Infect Dis Ther (2015) 4 (Suppl 1):S39–S50
DOI 10.1007/s40121-015-0084-8

REVIEW

Antimicrobial Stewardship in the Emergency Department

Trang D. Trinh · Kenneth P. Klinker

To view enhanced content go to www.infectiousdiseases-open.com
Received: June 8, 2015 / Published online: September 11, 2015

ABSTRACT

The literature contains robust evidence on the positive impact of antimicrobial stewardship programs (ASP) in the inpatient setting. With national policies shifting toward provisions of quality health care, the impetus to expand ASP services becomes an important strategy for institutions. However data on stewardship initiatives in other settings are less characterized. For organizations with an established ASP team, it is rational to consider expanding these services to the emergency department (ED). The ED serves as an interface between the inpatient and community settings. It is often the first place where patients present for medical care, including for common infections. Challenges inherent to the fast-paced nature of the environment must be recognized for successful ASP implementation in the ED. Based on the current literature, a combination of strategies for initiating ASP services in the ED will be described. Furthermore, common scenarios and management approaches are proposed for respiratory tract, skin and soft tissue, and urinary tract infections. Expansion of ASP services across the health care continuum may improve patient outcomes with a potential associated decrease in health care costs while preventing adverse effects including the development of antibiotic resistance.

Keywords: Antibiotic stewardship program; Emergency department; Emergency medicine; Implementation; Strategies

INTRODUCTION

Sir Alexander Fleming's discovery of penicillin in 1928 marked a momentous event in the history of modern medicine. In 1945, Sir Fleming forewarned against overutilization of antimicrobials during his Nobel Prize acceptance speech, hinting at the consequences of antibiotic resistance. Between

T. D. Trinh
Anti-Infective Research Laboratory, Eugene Applebaum College of Pharmacy and Health Sciences, Wayne State University, Detroit, MI, USA

K. P. Klinker (✉)
College of Pharmacy, University of Florida, Gainesville, FL, USA
e-mail: klinkkp@cop.ufl.edu

2000 and 2010, antimicrobial utilization increased by 36% globally [1]. The majority of the increase occurred in rapidly developing countries, and the United States ranked third in the world for total antimicrobial consumption [1]. As a result of these practices, there has been a marked increase in multidrug-resistant (MDR) pathogens, including methicillin-resistant *Staphylococcus aureus* (MRSA) and extended spectrum beta-lactamase-producing organisms (ESBL) [2]. These resistant isolates are no longer limited to health care settings, but in recent years have emerged in the community [2]. Consequently, the World Health Organization and US Centers for Disease Control and Prevention (CDC) have identified antimicrobial resistance as a serious public health threat [3].

Infections from resistant organisms are associated with poor patient outcomes with increased morbidity and mortality [4]. The management of resistant infections also contributes to rising health care costs [4]. Furthermore, the rate of eroding antimicrobial susceptibility patterns has outpaced the rate of novel antimicrobial drug discovery. In response to an impending post-antibiotic era, physician Dale Gerding introduced the concept of antimicrobial stewardship programs (ASP). The overarching goals for ASP include optimizing antimicrobial therapy to enhance patient safety, reduce inappropriate antimicrobial use, and preventing antimicrobial resistance. Two core strategies were developed, forming the foundation for ASP. Prospective audit with intervention and feedback involves interaction and feedback between an infectious diseases (ID) physician/pharmacist and the ordering prescriber at the point of order entry [5]. Formulary restriction and preauthorization establish minimum requirements for antimicrobial utilization. These standards are often developed based on local susceptibility patterns, safety issues, concern for secondary infections, and affordability (inpatient and outpatient). In conjunction with supportive strategies (i.e., education, decision support services, treatment algorithms), these core strategies ensure a robust ASP presence. The literature contains substantial evidence on the efficacy of these strategies leading to the development of an endorsed ASP guideline and inclusion with the National Action Plan [5, 37].

Despite fewer data on ASP implementation in other health care settings, ASP efforts should expand across the care continuum, including the emergency department (ED). An estimated 142,000 ED visits occur annually secondary to adverse events associated with antimicrobial therapy, emphasizing the need for ASP in this fast-paced environment [6]. The three most common infections encountered in the ED are respiratory tract, skin and soft tissue, and urinary tract infections (UTIs) [6]. These common infections are managed in both in- and outpatient settings, and ED practitioners are involved with establishing empiric and definitive treatment. As health care legislation continues to evolve, ED practitioners will be expected to expand ASP by promoting adherence to prescribing guidelines, integrating point of care technologies, and establishing strategies to avoid antimicrobials for viral respiratory tract infections or uncomplicated abscesses.

