Principles and Practice of Antibiotic Stewardship in the ICU

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In the face of emerging drug-resistant pathogens and a decrease in the development of new antimicrobial agents, antibiotic stewardship should be practiced in all critical care units. Antibiotic stewardship should be a core competency of all critical care practitioners in conjunction with a formal antibiotic stewardship program (ASP). Prospective audit and feedback, and antibiotic time-outs, are effective components of an ASP in the ICU. As rapid diagnostics are introduced in the ICU, assessment of performance and effect on outcomes will clearly be needed. Disease-specific stewardship for community-acquired pneumonia that relies on clinical pathways may be particularly high-yield. Computerized decision support has the potential to individualize stewardship for specific patients. Finally, infection control and prevention is the cornerstone of every ASP.

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Stewardship: the conducting, supervising, or managing of something; especially: the careful and responsible management of something entrusted to one's care.¹

Defining Antibiotic Stewardship

Antibiotic stewardship has recently been defined as “coordinated interventions designed to improve and measure the appropriate use of antimicrobials by promoting the selection of the optimal antimicrobial drug regimen, dose, duration of therapy, and route of administration.”² Earlier forms focused on financial stewardship of more expensive antibiotics, which colored subsequent bedside clinician responses to antibiotic stewardship efforts.

This revised definition of antibiotic stewardship is born out of serious concerns regarding rising antibiotic resistance, partially due to the overuse and misuse of these drugs.³⁻⁵ Financial concerns have now taken a more secondary place to fear of pan-resistant bacteria and infectious complications reversing the life-years gained by modern medical interventions, such as organ and bone marrow transplant.^{6,7}

Concern for antibiotic resistance dates back to the 1940s when Alexander Fleming noted that inappropriate use of a new antibiotic, penicillin, could lead to microbial resistance.⁸ His theory became reality within

ABBREVIATIONS: ASP = antibiotic stewardship program; ATO = antibiotic time-out; CAP = community-acquired pneumonia; CARB = Combating Antibiotic-Resistant Bacteria; CDC = Centers for Disease Control and Prevention; CDI = *Clostridium difficile* infection; HAP = hospital-acquired pneumonia; ID = infectious diseases; IDSA/ATS = Infectious Diseases Society of America/American Thoracic Society; MDR = multidrug resistant; MRSA = methicillin-resistant *Staphylococcus aureus*; PCR = polymerase-chain reaction; PCT = procaltitonin; VAP = ventilator-associated pneumonia

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years, as strains of bacteria with β -lactamase enzymes were discovered. Methicillin-resistant *Staphylococcus aureus* (MRSA) was discovered the following decade.⁹ Imipenem was the first carbapenem used clinically in 1985 and, less than a decade later, Enterobacteriaceae with carbapenemases were discovered.¹⁰ The trend continued, with release of each new class of antibiotic followed by emergence of a bacterial strain harboring resistance to that drug. The crisis in antibiotic resistance began when, for a variety of reasons, development of new antibiotics was unable to keep up with the emergence of resistance to other classes or earlier generations of antibiotics. The implications of a growing population of antibiotic-resistant microorganisms are vast. Patients with resistant infections have a mortality rate and financial burden two times higher than that of patients with susceptible infections.¹¹ Clinicians often lack crucial information needed to treat these infections, and thus 30% to 60% of antibiotics prescribed in the ICU are not indicated (inappropriately broad) or inappropriately narrow.¹² Excess or excessively broad antibiotics are associated with their own consequences but, more importantly, drive increasing resistance to the specific antibiotic or antibiotic class. The volume of antibiotic use, sometimes measured in tonnage per year, is the most consistent driver of increasing antibiotic resistance. Hospital use and physician prescribing patterns therefore are critical foci for antibiotic stewardship efforts.

Several issues drive inappropriate antibiotic use in hospitalized patients. First, many clinicians use antibiotics for clinical scenarios in which antibiotics are unwarranted, like asymptomatic bacteriuria in patients with indwelling catheters.^{13,14} Patients admitted with upper respiratory infection symptoms, particularly during winter seasons, often receive antibiotics even when no evidence of bacterial infection is present.^{15,16} When guidelines do recommend antibiotic therapy, many clinicians fail to adhere to the appropriate duration and extend the treatment by several days.^{17,18} Inappropriate antibiotics are associated with a myriad of significant consequences including *Clostridium difficile* infection (CDI), longer length of hospital stay, higher hospital costs, nephrotoxicity, and nosocomial infection (Table 1¹⁹⁻³⁰).

