods can be used to remove duplicates from individual patients (eg, include only the first isolate per hospitalization vs first isolate per year vs first isolate every 30 days, etc), and these methods can result in considerable differences in the percent-susceptible statistics generated.⁶⁻⁸ The CLSI M39-A2 guidelines recommend that only the “first isolate (per patient) of a given species per analysis period” be included “irrespective of body site, antimicrobial susceptibility profile, or other phenotypic characteristics.”¹

The mechanism for eliminating duplicate isolates varies among the commercial software commonly

employed to generate cumulative antibiogram data in clinical laboratories. Laboratory information system (LIS) and other software programs are often used to assist institutions in analysis and presentation of cumulative antibiogram data. This software might be within the general LIS or may be part of an automated susceptibility test instrument. It is important to know if and how duplicates are eliminated when critically reviewing cumulative antibiogram data.

The aim of all health care institutions is to develop a useful and accurate antibiogram based on the principles set forth in the CLSI M39-A2 recommendations.¹ This ensures that physicians, microbiologists, pharmacists, infection control committees, and other health care workers have accurate information. Additionally, it is important for health care practitioners to be familiar with antibiogram issues and know how to apply the data in clinical practice. The Centers for Disease Control and Prevention and CLSI, along with accreditation organizations and regulatory agencies, emphasize the need for an accurate institutional antibiogram that is standardized and can guide empiric therapy and prevent antibiotic resistance.

SUMMARY

Monitoring of antibiotic resistance continues to be important as microbial pathogens develop antibiotic resistance. Antimicrobial susceptibility testing has evolved over the last 60 years and will continue to evolve as new antibiotics and procedures are adopted. The CLSI M39-A2 document has guidelines for preparation of antibiograms that will improve their quality. The use of these guidelines will result in tools to track antibiotic resistance as well as to assist the physician in making empiric antibiotic selections.

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How to Make Antimicrobial Stewardship Work: Practical Considerations for Hospitals of All Sizes

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Abstract

Implementation of an antimicrobial stewardship program in a hospital is complicated by a variety of challenges. Key issues facing stewardship personnel include recruiting personnel and building relationships, establishing program metrics, selecting stewardship strategies, working with clinicians, reporting results, and adapting the program. These issues can present different challenges at community hospitals and academic medical centers. Strategies for overcoming these challenges require accounting for the unique characteristics of each institution.

Key Words—antimicrobial stewardship, microbiology, hospital pharmacy

Hosp Pharm—2010;45(11 Suppl 1):S10–S18

Antimicrobial stewardship programs are increasingly recognized as important quality initiatives for health care institutions. Recent guidelines from professional societies^{1,2} and reviews^{3–6} describe the importance of stewardship, various strategies for achieving stewardship goals, and the evidence base supporting different interventions. Fewer publications adequately discuss the practical aspects of implementing such programs.⁷ Moreover, most studies of antimicrobial stewardship programs come from academic medical centers or other large institutions. Different challenges are likely to be faced by the community-based, non-teaching institutions that constitute the vast majority of US hospitals.⁸ In this article, we provide advice on some of the practical aspects of starting a new stewardship program or expanding an existing program, with special commentary regarding the unique challenges facing community and teaching institutions.

BUILDING OR BUILDING UP A STEWARDSHIP PROGRAM Personnel and Relationships

It is essential to identify and engage appropriate personnel during the early phases of antimicrobial stewardship program development. Recent guidelines identify infectious diseases (ID)-trained physicians and

ID-trained clinical pharmacists as core members of an antimicrobial stewardship team, with support and collaboration from a clinical microbiologist, an information system specialist, an infection control professional, and a hospital epidemiologist.¹ The value of ID specialist team leaders cannot be underestimated.⁹ However, there are barriers to effective recruitment of ID-trained physicians and pharmacists for such positions.⁷ Fear of forming a less-than-perfect team should not hinder the program development. When faced with resource limitations, other personnel may be considered, as outlined in **Table 1**. Programs in resource-limited settings may not be comprehensive, but they can perform selected antimicrobial stewardship activities appropriate to available resources.