First, frontline ED practitioners can critically evaluate patients and determine appropriate empiric antimicrobial therapy with subsequent admission, observation, or discharge. Second, assessments and corresponding treatment plans are highly valued by their inpatient colleagues. For admitted patients, implementing changes to antimicrobial therapy initiated in the ED

poses challenges for ASP members. Third, antimicrobial overprescribing in the ED incurs consequential downstream effects. Therefore, ED practitioners are uniquely positioned to implement ASP initiatives and affect change for the entire organization. ASP members have the opportunity to engage in dialogue and incorporate collaborative ASP interventions with ED practitioners.

Appropriately, May and colleagues [7] brought attention to ASP implementation in the ED with a call to action and concept paper published in 2012. The purpose of this paper is to summarize the existing literature on various ED-based ASP processes, with a focus on managing three commonly encountered infections. Please note this review is based on previously conducted studies and does not involve any new studies of human or animal subjects performed by any of the authors.

ASSESSMENT OF ED CAPACITY FOR ASP IMPLEMENTATION

Identification of potential barriers to successful implementation remains a crucial first step for any new ASP. Inherent to the emergent nature in the ED, challenges are characterized by high turnover rates for both patients and practitioners. The majority (67%) of triaged ED patients waited <1 h to be seen by a practitioner [8]. The remaining one-third (35%) of patients spent between 2 and 4 h from triage to discharge or admission [8]. Additionally, the Centers for Medicare and Medicaid Services (CMS) Core Measure to increase ED throughput and enhance patient satisfaction contributes to higher patient turnover rates. Increasing patient throughput pressures clinicians to maximize diagnostic efficiency while maintaining accuracy.

High ED practitioner turnover rates also challenge ASP implementation and sustainability. In the case of patients who bounce back after discharge, this variability in ED practitioners decreases continuity of care and may lead to unnecessary changes in management. The use of validated bedside scoring tools for risk assessment may standardize the care provided among ED practitioners.

In conjunction with increased patient throughput and higher practitioner turnover rates, operational challenges are present in the ED. Rapid decision-making occurs, oftentimes in the absence of meaningful microbiologic information. National health care quality benchmarks, such as CMS Core Measures, may partly drive the decision-making process for empiric antimicrobial prescribing. Certainly, sepsis and other life-threatening cases warrant appropriate and prompt antimicrobial administration because it confers a mortality benefit [9]. However, it should be noted that antimicrobial selection in the ED has the potential to determine the treatment course for both admitted and discharged patients. Observed in clinical practice, antimicrobial regimens initiated in the ED are often continued with reluctance to deescalate even when another provider has assumed care of the patient. This approach creates inefficiencies for the ASP team to enforce inpatient initiatives and restrictions. Therefore, strategies to maximize resources that assist in rational and meaningful decision-making processes are paramount for ED practitioners. The combination of diagnostic uncertainty, compromised patient care through delays in antimicrobial administration, and predefined quality expectations perpetuate prevalent misuse of broad-spectrum antimicrobials in the ED. After identifying existing and

potential challenges, the next step involves garnering support for implementation of stewardship services in the ED.

POTENTIAL STRATEGIES FOR ASP IMPLEMENTATION IN THE ED

The following are general antimicrobial stewardship strategies that transcend across settings, but can be applied to commonly encountered scenarios in the ED. A combination of these strategies is most effective for developing robust ASP services in the ED.

Key Players on the ASP "Dream Team"

Successful ASP implementation in the ED depends on gaining support from key opinion leaders in the emergency medicine department and administrative leaders in the organization. Limited resources, reimbursement concerns, lacking operational infrastructure, and perception of low efficacy are roadblocks to ASP presence in the ED [7]. Similar to ASP implementation in other settings, circumventing these barriers first requires buy-in and support from an ED clinician volunteer who will serve as a liaison on the ASP committee at the institution. This ED clinician champion can effectively communicate new initiatives and resolve disagreements with their prescriber colleagues. This individual may buffer the pressure to overprescribe outside of clinical guidelines as a response to patient satisfaction. They may also strengthen other ED prescribers' comfort in withholding antibiotics for milder infections that do not require treatment.