National recognition of the burden of antimicrobial resistance and the complications associated with inappropriate antibiotic use culminated in 2014 with the release of Presidential Executive Order 13676 by President Obama on Combating Antibiotic-Resistant

Bacteria (CARB).³¹ Similar concerns and efforts occurred in Europe. A major component of the CARB action plan is enhanced antibiotic stewardship programs (ASPs) in order to preserve the activity of both currently available and potential future antibiotics. Infectious diseases societies updated their guidelines in 2016 to gain the benefits of antibiotic stewardship: “improved patient outcomes, reduced adverse events including *Clostridium difficile* infection (CDI), improvement in rates of antibiotic susceptibilities to targeted antibiotics, and optimization of resource utilization across the continuum of care.”³² The Centers for Disease Control and Prevention (CDC) published a similar statement in 2014 and has been leading the federal efforts to improve antibiotic stewardship.³³

Antimicrobial Stewardship in the ICU

Antimicrobial stewardship is particularly pertinent for the ICU. Many ICUs become sinks for multidrug-resistant (MDR) pathogens, accumulating patients with treatment failure due to antibiotic resistance. Prolonged duration of mechanical ventilation also predisposes to recurrent ventilator-associated pneumonias (VAPs), with each pathogen more resistant than the previous. As a consequence, intensivists regularly face the adverse effects of excess antibiotic therapy.

Unfortunately, intensivists are also the cause of antibiotic resistance. Empirical regimens designed to cover potential MDR pathogens are continued too long or too broadly, selecting precisely for the resistant pathogens they were intended to treat.³⁴ For example, many patients with MRSA pneumonia are already receiving vancomycin; *Pseudomonas aeruginosa* infections occur only in patients who have been receiving prior antibiotic therapy.

Published guidelines provide strategies for developing ASPs in the general hospital setting. However, antimicrobial stewardship in the ICU requires consideration of several unique factors. Judicious use of antibiotics in the ICU is essential to control the development of resistant organisms, and the benefits of implementing an ASP in the ICU are well documented. Studies have shown that ASPs reduce rates of antibiotic resistance, duration of ventilation, days of antibiotic use, and health-care costs in critically ill patients.³⁵ Table 2^{33,36-45} summarizes key elements of an ASP in an ICU setting and the associated benefits. Because of these

TABLE 1] Consequences of Antibiotic Overuse or Misuse and the Potential Impact of an Antibiotic Stewardship Program to Address These Issues

Consequences of Inappropriate Antibiotic Use	Benefits of Antibiotic Stewardship Program
Increased rates of CDI and other nosocomial infections	Decrease in CDI with incidence rate ratio of 0.35 ¹⁹ Decrease in CDI incidence from 2.2 to 1.4 cases per 1,000 patient-d ²⁰ Decrease in CDI incidence by 60% ²¹ 52% risk reduction of CDI ²² Decreased rate of CLABSI from 6.9 to 1.2 per 1,000 catheter-d ($P < .05$) ²³
Longer hospital LOS ^a	Mean hospital LOS reduced by 2.9 d ²⁴ Average 3.3-d reduction in length of stay ($P = .0001$) ²⁵
Increased costs	Antibiotic expenditures decreased by 53% ²⁶ 25% acquisition cost reduction per patient-d ²⁷
Prolonged treatment durations	Decreased antibiotic use by 55% ²⁸ Decreased duration of treatment from 14.1 to 11.9 d ²⁹ Decreased duration of treatment ³⁰

CDI = *Clostridium difficile* infection; CLABSI = central line-associated bloodstream infection; LOS = length of stay.

^aNote that other studies have shown no difference in length of stay with implementation of an antibiotic stewardship program.

benefits, antibiotic stewardship is a core competency of critical care physicians and should be practiced in all critical care units. This review serves to identify and discuss special considerations for antibiotic stewardship in the ICU.