Lines of authority and reporting structure should be established early in program development. Because antimicrobial stewardship focuses on optimal patient outcomes, the responsibility of holding the program accountable to its goals should fall to the patient safety and/or quality assurance departments. In addition, authority for stewardship activities should be achieved through policy and protocol approval from appropriate medical staff committees, including infection control and pharmacy and therapeutics (P&T). Furthermore, to provide program initiatives with the

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Table 1. Practical considerations for potential antimicrobial stewardship team resources

Ideal resources	Potential alternative resources
Infectious diseases (ID) physician	Other “physician champion” <ul style="list-style-type: none"> • Staff physician with ID interest • P&T chair or committee member • Local thought/practice leader • Physician groups who frequently prescribe antimicrobials Residents/fellows
ID pharmacist	Non-ID-trained clinical pharmacist Staff pharmacists Residents/students Working director of pharmacy
Clinical microbiologist	Microbiology laboratory technician Pathologist
Infection control coordinator	Nursing staff Patient safety representative
Information systems specialist	Information systems staff Commercial data-mining programs

Note: P&T = Pharmacy & Therapeutics.

necessary “teeth” to be successful, hospital administration must provide support in addressing issues with protocol compliance upon implementation.

Metrics and Benchmarking

Measurement is a key issue in antimicrobial stewardship. Stakeholders, especially in administration, will initially press for data on the justification for a stewardship program and will later press for data to demonstrate the program is having an effect. Obtaining as much preintervention data as practicable is key. These data should be both broad (across many areas) and deep (as far back in time as is reasonable). Having a broad scope of data allows institutions to determine where to best invest their limited resources. Does the institution have an issue with rampant carbapenem use? High *Clostridium difficile* rates? Poor IV to PO conversion? These problems may require different approaches. Obtaining data that are deep allows for identification of trends over time. This is particularly important when measuring the impact of interventions on aggregate measures such as total antimicrobial use or percentage of resistant organisms. These indices, in the absence of (and often even in the presence of) stewardship programs, tend to increase over time.¹⁰⁻¹² Thus, the ability of a stewardship program to reduce the rate of increase of these indicators is a substantial accomplishment, even if the absolute level cannot be reduced. These effects cannot be detected without several historical data points.

Studies have used a variety of measurements to evaluate stewardship programs. These can be categorized as *process metrics*, such as how many recommendations are made or what percentage of recommendations are accepted, or *outcomes metrics*, such as percentage of patients receiving guideline-appropriate therapy or hospitalwide antimicrobial resistance levels. Studies of antimicrobial stewardship typically incorporate both types of metrics.¹³⁻¹⁷ Table 2 displays an approach to the process and outcome metrics for antimicrobial stewardship programs. In this scheme, the ultimate outcome metric is the percentage of patients with infections who are successfully treated with a regimen that is minimally toxic and maximally cost-effective. This metric per se is not practically measurable outside of research settings. However, by examining the determining factors that drive the components of this outcome, one can derive some metrics that provide part of the picture as to the quality of care.

After these data are collected, institutions have 3 options for interpreting them: (1) quality assurance – comparison of the data to some agreed-upon standard (eg, 90% of patients receive guideline-compliant therapy for pneumonia); (2) intrahospital comparisons – comparison of the data to the institution’s historical data or to other patient care groups in the institution (eg, percent of patients being switched from IV to PO therapy over time or on surgical vs medical services), and (3) interhospital comparisons – comparison of the data to those obtained in similar institutions (eg, a methicillin-resistant *Staphylococcus aureus* [MRSA] infection rate below that of other hospitals). The interhospital comparison is typically known as *benchmarking* and is an approach to improving health care quality.^{18,19} Patient-level metrics are more appropriate for intrahospital comparison and quality assurance. They are “closer” to the ultimate outcome metric of appropriate, cost-effective treatment than ecologic metrics, which involve data aggregated across large numbers of patients. Ecologic metrics are suitable for intra- or interhospital benchmarking, but they are more removed in the causality chain from patient-level outcomes. Ecologic metrics are best used in conjunction with some sort of risk adjustment that accounts for differences in host factors (patient populations) between institutions.²⁰

Considerations for community hospitals

Perhaps the most daunting challenge in building an antimicrobial stewardship program at a small community hospital is the lack of sufficient resources,