In addition to the ED clinician champion, the inclusion of a dedicated clinical pharmacist in the ED adds several values. The benefits include reducing medication errors, shortening treatment durations, and decreasing associated cost of care [10, 11]. Regardless of the ED coverage model, clinical pharmacists provide real-time educational feedback and consultation to practitioners, promote medication safety by thorough verifications of drug allergies and comorbidities, communicate results from microbiology culture and susceptibility reports, facilitate transitions in care including comprehensive medication distribution and reconciliation, and offer support for non-ID issues such as codes [11]. One example underscores the importance of medication reconciliation for patients on antiretroviral therapies. If full integration of a dedicated ED pharmacist is not feasible for the organization, it may be worthwhile to have the ASP pharmacist perform stewardship activities in some capacity. Sharing the responsibilities with an internal medicine or medication reconciliation pharmacist to perform these functions may also work. Ultimately, the presence of a clinical pharmacist in the ED provides several aforementioned benefits to the organization. These stewardship examples ensure patients receive appropriate antimicrobials when they present to the ED.

Real-time follow-up as well as interpretation of microbiologic culture data is a core stewardship activity that is particularly relevant in the ED. Through coordination with the microbiology laboratory, the clinical pharmacist can efficiently disseminate results to prescribers. Dedicated pharmacists who can proactively review positive cultures and adjust recommendations are critical to this process [12, 13]. In particular, this applies to discharged patients for whom culture data may not result until 72–96 h post-discharge, often observed in cases of UTIs. This process decreased the time between positive culture review and time to

follow-up with the patient or primary care provider, if indicated [13]. Furthermore, a multidisciplinary approach to culture follow-up has also been associated with a decrease in return ED visits within 72 h and hospital readmissions within 30 days [14]. More than 25% patients required post-discharge interventions, primarily because of pathogen non-susceptibility [14]. This study emphasizes the importance of appropriate antimicrobial selection while patients are housed in the ED. Culture follow-up also allows the ED to take ownership of the care provided to their patients.

Technological Assistance for ASP

The field of rapid diagnostics largely impacts ID management for admitted patients [15]. Direct testing from specimen versus culture-based testing minimizes turnaround times for organism identification and antimicrobial susceptibility information. Rapid diagnostics has the potential to minimize empiric use of broad-spectrum antimicrobials, thereby allowing for a thoughtful and targeted approach to antimicrobial selection. One of the benefits and the role of rapid molecular diagnostics in the ED are the immediate results provided by point-of-care tests (POCT). Examples include rapid streptococcal antigen tests and respiratory viral panels. Risk assessment combined with POCT may enable ED practitioners to initiate more directed, narrow-spectrum antimicrobial therapy. POCT can also guide appropriate antimicrobial selection for discharge of less serious infections that do not require admission. These tests may reduce overall antibiotic use and facilitate earlier changes in antibiotic regimens for certain infections [16]. Despite limited widespread acceptance of POCTs in the ED, primarily because of cost and potential laboratory workflow constraints, research and development in rapid diagnostics continues to grow. The possibility of individualized care for all patients who present to the ED remains a promising prospect in the near future. In general, these tests are most useful when used appropriately with expert interpretations.

In the age of electronic health records (EHR), clinical decision support (CDS) may effectively deliver pertinent information to ED practitioners at the point of care. This strategy relies on an informatics team and a sustainable technological infrastructure. Ideally, the information should be concise to minimize alert fatigue and information overload. Features should incorporate relevant patient data (e.g., drug allergies, previous culture results, contact precautions, current renal function) aligned with current evidence-based and institutional-specific recommendations [7]. With federal mandates on EHR implementation, CDS is an area with potential growth and high impact for ASP interventions. Prior to broad implementation of EHR, effective CDS programs have been associated with 12–14% reduction in antimicrobial prescriptions [40].

ED-Specific Information

Antimicrobial order forms or order sets, clinical pathways, and an ED-specific antibiogram, if feasible, are examples of resources that may assist ED prescribers during their decision-making process [7].

Order forms and sets are intended to guide a prescriber at the point of electronic order entry. Potential messages that appear with an order may include best practice alerts (BPA), criteria for use with restricted agents, and associated monitoring parameters for specific drugs. Examples are antimicrobial components for a

sepsis protocol order set or an antiretroviral panel alerting prescribers that medication reconciliation is needed for an admitted patient. These order forms may prompt ED practitioners to consult ID and/or facilitate communications with the ED or ID pharmacists.

Evidence-based clinical pathways and algorithms may potentially shape prescribing practices and ensure consistency among rotating ED practitioners. After approval from the Pharmacy and Therapeutics (P&T) Committee, the pathways should be available on the intranet for easy retrieval by all staff. The information should target commonly encountered infections in the ED such as community-acquired pneumonia (CAP), UTI, and *Clostridium difficile* infection. It may be beneficial to have recurring educational sessions or grand rounds with ED prescribers to further enforce these pathways. This promotes dialogue and the exchange of ideas while allowing for valuable visibility of the ED clinical pharmacist. Integrating pharmacy students and residents into this educational process provides them with experiences offering in-service presentations to an interdisciplinary group.