Barriers to Successful Antibiotic Stewardship

Several barriers limit the success of antibiotic stewardship in the ICU. Two prominent issues are (1) diagnostic uncertainty and (2) fear of not adequately covering the causative pathogen, especially with septic

TABLE 2] Summary of Key Elements of an Antibiotic Stewardship Program in the ICU

Key Elements of ASP in ICU	Summary	Outcomes
Leadership	Collaboration between critical care physician, ID pharmacist, and hospital's ASP ³³	Not applicable
Prospective audit and feedback	Review of broad-spectrum antibiotics on day 3 and deescalate when appropriate	Decrease in days of broad-spectrum antibiotics ³⁶ Reduced rate of CDI ³⁷ Decreased hospital LOS ³⁷
Antibiotic time-out	Physician/trainee-led approach to review antibiotic indications on a biweekly basis and monthly teaching sessions for trainees	Decreased use of fluoroquinolones ³⁸ Some cost savings ³⁸
Rapid diagnostics and laboratory testing	Viral multiplex PCR platform Rapid PCR for MRSA Serial procalcitonin	Decreased hospital LOS, ICU admission rates ³⁹ Decreased use of empiric vancomycin ⁴⁰ Shorter duration of antibiotics ^{39,40}
Clinical pathways	Guide that asks physicians to enter signs/symptoms and provides recommendations for antibiotics Beneficial in diagnoses when treatment guidelines are well established	Decreased length of ICU stay for patients with CAP ^{41,42}
Computerized decision support	Electronic decision support that uses antibiograms and patient data to generate antibiotic recommendations	Decreased antibiotic use ⁴³ Cost savings ⁴³ No negative impact on mortality ^{43,44}
Infection control	Preventive strategies such as handwashing, contact/droplet precautions	Decreased rates of nosocomial infection ⁴⁵

ASP = antibiotic stewardship program; CAP = community-acquired pneumonia; CDC = Centers for Disease Control and Prevention; ID = infectious diseases; MRSA = methicillin-resistant *Staphylococcus aureus*; PCR = polymerase chain reaction. See Table 1 legend for expansion of other abbreviations.

shock. These two factors act synergistically to increase use of multiple and broad-spectrum antibiotics and increase reluctance of critical care physicians to deescalate or stop antibiotics.

The exact source of infection is often not clear in a patient transferred to the ICU for septic shock, and empirical antibiotic regimens are necessarily broader than needed once the source and etiology have been identified. Therefore, the ASP strategy of prior authorization for broad-spectrum antibiotics is perceived as potentially dangerous for critically ill patients.⁴⁶ The most common serious infection in the critically ill is pneumonia.⁴⁷ The diagnostic uncertainties regarding the presence of pneumonia or not and, even more, its bacterial etiology are major drivers of broad-spectrum, empirical antibiotic regimens. Even urinary tract infections in the critically ill or immunocompromised patient cannot be easily separated as cases of colonization or true infection.

Multiple studies in the critical care literature find association between inappropriate empirical antibiotic therapy and worse outcomes, including mortality. For septic shock, the time delay associated with increased mortality can be measured in hours.⁴⁸ Unfortunately, this proper focus on initially appropriate empirical antibiotic therapy is too often used to justify inappropriately broad subsequent antibiotic therapy. A common example is the use of broad-spectrum combination gram-negative coverage for a patient with septic shock from community-acquired pneumonia (CAP) despite the absence of risk factors for MDR pathogens. Another example of inappropriately broad therapy is vancomycin for a patient with no recent hospitalization or antibiotic therapy who presents for acute cholecystitis.

One remedy to these two barriers is more accurate diagnosis. For intubated patients, an alternative is lower respiratory sampling via bronchoalveolar lavage (bronchoscopic or nonbronchoscopic) and/or protected specimen brush with quantitative cultures. As do the European hospital-acquired pneumonia (HAP)/VAP guidelines,⁴⁹ the Infectious Diseases Society of America/American Thoracic Society (IDSA/ATS) guidelines acknowledge that distal sampling and quantitative cultures can assist in antibiotic stewardship.⁵⁰ Endotracheal aspirate cultures consistently are positive more often and more frequently have polymicrobial growth than distal sampling and quantitative cultures leading to the need to cover almost three times more

bacteria.⁵¹ The third major barrier to antibiotic stewardship in the critical care unit is underappreciation of the toxicity of antibiotics. A mindset that antibiotics “can’t hurt” in questionable indications is common. Unfortunately, intensivists are often guilty of a “spiraling empiricism” mindset that more severely ill patients require more antibiotics, broader spectrum agents, and so on. Antibiotic toxicity may occur directly from the antibiotic itself, for example, nephrotoxicity from aminoglycosides; but probably more importantly, each antibiotic course may affect the lung and gastrointestinal microbiome, predisposing to colonization by more pathogenic bacteria.

To be effective in critical care units, antibiotic stewardship efforts need to address each of these issues.