Table 2. Potential antimicrobial stewardship program metrics

	Determining factors	Patient-level metrics examples	Ecologic metrics examples
Outcome metrics			
What percent of patients with infections...	-Host factors <i>-Appropriate diagnostics performed</i>	-% VAP patients with respiratory cultures -% of patients with paired blood cultures	-No. of blood cultures/infection-related ICD-9
are successfully treated...	-Host factors <i>-Selection of effective antimicrobial</i> <i>-Effective dose</i> <i>-Adequate duration</i>	-% of guideline-appropriate regimens by disease state -% of regimens with in vitro activity -No. of days to in vitro active drug -% of patients with effective dose	-Antibiogram (% susceptible by drug-organism) -No. of resistant infections/1000 PD -DDD or DOT/1000 PD -Mean duration of therapy
with minimal toxicity...	-Host factors <i>-Selection of least toxic effective antimicrobial</i> <i>-Safe dose</i> <i>-Minimal effective duration</i>	-Audit of high-toxicity antimicrobials -% of patients with appropriate dose -% of serum levels in safe range	- DDD/1000 PD of high-toxicity antimicrobials vs peer institutions
with the most cost-effective regimen?	-Selection of least expensive effective antimicrobial -Cost-effective dose -Cost-effective route -Cost-effective duration	-Audit of high-cost antimicrobials -Eligible patients switched IV → PO for high-bioavailability antimicrobials	-Total antimicrobial expenditures/PD -Total expenditures by infection -Days of IV vs PO for high-bioavailability antimicrobials
Process metrics			
What is the level of activity and acceptance of the stewardship program?	-Number of stewardship personnel -Time dedicated to stewardship -Attitude of clinicians towards stewardship	-Types of recommendations made -No. of recommendations made/time period -% of recommendations implemented	-No. of FTEs/1000 PD dedicated to stewardship

Note: Italics identify modifiable factors. VAP = ventilator-associated pneumonia; PD = patient days; DDD = defined daily dose; DOT = days of therapy; FTE = full-time equivalent positions; IV = intravenous; PO = oral.

including core and support personnel. Many rural institutions have few, if any, ID physicians on the medical staff available for routine consultations, let alone an ID physician with the dedicated responsibility for directing a stewardship program. In these cases, recruitment of an alternate physician champion with an interest in infectious diseases is important for oversight of the program.

Academic medical centers tend to be the most appealing options as practice sites for ID-trained pharmacists, thus creating a recruiting challenge for smaller community hospitals. When ID pharmacists are not available as resources, non-ID-specialist clinical pharmacists should make efforts to increase their comfort level and improve competency with ID-related issues in order to serve as a team member. Acquiring ID knowledge and skills may be achieved by shadowing

other pharmacist, physician, or microbiology experts; reading key guidelines and review articles; attending ID professional conferences; or completing one of the stewardship certification programs currently under development.

Unfortunately, in many rural hospitals – particularly critical access facilities (with 25 acute care beds or less) – a single pharmacist may serve the entire facility. In this setting, the pharmacist’s responsibilities typically include operational patient care activities, such as order entry and medication distribution, inventory management, and serving as director of pharmacy, clinical pharmacist, and P&T committee member. The pharmacist may be unable to prioritize and incorporate time-intensive antimicrobial stewardship activities into the work flow. Thus, stewardship strategies should be tailored according to available resources.

Beyond physician and pharmacist core members, availability of important support personnel is often far from ideal at community hospitals. Many small community hospitals do not have the resources to support an in-house microbiology laboratory and therefore must outsource this service. This situation poses challenges such as delays in obtaining routine culture and susceptibility results and uncertainty about the methodologies used to provide cumulative antibiograms. In other cases, a community hospital may have a microbiology laboratory onsite, but it may be run by technicians who lack clinical microbiology expertise. In such situations, the core members of the stewardship team should be empowered to spearhead a collaboration to ensure that certain policies and procedures of the laboratory are designed to complement key program initiatives. For example, if a nonformulary antimicrobial agent is routinely tested as part of an automated susceptibility testing panel, the results for this drug should be suppressed from reporting to medical staff. Likewise, to supplement efforts to encourage antimicrobial streamlining, results for broad-spectrum agents should be suppressed when the organism is susceptible to a more narrow-spectrum, clinically appropriate agent, per the guidelines of the Clinical and Laboratory Standards Institute (CLSI).²¹

Many community hospitals may not have the sophisticated information technology needed to optimally support antimicrobial stewardship activities. For example, physician order entry offers nearly unlimited potential to provide guidance and decision support to improve antimicrobial prescribing on the front end. However, implementation of this program can be costly and require a massive training effort and therefore may not be practical for smaller hospitals. These hospitals must rely on more labor-intensive methods of policy implementation. Without adequate information systems resources, data gathering and analysis can be cumbersome and sometimes nearly impossible. These limitations should be considered when selecting metrics for reporting at program onset. The team should ensure that it is feasible to gather and analyze the metrics pertaining to each program goal in a timely manner, given limited availability of information systems resources.