Lastly, creating an ED-specific antibiogram based on ED isolates may be useful for tracking resistance in community and health care settings. This entails collaborating closely with the microbiology department to generate this information. Similar to clinical pathways, the antibiogram should be posted to the intranet. Though it is a powerful tool, routine education and dissemination of information to house staff is necessary for effective interpretation of the antibiogram. A clinical pharmacist in the ED can facilitate these educational and interpretive processes. They can guide prescribers on selection of an appropriate empiric antimicrobial agent, incorporating susceptibility data generated by the antibiogram.

ED MANAGEMENT APPROACHES FOR THREE COMMON INFECTIONS

Respiratory tract, skin and soft tissue, and urinary tract are the three most common infections encountered in the ED [6]. Therefore, it is important to highlight potential treatment strategies and opportunities for stewardship initiatives for these three infections.

Acute Respiratory Tract Infections

Evidence for antimicrobial overprescribing has been well established for acute respiratory tract infection (ARTI) ambulatory treatment, owing to fear of patient complaints and dissatisfaction. Donnelly et al. characterized antibiotic utilization in pediatric and adult patients receiving care for ARTI in the ED from 2001 to 2010 using National Hospital Ambulatory Medical Care Survey data. ARTIs account for nearly 12% of all ambulatory care visits annually [17]. Nasopharyngitis, bronchitis or bronchiolitis, viral pneumonia, and influenza were identified as not requiring antibiotics. Expectedly, the use of antibiotics in viral illnesses has not been shown to improve patient outcomes. However, more than half (61%) of ARTI cases with viral etiologies inappropriately received an antibiotic [17]. Further, Kronman et al. [39] estimated bacterial prevalence to be 27.4% among common ARTIs. When assessing antimicrobial prescribing frequencies, health care providers may have inadvertently prescribed 11.4 million antimicrobial courses. These data highlight the need for integrating strategies that minimize overtreatment (i.e., watch-and-wait strategies,

contingency antimicrobial prescriptions, or rapid diagnostics tools).

Ong et al. [18] surveyed ED physicians and patients at ten EDs based in academic medical centers in the US. They sought to characterize prescribing practices as well as patient expectations and satisfaction. The study population included pediatric and adult patients who had a single diagnosis of uncomplicated acute bronchitis or upper RTI. The results are consistent with the findings previously reported by Donnelly et al. ED physicians inappropriately prescribed antibiotics for about two of every three (68%) patients with acute bronchitis and about one of every ten (9%) patients with upper RTI [18]. Moreover, physicians prescribed antibiotics when they believed patients were expecting them. However, these physicians were only able to accurately identify true patient expectations in about a quarter of patients. Additionally, the receipt of antibiotics was not associated with patient satisfaction. In fact, patients reported greater satisfaction when they had a better understanding of their illness. This message remains the mainstay for the CDC's *Get Smart: Know When Antibiotics Work* campaign. In this national campaign, the use of viral illness prescription pads as a patient education tool to explain supportive care measures can increase patient satisfaction.

Consequently, Ong et al. [18] illustrated how physicians' misperception of patient expectations can lead to overprescribing of antibiotics. Additionally, rates of antibiotic prescribing were similar across all ED settings, whether academic or community based. ED physicians often cited the presence of green or bloody phlegm as a factor for prescribing antibiotics [19]. However, data are lacking to indicate this is due to a bacterial infection [19]. This may represent potential educational interventions. Incorporation of order forms and clinical pathways may also provide prescribing guidance. Lastly, technology such as rapid diagnostics with respiratory viral panels may also play a substantial role in decreasing inappropriate antibiotic use in the ED. An analysis by Blaschke and colleagues [38] identified a reduction in ancillary testing (i.e., cultures, chest radiographs) and antibiotic prescriptions when integrating rapid influenza testing into practice. In contrast, there was a significant increase in anti-influenza therapy. These data highlight the potential for identifying causative organisms associated with RTI and minimize overtreatment.

In addition to rapid diagnostics and bedside scoring tools, several studies report the use of procalcitonin (PCT) to differentiate between infectious versus noninfectious inflammatory conditions [20]. PCT is a precursor peptide to the hormone calcitonin. It becomes acutely elevated in bacterial infections, but rapidly decreases during clinical recovery [15]. Compared with other inflammatory biomarkers, PCT has demonstrated superior diagnostic accuracy when compared to C-reactive protein [21, 22]. The interest in utilizing PCT to guide antibiotic therapy has been evaluated for both ARTI and sepsis across multiple care settings.