Key Elements of a Successful Antibiotic Stewardship in the ICU

Leadership

CDC guidelines for implementation of a hospital ASP state that leadership commitment is crucial to the success of the program. While an infectious diseases (ID) pharmacist and an ID physician are typically responsible for the overall ASP, integration with ICU leadership is critical for success. Collaborative practice and sharing of antibiotic utilization data between the ASP and ICU leadership are likely to exert the greatest benefit.

Prospective Audit and Feedback

Early and appropriate antibiotics are a cornerstone of therapy for critically ill patients with suspected infection.^{46,48} Thus, broad-spectrum empiric antibiotics in conjunction with an aggressive diagnostic evaluation for the source of infection are a critical care standard. As diagnostic results become available, clinician reexamination of the appropriateness of each administered antibiotic for potential discontinuation or deescalation is important. Unfortunately, current rates of antibiotic deescalation are generally 30% to 50% in patients with serious infections, likely due to the barriers mentioned above.⁵² However, available data advocate for the safety of deescalation of empiric antibiotics. A meta-analysis evaluating 30-day mortality found no safety concerns and even trends to lower mortality with antibiotic deescalation.^{37,53} Thus, deescalation has not been associated with harm and possible benefits exist, including decreased drug toxicities, decreased resistance to the broader antibiotics, and a limiting of the effect on

normal microbiomes. The possible benefits, except for drug toxicities, are currently more theoretical than documented by high-level evidence.

A standardized audit and feedback method is an effective way to ensure that empiric antibiotics are reviewed and deescalated appropriately.⁵⁴ However, audit and feedback can be accomplished by at least two methods. The first is feedback to individual clinicians regarding individual situations. A 2012 analysis by Elligsen et al³⁷ reviewed outcomes of an audit and feedback program implemented at their hospital. All patients in the ICU who had received 3 days of broad-spectrum antibiotics with a third-generation cephalosporin, carbapenem, β -lactam/ β -lactamase combination drug, or vancomycin were included in the audit. On day 3 of therapy the case was reviewed by a senior ID pharmacist, and recommendations for drug optimization were placed in a note in the patient chart and verbally communicated to the treating physician. This physician had the option to accept or reject the suggested change. A similar approach was applied on day 10 of broad-spectrum antibiotic therapy. The study demonstrated reduction in the use of broad-spectrum antibiotics and rate of CDI with no increase in hospital length of stay or mortality. Another audit and feedback program by Khmour et al³⁶ found similar results. In this prospective review, clinical pharmacists created a hospital-specific antibiogram to account for their resistance patterns. The pharmacists reviewed antibiotic prescriptions of all patients in their 12-bed ICU on days 2, 4, and 7 of therapy and made recommendations on deescalation or discontinuation of antibiotics. Mortality was unaffected by this audit and feedback program, but the duration of therapy and hospital length of stay significantly decreased.

Prospective audit and feedback should be a key element of antibiotic stewardship in the ICU. The program should review major antibiotics on a prespecified day of therapy, typically the third day of therapy when culture results are likely available. However, with the development of rapid diagnostic testing, earlier audit may be appropriate. Importantly, the audit and feedback program should utilize a hospital-specific antibiogram when suggesting changes to antibiotics to account for local resistance patterns.⁵⁵

The other strategy for audit and feedback is more general antibiotic usage in a defined patient population. For these purposes, data on days of therapy per 1,000

patient-days for target antibiotics can be supplied to a group of ICU practitioners. Once sufficient data are available, physician-specific days of therapy per 1,000 days of all antibiotics or specific target antibiotics or groups can be provided. This type of audit and feedback has been very successful for surgical site infections, particularly with anonymous peer comparisons.

Antibiotic Time-Outs

Antibiotic time-outs (ATOs) are an important element of stewardship programs because they encourage clinicians to take ownership of the antibiotic review process and require less direct ASP involvement. Graber et al³⁸ introduced an electronic ATO, in conjunction with a hospital-wide marketing campaign regarding the project, consisting of a dashboard with the patient's infection history, a list of approved antibiotic indications, and automatic approval for continuation of antibiotics if prescribed for the listed indications. Physicians received the electronic ATO in the electronic medical record for every patient they were treating. Six months after implementation, significant decreases in both piperacillin and vancomycin, the two targeted antibiotics, were found. Another study found semifavorable results with a trainee-led antibiotic self-stewardship program, including in the critical care units.⁵⁶ In this program, third-year residents were provided with 30-min teaching sessions every month. They then completed a twice-weekly online checklist for each of their patients being treated with carbapenems, moxifloxacin, piperacillin-tazobactam, and vancomycin. By 18 months after the program was introduced, a decrease in moxifloxacin use was observed along with cost savings. However, overall use of antibiotics did not decrease.