Considerations for teaching hospitals

Most teaching hospitals do not have a lack of qualified ID-trained physicians. However, given the commitments these physicians have to teaching and research, it may be difficult to find a physician willing to commit the time to become the stewardship

champion. It is important that all of the ID physicians understand and endorse the stewardship program, even those who may only spend a small amount of time on clinical service because of research commitments.

Academic medical centers may be able to expand the pool of stewardship personnel by recruiting trainees. Some centers have fellowship programs for training future physicians to become ID specialists. These fellows may be incorporated as active members of stewardship programs to good success because of their close working relationship with the housestaff that do the antimicrobial prescribing. However, it is important that the fellows feel invested in the program, otherwise they may serve as “rubber-stamp” stewards or, worse, actively undermine the stewardship personnel. Participation in antimicrobial stewardship is an excellent learning opportunity for pharmacy students or residents and provides more personnel to help with day-to-day stewardship activities.

Many large teaching hospitals have the information technology infrastructure – electronic medical records, computerized physician order entry – to make key data easier to access. However, there is likely to be quite a bit of data to sift through, so engaging the services of an information technology specialist is helpful. Personnel tasked with support of the infection control program should be cross-trained to handle stewardship queries. The effect of stewardship programs on various metrics may be of interest as a research question to academicians, who can provide assistance with data collection, study design, and statistical analysis.

Benchmarking program metrics is key in tertiary care institutions. There is a tendency among clinicians at these institutions to believe that the care of complex patients justifies almost any level of antimicrobial use. The comparison of antimicrobial use and outcomes data with those of peer institutions to the finest level of detail available (eg, by service or diagnosis group) can provide an honest picture of how a program is measuring up. Such data may be readily available if the hospital participates in groups such as the University HealthSystem Consortium (www.uhc.edu).

PUTTING STEWARDSHIP INTO PRACTICE **Selecting Stewardship Strategies**

After the decision is made to launch a stewardship program or re-evaluate an existing one, key stakeholders are engaged, and data for metrics are located, the next consideration is what to do. In other words, what activities will be performed, by what personnel, with what frequency, and with what authority. Table 3 lists these considerations with examples of each.

Details of different strategies have been extensively reviewed.^{1,3,4} Tailoring the activities to the goals and resources of the individual program is the task of the stewardship committee.

The importance of marketing and advertising a new or revised stewardship program should not be underestimated. Few things are more frustrating to health care personnel than dealing with new rules and procedures they are unaware of. Moreover, the misunderstandings that result from a lack of knowledge of stewardship procedures may compromise patient care. Advertising can be pursued through a number of mechanisms, including new practitioner orientation, staff newsletters, grand rounds, or other educational forums, and via hospital Internet/intranet and e-mail systems.

Working With Clinicians

Collaboration with clinicians who are outside of the formal stewardship team is encouraged to ensure buy-in for various initiatives. Key stakeholders from hospital departments that will be affected by stewardship activities should be identified and consulted during the development and introduction of a new initiative. For example, during the development of a pneumonia order set, stakeholders might include pulmonologists and emergency medicine physicians; for a surgical prophylaxis guideline, a surgeon should be involved in development and implementation. By giving clinicians ownership of these initiatives, they become invested in the success of the program.

Early involvement of key stakeholders may help to avoid resistance among clinicians; however, unforeseen

issues may arise despite valiant efforts to “cover all the bases.” In such situations, attempts should be made to understand the reasons for noncompliance in order to effectively address the concerns. Oftentimes, clinician resistance can be overcome with direct education. Perhaps the physician is unaware that *Candida* species isolated from a sputum culture likely represents colonization and need not be treated²² or that definitive data exist for shortening the course of antibiotic therapy for most ventilator-associated pneumonias.²³ Education about these issues can reassure the physician that stewardship team recommendations are, in fact, evidence-based and in the best interest of the patient. Feedback to departments or physicians regarding compliance to stewardship guidelines and/or interventions in the form of a regular “report card” may also be effective in improving compliance.^{24,25} Clinicians are often willing to change their prescribing patterns when they become aware that their practices vary significantly from those of their peers. This feedback must be provided diplomatically with an understanding of the political climate of any individual hospital. If one-on-one feedback is ineffective, these “report cards” can be sent to hospital administration or medical staff leadership for further action.