Schuetz et al. [23] performed a meta-analysis examining the safety of PCT algorithms to guide antibiotic initiation and treatment duration in patients with ARTI across multiple care settings. The authors concluded that PCT algorithms effectively reduced overall antibiotic exposure in patients by 50%, from 8 to 4 days. They did not observe an increase in mortality or treatment failure rates. Additionally, the use of PCT in the ED differentiated congestive heart failure versus ARTI resulted in a reduction in adverse events and antimicrobial consumption

[24]. Studies supporting the use of PCT in other ARTI include chronic obstructive pulmonary disease exacerbations and CAP [25–27]. Consistent with data from the meta-analysis, these studies highlighted a reduction in antibiotic exposure. Challenges to widespread implementation of PCT-based algorithms may include the cost and logistical workflow. However, incorporation of PCT testing in the ED may be an effective strategy to reduce antimicrobial misuse for ARTI.

Skin and Soft Tissue Infections

Despite evolving terminology for skin and soft tissue infections (SSTI) throughout the years, the incidence has risen in the past decade [6]. The spread of community-acquired MRSA (CA-MRSA) infections may have contributed to the rise along with increases in resource utilization [28]. An analysis of ED prescribing patterns for skin infections conducted between the years 2007 and 2010 revealed a stable rate of ED visits, but noted an increasing rate of anti-CA-MRSA antibiotics for skin infections [28]. Furthermore, patients were frequently either overtreated with combination therapy for cellulitis (included agents active against CA-MRSA) or received unnecessary therapy following incision and drainage (I&D) of uncomplicated abscesses. In contrast, when antimicrobial therapy was warranted for the treatment of purulent cellulitis, 16% of patients failed to receive therapy active against CA-MRSA. These findings highlight the importance of proper wound classification and risk stratification in patients with acute bacterial skin and skin structure infections (ABSSSIs).

Current recommendations for skin and skin structure infections from the Infectious Diseases Society of America (IDSA) suggest that skin abscesses do not require antibiotic treatment post successful I&D [29]. The guidelines also recommend the use of agents effective against streptococci for nonpurulent cellulitis. However, these recommendations are rarely integrated into clinical practice, and patients are often overtreated for simpler skin infections [28]. Another situation that supports the need for an ED-based ASP service is the frivolous administration of vancomycin in the ED. Mueller et al. [30] reported in their single-center study that 68% of patients received one-time doses of vancomycin prior to discharge, whereby 73% of these patients were under-dosed with <15 mg per kg of body weight. This study highlights the real possibility of developing resistance if these prescribing behaviors are not addressed.

Unfortunately, these patients typically present to the ED or another ambulatory clinic as their initial point of entry into the health care system, yet the 2014 IDSA update did not address management issues specific to the ED. Appropriately, a best practice guideline for the management of skin infections has been outlined specifically for ED practitioners [31]. The treatment approach is to risk stratify based on disease severity and ensure patients receive appropriate levels of care (e.g., emergent surgical interventions for severe sepsis and necrotizing fasciitis).

For low-risk patients who can be managed in an outpatient setting, the best practice guideline divided the group into nonpurulent versus purulent cellulitis [31]. Consistent with the IDSA guidelines, patients evaluated to have nonpurulent cellulitis can be treated with non-MRSA active oral antibiotics and discharged. Patients with purulent cellulitis should be covered with MRSA-active oral antibiotics and discharged. Conversely, patients requiring intravenous antibiotics were

further stratified to those eligible for outpatient parenteral antimicrobial therapy (OPAT) based on the presence of comorbid conditions (e.g., diabetes mellitus, vascular disease). The recent approvals of long-acting lipoglycopeptide agents such as dalbavancin and oritavancin, which possess activity against gram-positive organisms including MRSA, may play a larger role in OPAT clinics. With these newer agents, the treatment paradigm for skin infections diverts stable patients with milder infections away from admission. Therefore, ED stewardship strategies should focus on a comprehensive and validated process to determine illness severity and risk stratification for skin infections.