Checklists introduced into many ICUs can be adapted for antibiotic stewardship purposes as well. However, use of the checklist as a decision-making tool, rather than another task to perform, is critical to success. Weiss and Wunderink⁵⁷ found that face-to-face prompting when checklist components were not overtly addressed on work rounds was associated with significant improvements in intermediate end points addressed by the checklist and a decrease in mortality, while a similar intervention with electronic checklists was not.⁵⁸ Retrospective analysis found that the dominant checklist component associated with improved mortality was regarding continuation of antibiotics.⁵⁹ In the common comparison with airplane pilot checklists, the

face-to-face prompter functions as the copilot, who actually verifies that checklist components have been performed by the pilot.⁵⁷

Rapid Diagnostic and Laboratory Testing to Reduce Inappropriate Antibiotics

The emerging availability of rapid molecular diagnostic tests may address the greatest barrier to antibiotic stewardship in the ICU. Panels for rapid detection of respiratory viruses are well established, and implementation is associated with decreased ICU admission rates and hospital length of stay.⁶⁰⁻⁶² Data for rapid diagnostic testing for bacterial and fungal infections in the ICU are more limited. Detection of the *Legionella* urinary antigen is the most common method to diagnose *Legionella* pneumonia, and pneumococcal urinary antigen testing detects more cases than do culture methods.⁶³ Polymerase chain reaction (PCR)-based assays, such as the Cepheid GeneXpert assay, have a negative predictive value of 99.8% for the detection of MRSA.⁶⁴ Implementation of a rapid PCR-based diagnostic test for MRSA in patients with suspected VAP resulted in a 50% decrease in the empiric use of vancomycin and linezolid.⁶⁵ A small randomized trial of vancomycin/linezolid treatment based on the results of a rapid PCR for MRSA in BAL fluid found that the significant decrease in duration of anti-MRSA agent use was not only safe but associated with a trend toward mortality benefit in suspected MRSA pneumonia.⁴⁰ PCR assays for MRSA are significantly easier to validate than multiplex assays for gram-negative and other, gram-positive pathogens. Molecular methods to determine antibiotic susceptibility for gram-negatives are particularly challenging. Despite these hurdles, multiplex PCR assays for BAL fluid are likely to be more routinely available in the near future.⁶⁵

Serial procalcitonin (PCT) values may be used to shorten antibiotic duration for patients with severe sepsis and septic shock.⁶⁶ Studies in severely ill patients have found a survival advantage to the shorter duration of antibiotics when guided by PCT levels.³⁹ PCT is less likely to have a benefit when shorter courses, for example, 7 or 8 days for HAP/VAP, are the standard.⁴⁹ Serial specimens are much more helpful than a single assay, and 20% to 25% of cases do not reach protocol thresholds for antibiotic discontinuation.³⁹ Optimal management of these patients with a persistent proinflammatory state is unclear, but that doesn't necessarily indicate the need for prolonged courses of antibiotics. Empirical escalation of therapy in patients

with rising PCT has been associated with adverse outcomes.⁶⁷

Overall, much of the literature on rapid diagnostic testing affirms its use as a highly sensitive and specific tool for diagnosis. These tests will likely remain an adjunct to culture. The impact of these tests on clinical outcomes requires significantly more data. Adequate education regarding interpretation and reliability of the test results is critical to adoption of this new technology.

Clinical Pathways for Antibiotic Stewardship in the ICU

In the ICU, the most common infection treated with antibiotics is pneumonia. Given the critical nature of these patients, many practitioners defer to broad-spectrum antibiotics even when the diagnosis is CAP and only a β -lactam plus macrolide or respiratory fluoroquinolone is indicated.⁶⁸ Use of broad-spectrum antibiotics has been associated with worse mortality in these patients.