Considerations for community hospitals

Strategy selection when starting a stewardship program at small community hospitals should start with identification of areas for improvement while accounting for the availability of stewardship resources. In contrast to academic centers where many

Table 3. Considerations when selecting stewardship activities

	Examples
What activities will be performed. . .	-Authorization of restricted antimicrobials -Audit of and feedback regarding targeted antimicrobials -Pharmacokinetic dosing of antimicrobials -IV to PO conversion
by what personnel. . .	-Dedicated, trained ID pharmacist -ID physicians or physician trainees -Non-ID-trained clinical pharmacists -Hospital pharmacists -Pharmacy residents or students
with what frequency. . . .	-Performance of stewardship activities during evenings and weekends -Stewardship activities during ID pharmacist vacations -Authorization of restricted antimicrobials during off-hours
with what authority?	-Require preauthorization for restricted antimicrobials -Protocols for IV to PO conversion -Pharmacokinetic dosing protocols -Communication of recommendations via chart notes

Note: IV = intravenous; PO = oral; ID = infectious disease.

supplemental strategies may be implemented prior to the formation of a formal antimicrobial stewardship program, small community hospitals must often “start from scratch.” This can be overwhelming when considering where to start, taking into account the remaining work involved in formulating a comprehensive program. A potential strategy may be to work toward training staff pharmacists to assist with initiatives that require less ID expertise, such as IV to PO conversion or pharmacokinetic dosing. In addition, nontraditional personnel, such as case managers, may be of assistance in monitoring for appropriate duration of therapy per infection as well as IV to PO conversion initiatives.

Once these initial efforts gain traction, dedicated stewardship personnel may focus on more labor-intensive, ID-specific supplemental and core strategies. Even with these efforts, starting small and subsequently expanding may be more practical and successful than attempting to launch a comprehensive program from the start. For example, when beginning a prospective audit and feedback initiative, start with one targeted antimicrobial and add others when success has been demonstrated. Regardless of initial strategies, each new initiative must progress through the appropriate channels. Specific, medical staff–approved policies and procedures should guide the daily activities of the stewardship team. Even with this groundwork, a major challenge arises when administrators are unwilling or unable to effectively deal with resistant clinicians. When roles and responsibilities of stewardship team members are initially outlined, administrator roles and consequences for lack of compliance should be discussed as well.

A major challenge is posed when the hospital’s ID physicians are not fully supportive of the program. These ID physicians should serve as role models in stewardship for the remainder of the medical staff. Therefore, it is of utmost importance that their practices reflect initiatives of the stewardship team. In the community hospital setting, most consultant physicians are in private practice and may be unaware of how their practices differ from those of their colleagues and from the latest evidence-based recommendations. Although forums such as antimicrobial subcommittees, grand rounds, and ID divisions are consistently available at academic centers, community hospitals often lack this infrastructure. To ensure buy-in of these key physicians, the stewardship team should work to establish a forum for ID physicians to meet and discuss changes affecting the hospital as well as advances in the field in general. To overcome the possibility of

poor attendance or lack of interest, participation may be required for medical staff re-credentialing.

Considerations for teaching hospitals

Teaching hospitals with strong levels of personnel and information technology support can implement a broad package of stewardship interventions. If there is a group of clinical or decentralized staff pharmacists, some stewardship tasks (IV to PO switch, audit, and feedback) may be able to be “off-loaded” to these personnel instead of being performed by an ID pharmacist. At the same time, the high patient volume, acuity, and all-hours activity in many teaching hospitals can be a challenge to stewardship programs. For example, strategies requiring preauthorization of certain antimicrobials must be designed so that timely administration of these agents off-hours (weekends, evenings) is not compromised.

Medical residents as the primary prescribers of antimicrobials in a hospital presents opportunities and challenges. Residents are generally receptive to the educational and feedback interventions that form the core of stewardship programs. From a practical point of view, the near-constant presence of housestaff in the institution enables modifications to patients’ therapy to be executed more rapidly than when patients are cared for by private practice physicians who may only be in the hospital an hour a day. On the other hand, residents may be hesitant to directly implement suggested stewardship interventions (eg, changing or discontinuing antimicrobials) without consulting supervisory clinicians (attending physicians, fellows). On some services, the housestaff have very little discretion in antimicrobial prescribing: “Because my attending said so” may be the leading indication for antimicrobial therapy. In this case, there may be a substantial delay in implementing suggested stewardship interventions while the recommendation makes its way “up the ladder.” Thus, the importance of getting the buy-in of senior supervisory physicians to a stewardship program cannot be underestimated. It will be more productive to consult with senior clinicians to reach agreement on an acceptable set of guidelines for standard therapy for each service than to deal with each patient on a case-by-case basis.