Urinary Tract Infections

Similar to skin infections, the use of broad-spectrum antimicrobials extends to UTI treatment as well. IDSA guidelines state that asymptomatic bacteriuria (ASB) does not require antibiotic treatment [32]. UTI diagnosis based on a urinalysis (UA) or dipstick alone in the absence of symptoms leads to overuse of antibiotics [33]. Often observed in clinical practice, empiric UTI treatment with a broad-spectrum agent such as a fluoroquinolone is frequently initiated based on an improperly collected UA in the ED. Pallin et al. [33] reported that 58% of patients failed to receive instructions on urine sample collection, resulting in only 6% of patients performing the correct midstream, clean-catch technique. In addition, according to current guidelines, if local resistance rates for fluoroquinolone exceed 10% for common uropathogens such as *Escherichia coli*, then oral agents such as ciprofloxacin and levofloxacin are no longer recommended for empiric uncomplicated UTI treatment [34]. Considerations of these ecological effects also apply to trimethoprim-sulfamethoxazole (TMP-SMX). If resistance rates for uropathogens exceed 20%, TMP-SMX is no longer a recommended first-line option for uncomplicated cystitis, leaving clinicians with older agents such as nitrofurantoin and fosfomycin.

Despite these recommendations, guideline adherence is difficult in the ED without guidance from a dedicated pharmacist or ID specialist. Overtreatment of ASB, especially with fluoroquinolones, generates more collateral damage including *C. difficile* infections. In a recent study evaluating adherence rates to uncomplicated UTI guidelines in an ED setting, Hecker et al. [35] successfully implemented a UTI electronic order set with corresponding audit and feedback interventional periods. The study concluded that guided order sets accompanied with audit and feedback successfully reduced fluoroquinolone prescriptions for uncomplicated cystitis from 44% at baseline to 13% after the intervention period.

In another study conducted at an academic tertiary care hospital in Canada, the authors found that implementation of a best practice algorithm reduced empiric ciprofloxacin use for uncomplicated UTIs from 32% to 11% [36]. The interventions included monthly educational presentations to the ED practitioners. The eroding susceptibility patterns for fluoroquinolones were highlighted with an in-depth discussion on the adverse effects associated with this class. These materials were disseminated in the ED as well as the institution's intranet. Although this strategy is more labor intensive, it is effective and could be implemented if resources are available including rotation students and/or residents.

From a stewardship standpoint, CDS plays a large role in curbing inappropriate

broad-spectrum antimicrobial use or overtreatment. Combined with routine discussions regarding other treatment options such as oral beta-lactams (cephalexin) and older agents for patients with optimal renal function (nitrofurantoin), these strategies may steer prescribing practices away from the fluoroquinolones.

Another role for intervention entails culture data follow-up for discharged patients. For identified bug-drug mismatches (e.g., a patient was prescribed an antibiotic on discharge and subsequent susceptibility results identified the organism is resistant to that agent), the pharmacist is alerted to communicate information directly to the patient or primary care provider. The reconciliation process may involve patient assessment or the need for a new prescription. If these alerts are addressed in a timely manner, they may avert a potential readmission. These endeavors align with the overall health care goal of providing quality care while keeping costs at bay.

CONCLUSION

The ED offers a myriad of opportunities for creative antimicrobial stewardship interventions that could affect change across the care continuum. Antibiotics prescribed in the ED have far-reaching consequences downstream. Therefore, attention and resources need to be shifted to this setting. Inherent to the fast-paced nature of this environment, multiple ED-specific challenges exist. The challenges can be circumvented through various strategies to affect changes. Successful ASP implementation requires a collective and multidisciplinary effort. Ideally, an ED clinician champion proactively engaged with the ASP committee is the crucial step to initiate stewardship directives. Initiatives can be targeted at common infections: respiratory tract, skin, and UTIs. Ultimately, through provision of ASP services in the ED, prescribing practices may shift toward more rational and thoughtful decision-making. The overall goal is to provide improved care to our patients efficiently and effectively. More data capturing stewardship strategies in the ED are needed.

ACKNOWLEDGMENTS

This supplement was not sponsored by outside commercial interests. No source of funding was received for publication of this article. All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this manuscript, take responsibility for the integrity of the work as a whole, and have given final approval for the version to be published.

Conflict of interest. Trang Trinh has nothing to disclose. Ken Klinker is a member of the Advisory Board for Cempra, The Medicines Co., Cubist, and Durata.

Compliance with ethics guidelines. This article is based on previously conducted studies and does not involve any new studies of human or animal subjects performed by any of the authors.

REFERENCES

1. Van Boeckel TP, Gandra S, Ashok A, et al. Global antibiotic consumption 2000 to 2010: an analysis of national pharmaceutical sales data. Lancet Infect Dis. 2014;14(8):742–50.