One way to implement stewardship for CAP in the ICU is through clinical pathways. Clinical pathways are stepwise guides that utilize clinical data from an individual patient to provide antibiotic recommendations based on an algorithm of evidence-based practices. This approach is particularly appropriate for CAP because definitions and treatment guidelines for CAP are well established.⁶⁸ Adherence to guidelines for the treatment of CAP results in improved clinical outcomes and reduced pathogen resistance for hospitalized patients.^{41,42} The 2011 IMPACT-HAP (Improving Medicine through Pathway Assessment of Critical Therapy in Hospital-Acquired Pneumonia) study by Mangino et al⁶⁹ noted improvement in the diagnosis of nosocomial pneumonia and improved adherence with evidence-based antibiotics for HAP once a clinical pathway was developed and implemented. During the first phase of the study, investigators developed a consensus clinical pathway based on ATS/IDSA guidelines for management of nosocomial pneumonia, local antibiograms, and hospital formularies. The pathway stratified patients on the basis of risk factors for multidrug resistance on day 0 and then, on day 3, discontinued antibiotics in patients who qualified for a short course of therapy. The investigators reported a statistically significant improvement in appropriate empiric antibiotic therapy (31% preimplementation vs 44% postimplementation; $P = .01$). Thus, for defined infections, clinical pathways that incorporate local antibiograms with established

guidelines may help clinicians adhere to those guidelines, avoiding inappropriate antibiotics.

Computerized Decision Support

Electronic decision support is a highly effective tool that could be used in ICU-specific ASPs. Electronic decision support offers an individualized approach to antibiotic decision for each patient, rather than a generic algorithm that may not fully account for patient factors. Evans et al⁴⁴ implemented a computerized decision support program in their tertiary-care hospital ICUs over a 3-year period. The program incorporated white blood cell count, temperature, surgical data, chest radiograph, local antibiograms, and microbiological data to recommend the best antibiotic regimen for the patient (or if no antibiotics were indicated), suggested dose, route of administration, and infusion rate. Results showed that physicians followed the suggested regimen 46% of the time and the computer-suggested dose 93% of the time. Patients received significantly fewer antibiotics and less excessive antibiotics with an associated decrease in cost without a negative impact on mortality. More recent studies have replicated these findings and advocate for ASPs to incorporate an element of computerized decision support.⁴³ The caveat to electronic prompts is that clinicians should have the opportunity to reject the suggested regimen when it is not the most appropriate therapy for the patient. Note that face-to-face prompting, as opposed to an unprompted checklist, is more likely to lead to behavioral change.⁵⁸ Ideally, a computerized prompt would alert a designated team member to have a face-to-face discussion with the treating physician.

Infection Control

Infection control refers to preventive strategies that reduce the incidence of nosocomial infection. Infection control is the cornerstone on which antibiotic stewardship programs are built. Prevention of infection results in decreased antibiotic use and decreases antibiotic resistance pressure. Standard strategies include mandatory hand hygiene for all health-care workers. In the ICU, up to two-thirds of health-care workers carry *Candida* species on their hands.⁷⁰ Other data have shown that bacterial colonization is present on the majority of health-care workers' hands.⁷¹ With the use of hand hygiene, transmission of bacteria from employee to patient is significantly reduced. Hand cleansing with alcohol-based solutions is most effective and provides the longest time periods of compliance.⁴⁵

In addition to standard strategies, surveillance should be implemented to identify patients who require more than standard infection control practices. The two components to surveillance are epidemiologic review and computerized alerts.⁷² The epidemiologic review collects information on all nosocomial infections that have occurred in a specific unit and disseminates that information to help adjust hospital policies, as indicated. Computerized alerts are patient-specific and provide information on prior infections that may warrant additional infection control practices. Airborne, droplet, and contact precautions are examples of transmission precautions that should be implemented on a case-by-case basis. The combination of both epidemiologic review and computerized alerts maximizes infection control.

Summary

In the face of emerging drug-resistant pathogens and a decrease in the development of new antimicrobial agents, antibiotic stewardship should be practiced in all critical care units.

Antibiotic stewardship should be a core competency of all critical care practitioners in conjunction with the formal ASP. Prospective audit and feedback, and antibiotic time-outs, are effective components of an ASP in the ICU. As rapid diagnostics are introduced in the ICU, assessment of performance and effect on outcomes will clearly be needed. Disease-specific stewardship in community-acquired pneumonia that relies on clinical pathways may be particularly high-yield. Computerized decision support has the potential to individualize stewardship for specific patients. Finally, infection control and prevention is the cornerstone of every ASP. We believe that in the ICU, antibiotic stewardship should begin with a commitment from each intensivist to take ownership of his or her antibiotic-prescribing practices, with input from a pharmacist and with an ID physician available for consultation as needed.

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