EVALUATING AND ADAPTING A PROGRAM Reporting Results and Managing Expectations

Upon beginning or expanding a stewardship program, goals of the program should be explicitly stated (eg, using the metrics described previously) and a timeline for measuring progress toward the goals

should be specified. Once a program is up and running, there will be pressure to show positive results; pre-specified reporting dates and outcomes can help to clarify expectations. It is very important to note that some metrics, particularly ecologic measures such as total antimicrobial use and antimicrobial resistance, may require a very long time horizon (greater than a year) to show noticeable changes from the historical baseline.^{26,27} Thus, early program reports (a year or less after program implementation) should focus on process measurements (eg, number of interventions performed), patient-level outcomes (eg, compliance with guidelines), and cost savings/cost avoidance achieved. A full yearly report measuring progress on each of the program's prespecified metrics should be prepared. The report should be disseminated to the personnel and committees that have authority over the stewardship program and to other stakeholder groups outside of the "chain of command."

A challenge for initially successful programs is to improve on that success in subsequent years. There are

likely to be diminishing returns after successful implementation of any one particular strategy. This is where historical baseline data becomes key. By trending prior data (such as aggregate antimicrobial use, antimicrobial costs, or resistance) and extrapolating to the future, programs can demonstrate a continuing benefit even when these measures remain stable over time. **Figure 1** illustrates a hypothetical scenario in which an antimicrobial stewardship program is initiated in an institution with increasing total antimicrobial use. Although total antimicrobial usage at the last time point is higher than at the beginning of data collection, it is substantially lower than that predicted from the preintervention data. If a group wants to perform formal analyses on such longitudinal data, appropriate statistical techniques should be used.^{28,29}

Adapting the Program

After reports around selected metrics are compiled, they should be critically analyzed to determine the level of progress toward prespecified goals. If the goal is far