2. Moran GJ, Krishnadasan A, Gorwitz RJ, et al. Methicillin-resistant *S. aureus* infections among patients in the emergency department. N Engl J Med. 2006;355:666–74.

3. Centers for Disease Control and Prevention. Antibiotic resistance threats in the United States. 2013. http://www.cdc.gov/drugresistance/pdf/ar-threats-2013-508.pdf. Accessed 28 March 2015.

4. Shlaes DM, Gerding DN, John JF Jr, et al. Society for Healthcare Epidemiology of America and Infectious Diseases Society of America joint committee on the prevention of antimicrobial resistance in hospitals. Clin Infect Dis. 1997;25:584–99.

5. Dellit TH, Owens RC, McGowan JE Jr, et al. Infectious Diseases Society of America and the Society for Healthcare Epidemiology of America guidelines for developing an institutional program to enhance antimicrobial stewardship. Clin Infect Dis. 2007;44:159–77.

6. Centers for Disease Control and Prevention. National Hospital Ambulatory Medical Care Survey: Emergency Department. 2011. http://www.cdc.gov/nchs/data/ahcd/nhamcs_emergency/2011_ed_web_tables.pdf. Accessed 28 March 2015.

7. May L, Cosgrove S, L'Archeveque M, et al. Antimicrobial stewardship in the emergency department and guidelines for development. Ann Emerg Med. 2013;62(1):69–77.

8. Horwitz LI, Green J, Bradley EH. US emergency department performance on wait time and length of visit. Ann Emerg Med. 2010;55(2):133–41.

9. Dellinger RP, Levy MM, Rhodes A, et al. Surviving sepsis campaign: international guidelines for management of severe sepsis and septic shock. Crit Care Med. 2013;41(2):580–637.

10. Brown JN, Barnes CL, Beasley B, Cisneros R, Pound M, Herring C. Effect of pharmacists on medication errors in an emergency department. Am J Health Syst Pharm. 2008;65(4):330–3.

11. Cohen V, Jellinek SP, Hatch A, Motov S. Effect of clinical pharmacists on care in the emergency department: a systematic review. Am J Health Syst Pharm. 2009;66(15):1353–61.

12. Acquisto NM, Baker SN. Antimicrobial stewardship in the emergency department. J Pharm Pract. 2011;24(2):196–202.

13. Baker SN, Acquisto NM, Ashley ED, Fairbanks RJ, Beamish SE, Haas CE. Pharmacist-managed antimicrobial stewardship program for patients discharged from the emergency department. J Pharm Pract. 2012;25(2):190–4.

14. Dumkow LE, Kenney RM, MacDonald NC, Carreno JJ, Malhotra MK, Davis SL. Impact of a multidisciplinary culture follow-up program of antimicrobial therapy in the emergency department. Infect Dis Ther. 2014;3:45–53.

15. Avdic E, Carroll KC. The role of the microbiology laboratory in antimicrobial stewardship programs. Infect Dis Clin N Am. 2014;28(2):215–35.

16. Bauer KA, West JE, Balada-Llasat JM, Pancholi P, Stevenson KB, Goff DA. An antimicrobial stewardship program's impact with rapid polymerase chain reaction methicillin-resistant *Staphylococcus aureus*/*S. aureus* blood culture test in patients with *S. aureus* bacteremia. Clin Infect Dis. 2010;51(9):1074–80.

17. Donnelly JP, Baddley JW, Wang HE. Antibiotic utilization for acute respiratory tract infections in United States emergency departments. Antimicrob Agents Chemother. 2014;58:1451–7.

18. Ong S, Nakase J, Moran GJ, Karras DJ, Kuehnert MJ, Talan DA. Antibiotic use for emergency department patients with upper respiratory infections: prescribing practices, patient expectations, and patient satisfaction. Ann Emerg Med. 2007;50(3):213–20.

19. Gonzales R, Bartlett JG, Besser RE, Hickner JM, Hoffman JR, Sande MA. Principles of appropriate antibiotic use for treatment of nonspecific upper respiratory tract infections in adults: background. Ann Emerg Med. 2001;37:698–702.

20. Simon L, Gauvin F, Amre DK, Saint-Louis P, Lacroix J. Serum procalcitonin and C-reactive protein levels as markers of bacterial infection: a systematic review and meta-analysis. Clin Infect Dis. 2004;39(2):206–17.

21. Uzzan B, Cohen R, Nicolas P, Cucherat M, Perret GY. Procalcitonin as a diagnostic test for sepsis in

critically ill adults and after surgery or trauma: a systematic review and meta- analysis. Crit Care Med. 2006;34(7):1996–2003.

22. Christ-Crain M, Stolz D, Bingisser R, et al. Procalcitonin guidance of antibiotic therapy in community-acquired pneumonia: a randomized trial. Am J Respir Crit Care Med. 2006;174(1):84–93.

23. Schuetz P, Briel M, Christ-Crain M, et al. Procalcitonin to guide initiation and duration of antibiotic treatment in acute respiratory infections: an individual patient data meta-analysis. Clin Infect Dis. 2012;55(5):651–62.

24. Schuetz P, Kutz A, Grolimund E, et al. Excluding infection through procalcitonin testing improves outcomes of congestive heart failure patients presenting with acute respiratory symptoms: Results from the randomized ProHOSP trial. Int J Cardiol. 2014;175(3):464–72.

25. Stolz D, Christ-Crain M, Bingisser R, et al. Antibiotic treatment of exacerbations of COPD: a randomized, controlled trial comparing procalcitonin-guidance with standard therapy. Chest. 2007;131(1):9–19.

26. Long W, Deng X, Zhang Y, Lu G, Xie J, Tang J. Procalcitonin guidance for reduction of antibiotic use in low-risk outpatients with community-acquired pneumonia. Respirology. 2011;16(5):819–24.

27. Schuetz P, Christ-Crain M, Thomann R, et al. Effect of procalcitonin-based guidelines vs standard guidelines on antibiotic use in lower respiratory tract infections: the ProHOSP randomized controlled trial. JAMA. 2009;302(10):1059–66.

28. Pallin DJ, Camargo CA Jr, Schuur JD. Skin infections and antibiotic stewardship: analysis of emergency department prescribing practices, 2007–2010. West J Emerg Med. 2014;15(3):282–9.

29. Stevens DL, Bisno AL, Chambers HF, et al. Practice guidelines for the diagnosis and management of skin and soft tissue infections: 2014 update by the Infectious Diseases Society of America. Clin Infect Dis. 2014;59(2):e10–52.

30. Mueller K, McCammon C, Skrupky L, Fuller BM. Vancomycin use in patients discharged from the emergency department: a retrospective observational cohort study. J Emerg Med. 2015;15:1–8.

31. Pollack CV Jr, Amin A, Ford WT Jr, et al. Acute bacterial skin and skin structure infections (ABSSSI): practice guidelines for management and care transitions in the emergency department and hospital. J Emerg Med. 2015;48(4):508–19.

32. Nicolle LE, Bradley S, Colgan R, Rice JC, Schaeffer A, Hooton TM. Infectious Diseases Society of America guidelines for the diagnosis and treatment of asymptomatic bacteriuria in adults. Clin Infect Dis. 2005;40(5):643–54.

33. Pallin DJ, Ronan C, Montazeri K et al. Urinalysis in acute care of adults: pitfalls in testing and interpreting results. Open Forum Infect Dis. 2014;1(1):ofu019.

34. Gupta K, Hooton TM, Naber KG, et al. International clinical practice guidelines for the treatment of acute uncomplicated cystitis and pyelonephritis in women: a 2010 update by the Infectious Diseases Society of America and the European Society for Microbiology and Infectious Diseases. Clin Infect Dis. 2011;52(5):e103–20.

35. Hecker MT, Fox CJ, Son AH, et al. Effect of a stewardship intervention on adherence to uncomplicated cystitis and pyelonephritis guidelines in an emergency department setting. PLoS One. 2014;9(2):e878–99.

36. Landry E, Sulz L, Bell A, Rathgeber L, Balogh H. Urinary tract infections: leading initiatives in selecting empiric outpatient treatment (UTILISE). Can J Hosp Pharm. 2014;67(2):116–25.

37. The White House. National Action Plan for Combating Antibiotic-Resistant Bacteria. 2015. https://www.whitehouse.gov/sites/default/files/docs/national_action_plan_for_combating_antibotic-resistant_bacteria.pdf. Accessed 30 June 2015.

38. Blaschke AJ, Shapiro DJ, Pavia AT, et al. A national study of the impact of rapid influenza testing on clinical care in the emergency department. J Pediatr Infect Dis Soc. 2014;3(2):112–8.

39. Kronman MP, Zhou C, Mangione-Smith R. Bacterial prevalence and antimicrobial prescribing trends for acute respiratory tract infections. Pediatrics. 2014;134(4):e956–65.

40. Gonzales R, Anderer T, McCullouch CE, et al. A cluster randomized trial of decision support strategies for reducing antibiotic use in acute bronchitis. JAMA Intern Med. 2013;173(4):267–73.