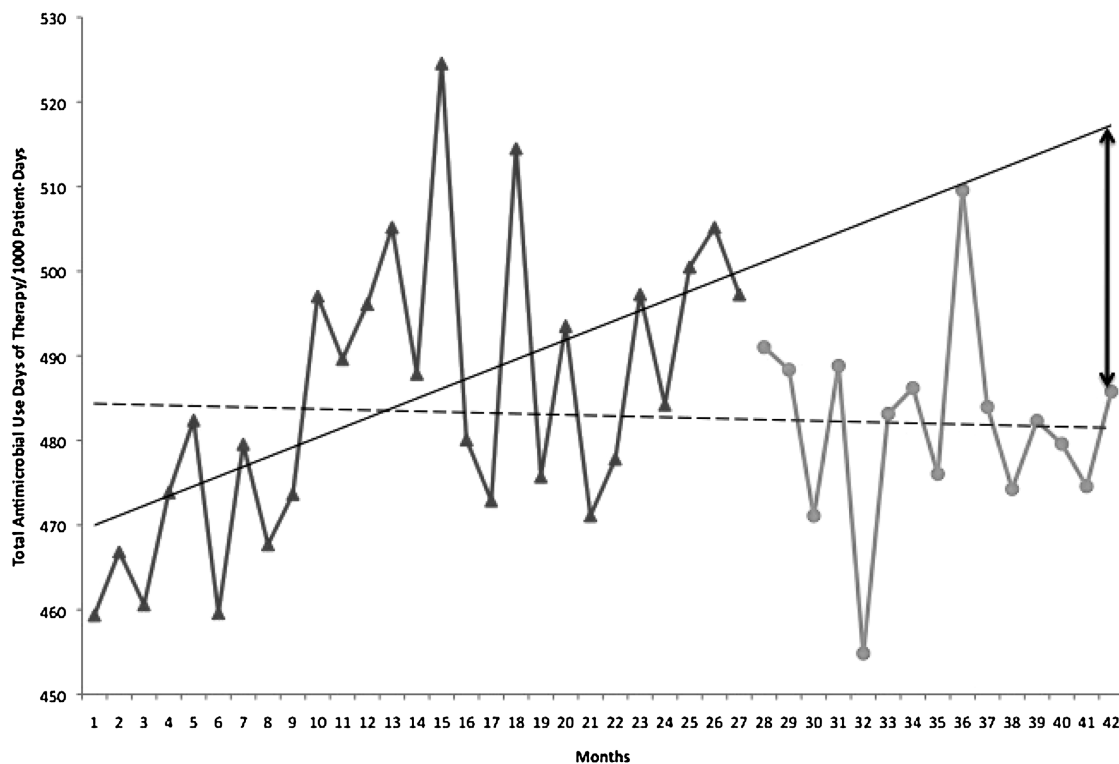


Figure 1. Measuring effects of antimicrobial stewardship interventions. Hypothetical changes in total antimicrobial use (days of therapy per 1000 patient days) at a hospital before and after implementation of an antimicrobial stewardship program. Triangles indicate antimicrobial use preintervention; circles indicate antimicrobial use post-intervention; solid line indicates linear trend of antimicrobial use preintervention; dotted line indicates linear trend of antimicrobial use postintervention; vertical line indicates difference between predicted and actual antimicrobial use.

from accomplished, what are the barriers to success? Are these barriers insurmountable? Aggressive pursuit of exact compliance to program goals increases the probability of alienating clinicians and compromising patient care. If progress has been slow but steady, a reassessment of time lines for attainment of a goal may be needed. For successful strategies, it is useful to reflect on the key components of the process to potentially apply a similar approach in future initiatives.

Considerations for community hospitals

When reporting results, consideration should be given to the audiences. Administrators will be interested in cost metrics as well as quality and process metrics. Medical staff at community hospitals are often further removed from the cost concerns and may be more interested in quality and patient care outcomes as well as ecologic metrics. Excessive focus on cost savings/avoidance metrics during reports to medical staff may convey the impression that the antimicrobial stewardship program is purely a cost-containment effort, potentially damaging the credibility of the team's efforts.

Barriers to success should also be reported. Bringing attention to the challenges the program faces may engage physicians to help provide solutions. Furthermore, any positive results can be used as a tool to demonstrate the importance of compliance with stewardship initiatives.

Considerations for teaching hospitals

Efforts should be made to include trainees in the reporting of stewardship measures. A brief educational session on the hospital's stewardship policies and discussion of the hospital antibiogram should be a part of orientation for new housestaff and fellows, as hospital policies and local drug resistance issues likely differ from where they previously trained. Yearly updates in educational sessions such as grand rounds can keep them informed about changes to the antibiogram and hospital policies. These sessions also let them know that the inconveniences that the program may pose for them on a daily basis are ultimately contributing to positive outcomes.

CONCLUSION

Professional societies and government organizations have begun advocating for the widespread adoption of antimicrobial stewardship programs in hospitals. However, little guidance is generally offered on the practical aspects of implementing such programs across the wide spectrum of hospitals in the

United States. There is no "one-size-fits-all" approach. Our recommendations can be summarized as follows: (1) understand what the problem areas are at your institution; (2) determine what resources are available (or may become available with the right appeals); (3) select stewardship strategies that best address the problems while accounting for the resources; (4) show off your success (or explain why success was not possible); and (5) use your success to secure more resources to address more problem areas. Never feel that a program needs to be built from scratch. Pharmacists across the country have been running antimicrobial stewardship programs for years and are generally more than willing to share advice, examples, and encouragement.

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1. Which of the following is not considered an ESKAPE pathogen?
 - a. *Klebsiella pneumoniae*
 - b. *Acinetobacter baumannii*
 - c. *Proteus mirabilis*
 - d. *Enterococcus faecium*
2. Which of the following methods is endorsed by the Infectious Diseases Society of America (IDSA) as an element of an effective antimicrobial stewardship program?
 - a. Prospective audit with intervention and feedback
 - b. Formulary restriction and preauthorization
 - c. Initiation of antimicrobial therapy within 10 minutes of suspected infection
 - d. Both A and B
3. Passive clinical decision support systems require the user to query the database for possible interventions.
 - a. True
 - b. False
4. The main goal of antimicrobial stewardship is to make financial improvements to the hospital's bottom line.
 - a. True
 - b. False
5. Which of the following is considered a goal of a comprehensive antimicrobial stewardship program?
 - a. Optimizing patient outcomes
 - b. Minimizing unintended consequences of antimicrobial therapy
 - c. Decreasing the incidence of multidrug-resistant pathogens
 - d. All of the above
6. An antibiogram should always include which of the following items?
 - a. Patient's age and sex and the unit to which the patient was admitted
 - b. Number of isolates included in the calculation and percent of isolates susceptible
 - c. Type of laboratory test used to determine the minimum inhibitory concentration
 - d. Cost of each antibiotic and route of administration
7. Which antibiotic susceptibility methods will not provide a minimum inhibitory concentration?
 - a. Disk diffusion
 - b. MicroScan
 - c. Etest
 - d. VITEK
8. In which situation would a molecular assay be used to detect antibiotic resistance?
 - a. To detect beta-lactamase in a *Haemophilus influenzae* isolate from an eye infection
 - b. To determine whether multiple *Pseudomonas* isolates from an outbreak in a unit are related
 - c. To determine whether gram-positive cocci in clusters from a blood culture are resistant to methicillin
 - d. To distinguish an isolate from the neonatal intensive care unit as *Staphylococcus aureus* or *Staphylococcus epidermidis*
9. Which of the following organizations provides specific guidelines that should be used when designing and preparing an antibiogram?
 - a. The Joint Commission
 - b. US Food and Drug Administration
 - c. Clinical Laboratory Improvement Consortium
 - d. Clinical Laboratory Standards Institute
10. How often should an antibiogram be developed and distributed throughout the hospital?
 - a. Once a month
 - b. Twice a year
 - c. Once a year
 - d. When there are enough isolates

11. A small community hospital does not have an infectious diseases-trained clinical pharmacist on staff, has only one part-time infectious diseases physician with privileges at the hospital, and outsources its microbiology processing to an outside laboratory. Which of the following describes the best approach to antimicrobial stewardship for this institution?
- A program customized to the resources available to the hospital can be developed.
 - A program should not be attempted in this situation due to the lack of resources.
 - A program is not necessary in community hospitals due to the low level of antimicrobial use.
 - A program can be established only if microbiology testing becomes an internal process.
12. Which of the following can be done by pharmacists who are not trained in infectious disease pharmacotherapy to improve their competency and comfort level in this area?
- Shadow other practitioners in the field
 - Read key guidelines and review articles
 - Complete a stewardship certification program once available
 - All of the above
13. Community Hospital X implemented an antimicrobial stewardship program 6 months ago. The best metrics to include in the first program report at the upcoming medical staff meeting include all of the following, except:
- Process measurements (eg, number of interventions performed)
 - Cost savings/cost avoidance
 - Ecologic measurements (eg, antimicrobial resistance rates)
 - Patient-level outcomes (eg, compliance with guidelines)
14. Which of the following is a disadvantage of having housestaff as prescribers at a teaching institution when implementing an antimicrobial stewardship program?
- Near-constant presence in the hospital
 - Willingness to learn about proper prescribing
 - Hesitancy to follow recommendations without approval of supervisory clinicians
 - Familiarity with newer antimicrobial agents
15. Which of the following would represent an intra-hospital comparison of antimicrobial stewardship metric data for a hospital?
- Comparing the methicillin-resistant *Staphylococcus aureus* (MRSA) rate at the target hospital to that of a similar hospital in the same city
 - Comparing the target hospital's quarterly use of carbapenems over the last 2 years
 - Comparing the target hospital's compliance with Surgical Care Improvement Project (SCIP) surgical prophylaxis guidelines to the hospital quality goal of 95%
 - Comparing the number of patients switched from intravenous fluoroquinolones to oral fluoroquinolones at the target hospital to what was reported in a recent journal article

ACCREDITATION

This program is co-sponsored by the Illinois Council of Health-System Pharmacists and ProCE, Inc. The Illinois Council of Health-System Pharmacists is accredited by the Accreditation Council for Pharmacy Education as a provider of continuing pharmacy education. This program is equivalent to 1.5 contact hours or 0.15 CEUs. This CE activity is provided at no cost.



ACPE Universal Activity Number:
121-999-10-073-H04-P

Activity type: Knowledge-based
Initial Release Date: 11/01/2010
Expiration Date: 11/01/2013

**FUNDING**

This activity is supported by an educational grant from Ortho-McNeil, Division of Ortho-McNeil-Janssen Pharmaceuticals, Inc., administered by Ortho-McNeil Janssen Scientific Affairs, LLC.

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